On the care and feeding of a gift horse: The recurrent cost problem and optimal reduction of recurrent inputs

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ON THE CARE AND FEEDING OF A GIFT HORSE: THE RECURRENT COST PROBLEM AND OPTIMAL REDUCTION OF RECURRENT INPUTS

by

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ABSTRACT

In contrast to the existing literature which explains the recurrent cost problem as largely the result of institutional impediments to LDC welfare maximization, this paper analyzes the problem by constructing a series of scenarios in which the less developed country would be led to reduce the flow of recurrent inputs to a development project in order to maximize its own welfare. A distinction is drawn between situations in which the project design is correct _ex ante_, and those in which it is wrong _ex ante_.

If the project design is correct _ex ante_, then the recipient country which deviates from the project design does so at a cost to its own welfare unless one or more of the assumptions embodied in the project design have turned out to be false. This paper develops a typology of the possible "surprises" that could lead a host country to reduce recurrent input to a project in order to maximize social welfare. It is proposed that donors use such a typology to help determine the true cause of recurrent input reduction in any given instance.

An alternative possible reason for the host country to reduce recurrent inputs to a project is that the project was incorrectly designed in the first place: i.e. the project design could be wrong _ex ante_. The paper uses a simple model of donor and recipient nation objectives to describe the contractarian relationship between the two nations with respect to the project design and implementation process. According to the model, the donor and recipient countries have a common interest in the output of the development project, but their interests are not identical. In the situation described by the model, both nations have an incentive to agree to a project design that is wrong _ex ante_. Subsequently the LDC's reduction of recurrent input can be viewed as its attempt to do the best it can given the inappropriate project with which it is saddled. The analysis is illustrated with a modified Edgeworth-Bowley box diagram.

Finally, the paper demonstrates that, like the free-rider problem, the recurrent cost problem can be formulated as a variety of the "prisoner's dilemma" game form. This observation leads to several policy recommendations for the resolution of the recurrent cost problem which are analagous to the solutions that have been developed for the general free-rider problem as it is characterized by the prisoner's dilemma. The paper concludes by summarizing the major policy implications of the analysis and by discussing some possible difficulties that would arise in attempting to implement the recommended policies.

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I. Introduction

Recently the distinction between the "capital cost" and the "recurrent cost" of a development project has received substantial attention among practitioners of development economics as a result of a growing perception by donor and recipient countries and by multilaterial agencies that there exists a "recurrent cost problem" in many developing countries. According to Peter Heller of the International Monetary Fund, a principal symptom of the problem is that "throughout the developing world the productivity of public investments and programs that are already in place has been seriously jeopardized by the failure of governments to provide adequately for their operation and maintenance over time" (Heller, 1979, p. 38). The recurrent cost problem is a cause for concern, not only because of the premature deterioration of past projects, but also because it "cast[s] a disturbing shadow on the economic viability of future investment programs" (Ibid.). The purpose of this paper is to apply some standard tools of microeconomic analysis to the recurrent cost problem in an attempt to understand more completely the causes of the problem and to suggest some policy initiatives that could help to resolve it.

The paper is organized into sections. The next section after this introduction, section II, sets the context for the later theoretical discussion by defining the term "recurrent costs" as it is commonly used, by briefly reviewing the literature which proposes a set of institutional causes of the recurrent cost problem, and finally by suggesting a characterization of the optimal recurrent expenditure for a development project that is somewhat richer than the frequently used assumption that recurrent costs are a fixed proportion of investment expenditures.

Sections III through VI then present a theoretical analysis of the recurrent cost problem which is consistent with the hypothesis that the relevant economic-decision-makers rationally maximize a welfare function of their home country. Section III develops in detail the possibility that even the most carefully designed project might encounter during its lifespan an unanticipated event to which the optimal response would be to reduce the flow of recurrent inputs to the project below the flow prescribed by the project design document. If the donor country is unaware of the magnitude of the change in the project's environment due to the unanticipated event or "surprise," it may perceive the reduction in flow of recurrent inputs as a move away from optimality rather than as a move towards it. Thus the donor might perceive a recurrent cost problem when closer examination would reveal the fault to lie with exogenous and unpredictable events. To assist in such a closer examination of individual projects, section III uses a optimization model of the behavior of the project manager to construct a typology of possible surprises which would lead to just such an optimal reduction in the flow of recurrent input.

But some of the types of surprises discussed in section III may be more exogenous than others. In section IV we illustrate how the sequential project design activities of more than one donor might lead to unanticipated increases in the price of a recurrent input despite the efforts of each project designer to coordinate the resource requirements of his project with those of other projects. In effect, the analysis of this section endogenizes one of the surprises which were treated as exogeneous in section III by somewhat relaxing the assumption that the original project design is correct.

In Section V we move from the world of possible surprises to a world of certainty about future prices and social preferences in order to examine the impact on the project design process of the removal of the assumption that design teams correctly perceive and maximize the welfare function of the host country decision-makers. In section V we instead assume that the objectives of the donor and the host country decision-makers can differ and, furthermore, that the opportunity costs of the various resources consumed by the project are valued differently by the two parties. We argue that both parties to the design decision have an incentive to design "too large" a project that calls for "too much" recurrent input. Subsequently it is rational for the LDC to reduce the flow of recurrent input to the project below that prescribed in the project document.

In Section VI we define the "free-rider problem" in order to consider the similarity between it and the recurrent cost problem. In this section we also informally compare three alternative models to that analyzed in section V and we discuss possible solutions to the free-rider problem. In the last section we briefly review the more important policy recommendations from the body of the paper and we conclude with some additional policy implications of the analysis.

II. Characterizations of Recurrent Costs and the Recurrent Cost Problem

An expenditure can be classified as "capital" or "recurrent" at either the macroeconomic level of the national accounts or the microeconomic level of individual projects. At the macroeconomic level the standard advice given to less developed countries has been that they should strive to rationalize their national accounts by distinguishing the two types of expenditures as clearly as possible. Some authors even argue that there exists a "strong correlation between the degree of underdevelopment of a given economy and the imprecision of the distinction between current and capital expenditures by the government."[1] However, the United States is a striking counter example to this hypothesis, since its national accounts distinguish these categories of expenditures much less precisely than do those of several less developed countries. In this section we touch only briefly on some of the implications of the practice of distinguishing these classes of expenditures at the level of the national budget of the less developed country (LDC). In most of this section and in sections III, IV, V, and VI we focus our analysis at the level of one or more individual development projects. Then in the concluding section we return to the aggregate level to discuss some of the implications of our analysis for policy at that level.

Practitioners of project analysis commonly distinguish between the "capital costs" of a project and its "recurrent costs." Use of the word "capital" for one of these categories of expenditure seems to imply that the distinction rests on an analogy with the two-factor production function of neoclassical theory, where the "capital" and "recurrent" costs are the streams of factor payments to the fixed and variable factors of production. Indeed in some respects use of the distinction between capital and recurrent costs at this micro-economic level does seem to be related to the distinction between fixed and variable factors: capital costs usually include the costs of building and importing the plant and equipment required by the project while recurrent costs typically include all salaries of local personnel. However, other examples of the application of the distinction seem to contradict the analogy with the two factor model of production. For instance, the cost of maintaining depreciating capital equipment would ordinarily be treated as a component of gross investment by the economic theorist, while the actual practice of project analysis is to treat maintenance as a recurrent cost. Another example of a contradiction is the classification of the salary expenses of expatriot personnel who provide technical expertise during only the initial stages of the project as a capital cost of the project.

The above examples suggest that the distinction between capital and recurrent costs has more to do with when the expenditure occurs and with whether or not the expenditure finances the purchase of goods and services produced locally, than with economic theory. This suggestion is supported by the recent O.E.C.D. definition of recurrent costs as the costs of "goods and services (for example, local personnel) required for maintaining and operating a given project or programme" (1979, parentheses in original). A practical definition of capital cost which complements the O.E.C.D. definition of recurrent cost might be "the start-up cost of a project, particularly those portions of the start-up cost attributable to imported goods and services."

But freed of its ties with economic theory, the distinction between capital and recurrent costs seems to lose its _raison d'être_. Since it is always possible to compute the present value of the stream of recurrent expenditures on a project and then to capitalize them at the inception of the project, why would project planners continue to draw such a sharp distinction between these two categories of expenditure? Perhaps a part of the answer lies in the observation by Heller that "some donors (with the notable exception of some European countries) shy away from providing long-term recurrent financing--particularly if it implies funding local costs" (1979, p. 39). If many donors display a strong preference for funding the capital costs of development projects and not the recurrent costs as defined by the O.E.C.D., this preference is enough to account for the persistence of the distinction between capital and recurrent costs.[2]

The best and most complete discussion of the recurrent cost problem is the short nontechnical article by Heller from which we have twice quoted (1979).[3] In this article, Heller draws on his own extensive previous work related to recurrent costs (1974, 1975a, 1975b, 1975c, 1976, 1977) and on his experience at the I.M.F. to generalize about the nature, the causes, and the possible solutions of the recurrent cost problem.

Heller proposes five reasons that, in the context of the intense development effort directed at some less-developed countries (LDC's) in the last two decades, help to explain why LDC's have often "underfinanced" the recurrent costs of development projects. First, Heller asserts that some countries "are unwilling to mount an adequate tax effort" to cover their recurrent expenditure commitments.[4] Second, "both donors and borrowers tend to equate development expenditures with investment and recurrent expenditure with consumption [and thus they tend to believe they should] curb recurrent expenditure in order to . . . finance investment.[5] Third, Heller summarizes the results of his own and others' work that demonstrates that a given amount of investment expenditure can generate widely varying amounts of recurrent expenditure depending on the nature of the project. He suggests that the mix of development projects may have unexpectedly shifted towards those which involve relatively larger amounts of recurrent expenditure. Fourth, he points out that in countries where the alternative use for public funds is the support of "activities that are the preconditions of and concommitant to the existence of the nation state," the opportunity cost of maintaining the planned flow of recurrent inputs to a development project may be too high. Finally, Heller points to the failure of planning and budgeting systems in the developed or developing countries to "identify when serious losses in project productivity may occur."

Heller's discussion of the causes of, and possible policy responses to, the recurrent cost problem has a strongly institutional flavor. For example, he stresses the "biases" of donors in favor of "basic needs" projects that happen to require large flows of recurrent inputs and the "biases" of LDC development institutions against recurrent expenditure and against raising taxes. He points out that "the movement of a project from the investment to the recurrent budget signals its fall from 'budgetary' grace, a decline in its 'visibility,' and its need to scramble for a share of recurrent funds." The underlying assumption of his discussion seems to be that the observation that actual recurrent input flow to a project is less than the planned flow is _prima facie_ evidence that donor and LDC institutions are separately and jointly failing to maximize the LDC's social welfare. If only these socially inappropriate biases could be corrected, Heller seems to say, and if only donor and LDC institutions gathered and used better information and behaved more flexibly and "rationally," then instances of a deviation of actual from planned recurrent input flow would diminish in frequency or disappear and LDC's would attain higher welfare levels than they otherwise can achieve.

Any practitioner of development economics or project analysis will recognize the truth of Heller's penetrating observations on the idiosyncracies of development institutions and project approval procedures which often fail to signal or counteract a deviation of actual from planned recurrent inputs and sometimes even exacerbate the gap between them. However, Heller's description seems to beg an important question. If the projects are chosen and designed to maximize the recipient's welfare at a planned level of recurrent inputs, why would there not arise powerful incentives to induce the host country to meet, or at least move toward, these welfare maximizing levels of recurrent input supply? Heller's focus on institutional and informational impediments appears to be insufficient to explain why the LDC's have not seemed to be motivated to correct their institutions and establish informational networks in order to maximize their own welfare.

In this paper we take a position that is perhaps extreme, but which we believe to be useful as a contrast to the view implicit in Heller's discussion. We assume away many of the institutional and informational constraints on the optimal planning of the flow of recurrent inputs that have been so clearly described by Heller. Our purpose is to ask whether a recurrent cost problem could appear even in the absence of these obstacles to appropriate development. Our analysis in subsequent sections demonstrates that there are many plausible situations in which the LDC would rationally choose to supply less than the planned amounts of recurrent inputs, thus appearing to the external observer to be "under-financing" recurrent costs.

In his original 1974 article, and again in his most recent 1979 piece, Heller has found it useful to define "the ratio of net recurrent expenditure commitments to the initial investment expenditure" on a project to be a constant which he calls the r coefficient (1974, p. 253). He then uses constant r coefficients so defined to project the recurrent cost "requirements" of any given investment expenditure. In a footnote, Heller qualifies his use of these constant coefficients by pointing out that the recurrent expenditures they prescribe are simply those that are necessary "to operate the project at a target level of output" (1974, p. 252). Hence he seems to disavow any explicit intention to suggest that the r coefficients represent the optimal expenditure on recurrent inputs for the project. Despite these qualifications, Heller's use of a constant r coefficient implies that the relationship between recurrent and investment expenditures is likely to be quite inflexible, perhaps for institutional reasons similar to those to which he attributes the entire recurrent cost problem.

While Heller qualifies his remarks sufficiently to demonstrate that he is well aware of the possibility that the r coefficient designed into the project is not the only one at which the project could operate, he and others have abstracted from the complexity of the development environment by calculating recurrent expenditure requirements for countries based on constant r coefficients.[6] In view of the fact that LDC's have not hesitated to treat the r coefficient as extremely variable, it may be useful to provide a richer characterization of the relationship between recurrent expenditures and investment than that implied by a constant coefficient. As a prelude to the more abstract discussions of subsequent sections, the rest of this section provides such a characterization.

For the purpose of the remainder of this section suppose that there exist only three possible (i.e., technologically efficient) ways to design a given project and that the three designs are mutually exclusive. Each of these different designs for the same project calls for a different initial capital stock measured in physical units and written K_1, K_2, K_3. For the moment we need not impose a ranking on these values. Suppose that in addition to the initial capital, the only other input is a recurrent input, x. Suppose the project lifetime is T years and that the decision on the quantity of x used in year zero is binding in the sense that the same quantity must be used in all future years until the end of the project. (For instance, x might be man-years of skilled manpower available only on contract for T + 1 years.)

A project design team is asked to determine which one of the three possible designs for the project yields the highest net present value assuming the wage rate of the recurrent input relative to the unit price of the capital stock is, and will remain, $\bar{w}$. To solve this problem, the design team must discover the maximum attainable net present value (NPV) for each of the three possible starting capital stocks. But for any given capital stock, K_i, the NPV will be a function of the level of x. The relationship that will typically exist between the NPV and x is depicted in Figure 1, which we will refer to as "the recurrent input profile of design i." Note that the maximum NPV for this design is attained at recurrent input level x_i^*.

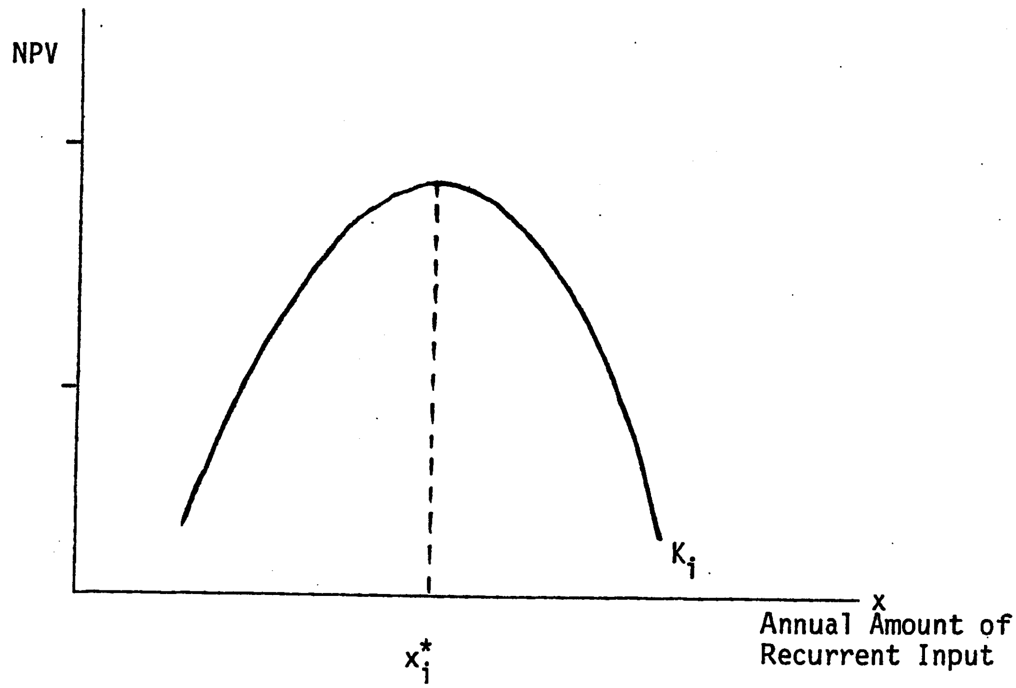

Figure 1: Relationship Between Net Present Value and Annual Recurrent Input Assuming Fixed Initial Investment and Wage Rate.

Peter Heller (1974, 1979) and others have used the "r coefficient" of a project as if it were the ratio of "required" recurrent expenditures to initial investment. In the context of this discussion we can define an r coefficient as the ratio

$$r = \frac{\bar{w}x}{K_i} .$$

where K_i and x are measured in physical units and $\bar{w}$ is fixed relative to the unit price per unit of purchased capital. But for project designs with recurrent input profiles that are continuous and have continuous first derivatives such as that in Figure 1, it seems clear that no particular level of recurrent input--and therefore no particular r coefficient--is "required." Rather some levels of recurrent input yield higher NPV's than others, while one particular level is optimal under the assumptions used to compute the cost and benefit streams which compose the profile. This optimal level of recurrent input can in turn be associated with an optimal r coefficient defined for a given K_i and $\bar{w}$ as

$$r_i^* = \frac{\bar{w}x^*}{K_i} \quad .$$

Only if the profile in Figure 1 drops precipitously to zero on either side of x^* would it be appropriate to use r_i^* as a measure of the "required" level of recurrent input for that project design.

Suppose that the design team explores the relationship between NPV and x for each of the three possible designs and plots them all on the same graph yielding Figure 2. This figure draws attention to the fact that the recurrent input profile of a project can differ in three important respects. First, and most obviously, the maximum NPV attained by a project can vary from one design to another. Second, the optimal level of recurrent inputs x_i^* can vary from design to design and is not necessarily correlated with the maximum NPV attainable with a design. Third, the steepness of the two sides of a recurrent cost profile, which represents the sensitivity of a design's NPV to perturbations in the level of recurrent input from the optimal level, can also vary from design to design.[7]

Examination of the figure reveals that design 1 attains the highest NPV of the three. However, on the basis of this figure we can immediately raise two issues which might make the design team reject design 1 in favor of one of the other designs. First, suppose that we know that certain institutional constraints which have been omitted from the project analysis prevent using any more than $\bar{x}$ units of x on this project. Then we will rank both design 2 and design 3 over design 1 and we will prefer 2. Alternatively, suppose that the quantity of x we must use each year (at $\bar{w}$ per unit) is a random variable with range $x_0 \leq x \leq x_M$. If we believe that the probability that x will be at either end of its range is substantial, and if we wish to maximize our expected NPV, then we may be led to choose design 3 over either of the other two. This choice would reflect the fact that design 3 is least "sensitive" or most "robust" to the level of recurrent input x. (The project designer's preference for design 3 would be strengthened if he were risk averse.)

However assuming that the project design team works in close collaboration with the host country government and that the government communicates its intentions in good faith,[8] the possibility that x is a random variable from the point of view of the design team becomes remote. The possibility that the amount of x available at $\bar{w}$ is inelastically supplied or rationed in the amount $\bar{x}$ seems more likely to arise in actual project design applications.[9] Thus we would

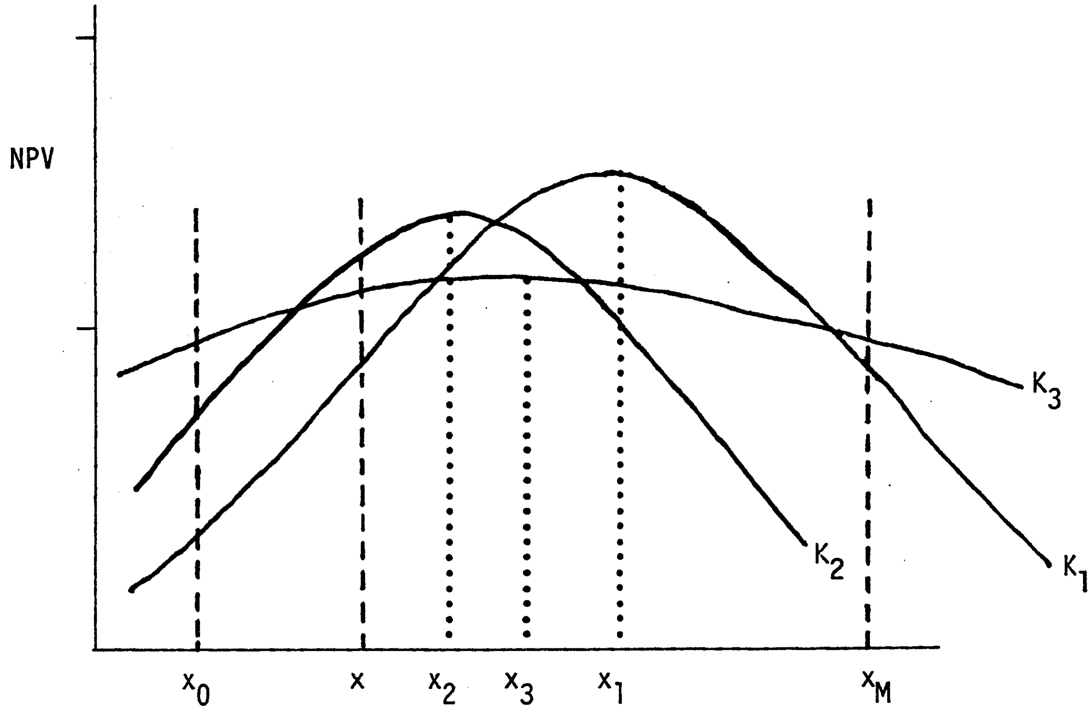

Figure 2: Relationship Between Net Present Value and Annual Recurrent Input for Three Different Levels of Initial Investment.

typically expect design teams to choose a design like 1 or 2 over one like 3 whose only advantage is robustness.[10]

Since the total capital cost of a project is routinely estimated in the early stages of a project design, it would be convenient for project designers if there were a simple relationship between the magnitude of the capital cost of a project design and the optimal level of recurrent expenditure associated with that design. To the extent that initial investment K_i and recurrent input x_i are substitutes, we might be tempted to argue that $K_1 > K_2$ implies $x_1^* < x_2^*$, so that we could deduce a ranking for the optimal r coefficients of the two designs: $r_1^* < r_2^*$. However, note that substitutability between K and x in the production processes of the project in question is not sufficient in general to deduce a ranking of the x_i^* from a ranking of the K_i because the two designs may differ in other respects. In particular, the two designs may produce different streams of output and have quite different maximal NPV's so that the pairs of input quantities (K_1, x_1^*) and (K_2, x_2^*) are not on the same output isoquant. Since this is the implicit assumption that must be adopted in some approximate form for the above argument to go through, nothing can be inferred about the ranking of the optimal r coefficients of two designs from the ranking of their respective capital costs.

III. A Typology of Surprises

If the manager of a development project chooses a level of recurrent input different from that prescribed by the original project design in order to optimize the same objective function used by the project designer, either the original design was technically flawed or intervening events have altered the values of some of the design parameters so as to falsify a plan which may have originally been "correct." We postpone to sections V and VI the consideration of a mechanism which could systematically bias project designs in a direction which would create a recurrent cost problem as an artifact of independent optimizing behavior by donor and recipient countries. In this section and the next, we focus instead on the possibility that a project is designed "correctly" from a perspective that we assume to be shared by the project designers and the host-country decision-makers. We then explore changes in project design parameters which would lead the welfare maximizing project manager to reduce recurrent inputs below planned levels.

Of course there is a sense in which any project design which incorrectly anticipates subsequent events is flawed. If the time of project designers were a free good, each design should specify a probability distribution for the time paths of all project design parameters whose future values are not known with certainty. The choice of projects would then be made to maximize some function of the expected present value of the project portfolio and its variance. In this world, no project design would specify a level of recurrent input for a project; instead it would specify a decision function which the project manager could use to choose the level of recurrent input in each period as a function of the current values of all parameters which were not known with certainty at the time of the project design. However, since the difficulty of parameterizing a project design rises geometrically with the number of parameters allowed to vary, and since the time of project designers is quite scarce, actual practice is to assume that the projected time paths of most, if not all, project design parameters are known with certainty.

When the value of a design parameter veers significantly away from its projected time path in a direction and to a degree not anticipated in the design, whether the design document is thereby proved to be in error depends on:

(a) whether the parameter in question could reasonably have been judged by the project designer to be highly subject to significant deviations from its projected time path, and

(b) whether the limited resources of the project designer would have been better allocated to parameterizing the design with respect to variations in the time path of that parameter given the designer's current knowledge and the opportunity cost to the design of that reallocation.

If in a specific case the answer to both these questions is "yes," then the designer should have parameterized the design with respect to the given design parameter and provided the project maanger with instructions for altering the flow of recurrent input to the project as a function of the observed time path of the uncertain parameter(s). Frequently, however, the designer "correctly" chooses to ignore the possibility that the given parameter might vary from its projected time path in order to devote more attention to other aspects of the design. Thus we define a "ex ante correct" project design as one which:

(a) assigns the same values as would be assigned by welfare maximizing host-country decision makers to all resources consumed by the project as well as to all project outputs,

(b) recognizes, among other things, the potential variability of those parameters judged by the best informed analysts of the day to be most likely to vary significantly from any expected time path, and

(c) parameterizes the design with respect to as many of those uncertain parameters as warranted given the limited resources available to the designer.

In this view the difficulty of parameterizing a project design, the scarcity of the time of project designers, and the uncertainty of any projection of a project parameter combine to ensure that many project designs which are "correct" ex ante will be based on projections of one or more design parameters which later turn out to be wrong ex post. It is this sense in which this section assumes that correct project designs can later be falsified by events.

Clearly any of a number of unanticipated events could occur during a project's lifetime which would lead the welfare maximizing project manager to reduce the level of recurrent input below that prescribed by a correct project design. In this section we use a simple model of optimal project design to construct a typology of such "surprises." We then use the typology to organize a discussion of the possibility that the enumerated surprises may have recently occurred with greater than chance frequency--thus generating the perception that there is a "recurrent cost problem" when in fact countries are responding optimally to events beyond their ability to control or even predict.

In constructing a model of project design optimization, we follow Marglin (1963) and Feldstein (1970) in supposing that, once the desireability of a given project is established, the optimal design for the project is that which maximizes the net social present value of the project subject to appropriate constraints.[11] In order to highlight the recurrent cost problem, suppose that there are only two times in the history of the project when decisions are made regarding project inputs. First, at the time of project design the project designer jointly chooses the optimal quantities of capital and recurrent input. After the capital is in place, the project is turned over to the project manager who, we assume, has no further control over the quantity of capital available to the project. However, the project manager is free to make an independent decision regarding the optimal quantity of recurrent input; he can decide either to follow the prescription of the project designer or to deviate from that prescription. But for simplicity we assume the manager's decision must be made once and for all during that period of time after the capital input has been installed but before the project begins to operate. The manager's decision then determines the flow of recurrent input to the project for the rest of the project's lifetime. Thus, in our model any unanticipated events that are to alter the manager's perception of the optimal level of recurrent inputs from the designer's perception must occur in this time period between the installation (or at least the commitment) of the capital input and the beginning of project operations.

In order to further simplify the exposition we assume that the quantity of recurrent input flowing to the project each year, once decided by the project manager, is identical in every year of the project's life. Similarly we assume that the annual quantity of project output is identical from year to year and is a function of the amount of original capital installed at the beginning of the project as chosen by the project designer and of the annual quantity of recurrent input as chosen by the project manager. These simplifications allow us to summarize the project's technology without time subscripts as

$$y = f(K, x) \tag{1}$$

where

y:	annual flow of project output,
K:	units of capital input before project begins to operate,
x:	annual flow of recurrent input,
$f(.)$:	the quasi-concave production function.

In view of these definitions, the objective function maximized by both the project designer and the project manager can be written in the following simple form:

$$V = B(y) - C(K, x) - (s-1)D(K, x) \; . \tag{2}$$

The functions $B(.)$ and $C(.)$ represent the present values respectively of the social benefits of the project's output and of the social costs of the factors of production used in producing that output, all discounted at the social rate of time preference. We assume that B(.) is strictly concave and that C(.) is weakly convex. If the project were entirely self-financing, the difference between these two quantities would be the net present social value of the project.

However, very few development projects are in fact self-financing. In most cases, despite some revenue that might be raised by the sale of the project's output, the project requires large infusions of public funds, first to finance the original capital investment and then to subsidize its continuing operating deficit. Unless the social opportunity cost of public funds used to finance the stream of project deficits is identical to their current value in consumption, financing the project deficit is an additional social cost which the project must bear.[12] Suppose that the opportunity cost of every dollar of deficit financing for the project can be valued at s dollars in terms of current consumption, where s is typically greater than one.[13] Then, if D(.) represents the discounted stream of project deficits financed from public funds, the additional social cost of the project imposed by those deficits is given by (s-1)D(.), the third term in equation (2). The function D(.) is assumed to be strictly convex.

The project designer chooses the values of the two variables K and x to maximize equation (2) given the project's technology as represented by equation (1). The first-order conditions for a solution to this design problem are:

$$\frac{\partial V}{\partial K} = \frac{dB}{dy}\frac{\partial y}{\partial K} - \frac{\partial C}{\partial K} - (s-1)\frac{\partial D}{\partial K} = 0\,, \qquad (3)$$

$$\frac{\partial V}{\partial x} = \frac{dB}{dy}\frac{\partial y}{\partial x} - \frac{\partial C}{\partial x} - (s-1)\frac{\partial D}{\partial x} = 0\,. \qquad (4)$$

We designate the values of K and x which satisfy the first-order conditions by K^* and x^*. Our assumptions regarding the curvature of B(.), C(.), and D(.) guarantee that V is strictly concave and thus that K^* and x^* also satisfy the second-order conditions for a maximum.

Now suppose that the quantity of capital viewed by the project designer to be optimal, K^*, is installed and control of the project is turned over to the project manager. Provided that the manager optimizes the same objective function used by the designer (which we have assumed above) and provided that there have been no changes in the project environment, the project manager will arrive at the same decision regarding the optimum level of recurrent input as the project designer.* However, suppose that some feature of the environment changes in a way not anticipated by the project designer. The project manager would quite properly choose a different level of recurrent input than that chosen by the designer. If the manager chooses a level which is less than x^*, the designer and the donor country which may have sponsored his efforts might become convinced that the project in question is suffering from a "recurrent cost problem" when in fact the manager has reduced recurrent inputs to the project in order to maximize social welfare.

In order to develop a typology of situations in which a donor country might incorrectly perceive a recurrent cost problem, we first write the project manager's decision problem as follows:

$$\max_{x} \; V(x|K^*) = B(y|K^*) - C(K^*, x) - (s-1)D(K^*, x) \qquad (5)$$

But the total social cost of the factors of production C(.) can be written as the sum of the fixed social cost of the installed capital and the variable social cost of the recurrent input which is the manager's choice variable:

$$C(K^*, x) = C^o + \int_o^x w(x)\, dx \qquad (6)$$

where

C^o: = fixed social cost of installed capital,

w(x): present value of the stream of per-unit factor prices of the recurrent input.[14]

Similarly the discounted stream of project deficits can be written as the sum of the fixed monetary cost of the installed capital and the discounted stream of operating deficits:[15]

$$D(K^*, x) = C' + w(x)\, x - py \quad , \qquad (7)$$

where

C': fixed monetary cost of installed capital,

p: present value of the discounted stream of output prices,

y: number of units of output in each period for t = 0, ... , T.

The project manager's single choice variable is x, the per period flow of recurrent input to the project. The optimal choice of x from the viewpoint of the manager is given by the value of x which satisfies the first- and second-order conditions for the solution to problem (5). By using equations (6) and (7) we write the unique first-order condition as

$$\frac{dB}{dy}\frac{\partial y}{\partial x} = \frac{\partial C}{\partial x} + (s-1)\frac{\partial D}{\partial x} \tag{8}$$

where

$$\frac{\partial D}{\partial x} = w(x) + x\frac{dw}{dx} - p\frac{\partial y}{\partial x} \tag{9}$$

Provided our assumptions regarding the general forms of B(.), C(.), and D(.) are also satisfied for the specific forms of those functions specified in equations (6) and (7), the second-order condition will be obeyed by a value of x that satisfies equation (8) and that value is thus the socially optimal level of recurrent input as computed by the project designer or, assuming prices, technology, and preferences remain unchanged, by the project manager. The various terms in equation (8) can be interpreted as follows:

$\frac{dB}{dy}\frac{\partial y}{\partial x}$	= MVP =	marginal present social value product of x,
$\frac{\partial C}{\partial x}$	= MSCX =	w(x) = marginal present value of the social cost or of the supply price of x,
$\frac{\partial D}{\partial x}$	= MD =	marginal increment to the present value of the deficit stream of x,
$(s-1)\frac{\partial D}{\partial x}$	= MSCD =	social cost of MD,
$w(x) + x\frac{dw}{dx}$	= MCX =	marginal present value of the cost of x to the project,
$p\frac{\partial y}{\partial x}$	= MRP =	marginal present value of the revenue product of x to the project.

Figure 3 illustrates the determination of the socially optimal level of recurrent input for the case in which the deficit minimizing level of recurrent input is less than the socially optimal level. Panel (a) of Figure 3 depicts the deficit minimizing level of recurrent input x as determined by the intersections of the MRP and MCX curves just as it would be for any enterprise facing an upward sloping supply curve for input x. This deficit minimizing level of x is the value which equates the right-hand-side of equation (9) to zero. Panel (b) derives the marginal deficit (MD) curve defined by equation (9) to be the difference between the MCS and the MRP curves. But according to equation (2) only the proportion (s-1) of the deficit is a social cost which must be set against the social benefits of the project. Thus panel (b) also illustrates the derivation of the MSCD curve as a proportion of the MD curve.[16] Note that MSCD must also intersect the horizontal axis at the deficit minimizing value of x.

Once the MSCD curve has been derived it is possible to compute the socially optimal level of x. Panel (c) of Figure 3 illustrates this computation. First the MSCX curve is reproduced exactly from panel (a). This upward sloping supply curve of x would represent the marginal social cost of x if the project were self-financing. Thus the intersection between MSCX and the marginal value product of x curve, MVP, determines the level of recurrent input, x^+, that would be socially optimal if the project were self-financing.

However, marginal units of x incur a social cost in excess of MSCX because of their impact on the project deficit which must be financed by public funds. Thus to find the marginal social cost of x we must add the MSCD curve to the MSCX curve to yield the MSC curve which

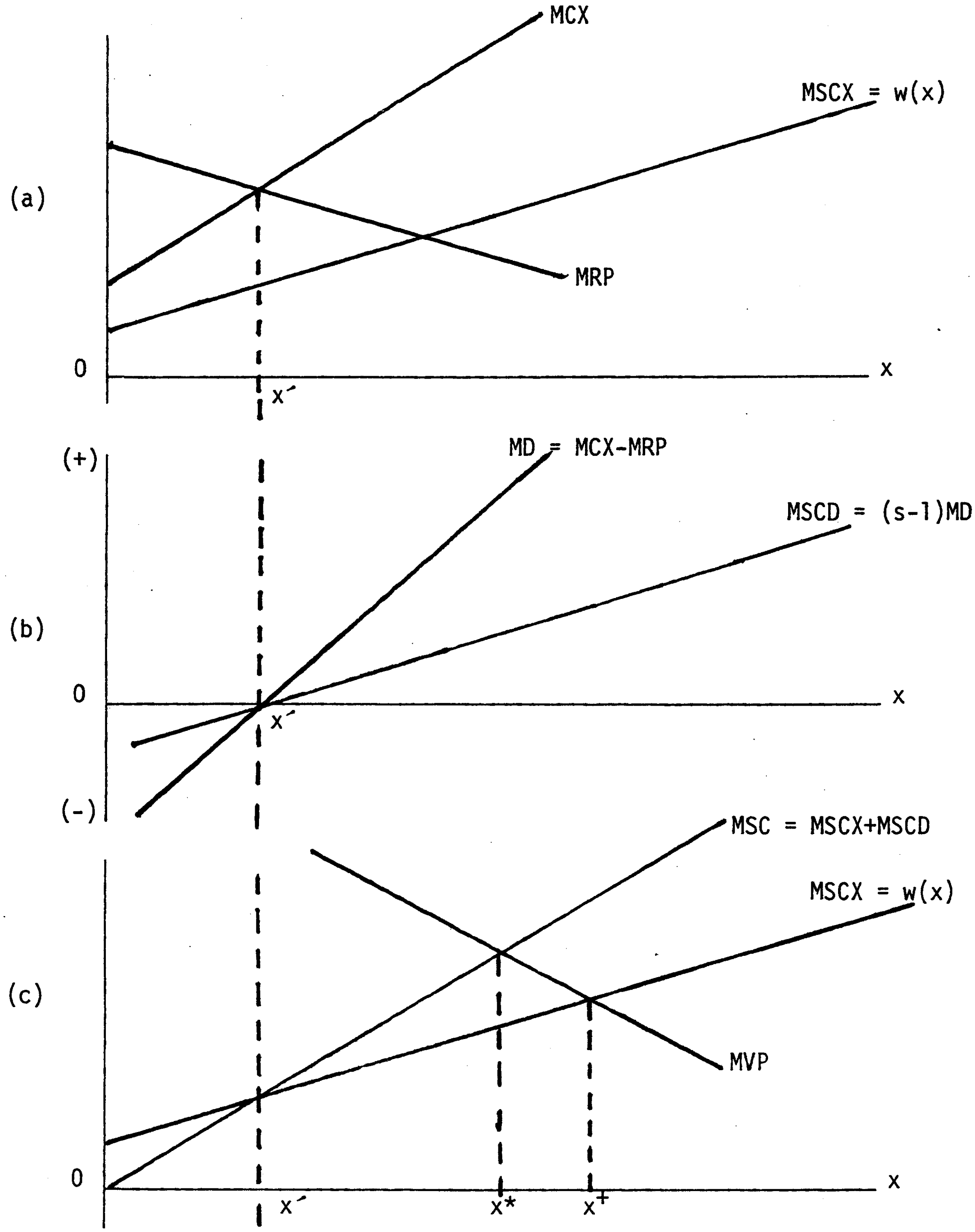

Figure 3. Determination of Socially Optimal Level of Recurrent Input, x*.

intersects the MVP curve at a value of x between x', the deficit minimizing value of x, and x^+, the value of x which would be socially optimal if the project were self-financing. The socially optimal level of recurrent input is thus equal to x*, a weighted average of x and x^+, where the weights depend on the elasticities of the several curves depicted in Figure 3.[17]

The optimal level of input, x*, will also be the planned level built into the project design if the project designer has correctly performed its function from the perspective of the project manager and of the host country's decision-makers. Now consider a point in time after the capital plant for the project has been installed (and therefore long after the project designer has left the country), but before a decision on the quantity of x to use has been implemented. On the basis of the model and the analysis to this point we can construct a typology of unanticipated events or "surpises" which would lead the project manager to purchase <u>fewer</u> than x* units of recurrent inputs. Each of the five types of "surprise" defined below corresponds to a change in one of the elements of equation (8) or (9) which, in turn, results in a shift of either the MSC or the MVP curve in panel (c) of Figure 3 and a corresponding change in the optimal level of x from x* to another lower value. The five types of unexpected events are listed in Table 1.

The important point to note with respect to this list of surprises is that any one of them would lead to the quite rational decision by the project manager on behalf of the host country to restrict recurrent inputs to one or more projects. The implication is that, when a recipient country allocates significantly less than the planned amount of recurrent

TABLE 1. Typology of "Surprises" Which Could Result in the Optimal Level of Recurrent Inputs Being Less than the Planned Level.

Type of "Surprise"	Mathematical Term of Equation (8) or (9) Affected	Curves Shifted in Panels (a) and (b) of Fig. 3	Curves Shifted in Panel (c) of Fig. 3
1. National Priorities	dB/dy smaller than expected		MVP shifts down
2. Technology	$\partial y/\partial x$ smaller than expected	MRP shifts down, MD shifts up, MSCD shifts up	MSC shifts up and MVP shifts down
3. Input Supply			
a) Level of Supply Price	w(x) larger than expected	MSCX shifts up, MCX shifts up, MD shifts up, MSCD shifts up	MSC shifts up
b) Elasticity of Supply	dw/dx larger than expected	MSCX rotates counterclockwise, MCX shifts up, MD shifts up, MSCD shifts up	MSC shifts up
4. Revenue from User Charges	p smaller than expected	MRP shifts down, MD shifts up, MSCD shifts up	MSC shifts up
5. Opportunity Cost of Public Funds	s larger than expected	MSCD rotates counterclockwise around its intersection with the abscissa	MSC rotates counterclockwise around its intersection with MSCX

inputs to a project, the donor must first determine whether the current situation differs from that faced by the project designer in any of these five ways before claiming with any legitimacy that its project is being unreasonably and irrationally starved of recurrent inputs.

Of course if surprises were random events, we might expect them to be distributed so as to result sometimes in the decision to <u>increase</u> x above the programmed level. However, casual observation confirms that recurrent input restriction below planned levels exceeds in frequency the excess provision of these inputs to an extent inconsistent with the hypothesis that the surprises are random events equally likely to affect x in either direction. If this observation is correct, the implication is that, in at least some countries, persistent forces have tended to result in input restriction more frequently than input augmentation.

But for the presence of persistent forces to be consistent with "surprises" as defined here, it is necessary to posit a mechanism that prevents project designers from learning from previous surprises.[18] It is perhaps sufficient to point out that few individual project designers have the opportunity to visit ongoing or completed project that they have personally designed in order to compare their projections of project-specific exogenous parameters to the actual time paths of those parameters. Even in instances when a designer does visit his own project, his design may have been substantially modified by bureaucrats and/or subsequent, second-guessing designers so that he may have trouble identifying the extent to which his own errors of anticipation are the cause of any difference between the planned and the actual flows of recurrent input. Of course, institutions which provide development assistance and host country development bureaucracies might be supposed to have a vested interest in gathering information which would inform project designers on the frequency of particular surprises. However, these institutions seem to spend much less on average to learn from the outcome of individual development projects than they do to design them in the first place. If neither the individual project designers nor even the institutions for which they work have any systematic procedure by which they can learn that certain events unanticipated by designers have recurred with greater than chance frequency, then it is possible for the tendency which produces a surprise to remain unnoticed for extended periods of time.

While the absence of learning mechanisms is sufficient to explain the persistence of surprises over time, Hirschman (1967) has introduced another hypothesis which may contribute to the explanation of the persistence of surprises or alternatively may provide the subconscious motivation for individuals and institutions engaged in development assistance to refrain from learning from their experiences any more than they have. Hirschman posits the existence of a "hiding hand" in the practice of project analysis which manipulates human actors as invisibly as Adam Smith's more celebrated appendage, and towards as benign an ultimate result. In Hirschman's words:

> Creativity always comes as a surprise to us; therefore we can never count on it and we dare not believe in it until it has happened. In other words, we would not consciously engage upon tasks whose success clearly requires that creativity be forthcoming. Hence, . . . since we necessarily underestimate our creativity, it is desirable that we underestimate to a roughly similar extent the difficulties of the tasks we face so as to be tricked by these two offsetting underestimates into undertaking tasks that we can, but otherwise would not dare, tackle. The principle is important enough to deserve a name: since we are apparently on the trail here of some sort of invisible or hidden hand that beneficially hides difficulties from us, I propose The Hiding Hand (1967, p. 13).

It requires but a minor extension of Hirschman's "general principle of action" (ibid.) to suggest that individuals and institutions engaged in development assistance may subconsciously be motivated by the hiding hand not to study the adverse surprises encountered by active development projects for fear that more complete knowledge of the difficulties future projects must surmount would discourage donors and recipients alike from even attempting them. If the hiding hand effectively discourages the study of ongoing and completed development projects, then neither the unexpected difficulties of those projects nor the creativity with which those difficulties are occasionally surmounted will become general knowledge. The donor will be left with only the superficial impression that "its" project is receiving less than the planned amount of recurrent input; thus it will conclude that there is a recurrent cost problem when in fact the observed reduction in recurrent input flow may have been a commendably creative and flexible response to an exogenous shock or surprise that, without that response, could have harmed the project far more than it has.

In the rest of this section we consider sequentially each of the five types of surprises defined in Table 1 in order to discover whether there is reason to believe that these surprises may have occurred more frequently than their opposites during the recent history of less developed countries. While our discussion will remain at a general level, applicable almost equally to all LDC's, the reader may be able to apply the arguments to individual countries that are familiar to him. The assumption throughout the ensuing discussion is that, for whatever reason, project designers have been unable to incorporate the experience of previous projects in their countries or others into the formation of their expectations about future events affecting the projects they plan. As a result, the same surprise can recur in different projects even within the same country despite the best efforts of project designers to produce "correct" project designs.

1. National Priorities. The priorities and goals of most nations fluctuate over time in ways that are difficult to predict. If projects of a certain type are most likely to be identified and designed near a peak in the cycle of public sentiment for that type of project, then it will frequently be the case that a project has a lower priority when it is operational than it had during its design. Thus the perhaps irresistable tendency to follow the latest fashions in identifying and designing projects could lead to the persistent "over-design" of projects and the persistent subsequent reduction in allocated national recurrent inputs by recipient countries.[19]

2. Technology. Since technical change is usually progressive rather than regressive, at first it seems difficult to imagine that project design teams would persistently over-estimate the marginal product of recurrent inputs. However, if we remember that such teams are frequently composed of individuals with a better understanding of the technical context in more developed countries than in less developed ones, we might suppose them to be persistently unrealistic in their high expectations of the marginal productivity of any given recurrent input.

Our model includes only a single recurrent input. However, in situations where there are multiple recurrent inputs, an important feature of the technology of the project is the degree to which the various recurrent inputs can be substituted for one another in producing the project's output. If the designer has a tendency to plan on a degree of substitutability that is characteristic of similar production processes in developed countries, then a possible surprise is the discovery that the actual production process permits much less substitutability than anticipated by the designer. Provided that the chosen technique of production is correct, this surprise will not affect the project unless some other exogenous parameter changes. However, suppose the supply price of a given recurrent input increases sharply. Rather than increase or cut back only slightly on the use of other inputs as the designer would have predicted to be optimal, the project manager will cut back drastically on these other inputs. Without knowledge of the actual low substitution elasticity, the donor will perceive the cutback in other complementary inputs as irrational and unjustified, claiming a "recurrent cost problem."

3(a) <u>Level of Supply Price</u>. A change in the supply conditions for a recurrent input to a project clearly can affect the welfare maximizing amount of that input used by the project. If the input is purchased on the world market and supply is perfectly elastic, then a possible surprise is an upward shift in the supply curve, w(x). In recent years several world prices have risen faster than might have been predicted by project designers, but the OPEC oil price increases of 1973 and subsequent years stand out as recent dramatic examples of price increases that the best informed project designers could not have been expected to predict. These increases forced upward the prices of gasoline and fertilizer, two important recurrent inputs to many projects. Conceivably the current focusing of attention on a "recurrent cost problem" could be largely attributed to this recent acceleration in the rate of price increase of oil and oil-derived inputs. Furthermore, in cases where the technology of a project permits little substitution among the several recurrent inputs, an increase in the supply price of oil might lead the welfare maximizing project manager to reduce the flow of other recurrent inputs to the project. The donor might then observe a reduction in several recurrent inputs which in fact is entirely attributable to the increases in the price of one of those inputs. The coincidence between the oil price increases and the appearance of the recurrent cost problem in the Sahel, while not conclusive, is too suggestive to be easily dismissed.

3(b). Elasticity of Input Supply. If the project is a sufficiently important user of a given locally supplied recurrent input, the supply curve of that input to the project will be upward sloping as we have drawn it in Panels (a) and (c) of Figure 3. While the fact that the supply curve is less than perfectly elastic may be understood and anticipated by the project designer, a less elastic supply curve than expected is a possible surprise that a project could encounter in the market for its recurrent input. Thus, the true input supply curve would be rotated counter-clockwise from those shown in Figure 3 and the resulting socially optimal level of the recurrent input would turn out to be lower than the designer prescribed for the project. The possibility that project designers have frequently over-estimated the elasticity of recurrent input supply for a few key local inputs is suggested by anecdotal evidence that some of these inputs have been quantity rationed as a result of shortages. Examples include skilled manpower of various types, managerial talent and experience, and certain locally produced man - factured intermediate inputs such as cement or tanned leather.[20]

4. Revenue from User Charges. Although some governments have resisted attaching user charges to the outputs of public projects, the recurrent cost problem itself has recently contributed to persuading governments that such charges are occasionally appropriate. In most

cases where user charges have been tried, they have proved an unequivocal success, arousing very little resentment from the population which has too often been disappointed by "free" programs. However, in some cases a project fails to collect anticipated revenue and is forced to cut back on the use of some recurrent inputs as a result. One situation in which revenue expectations may be disappointed is where user charges are collected not from the individual user, but from some larger communal aggregate. In the case of one health worker project in West Africa, in which the worker was to collect his salary from the village he served rather than from the individual patients, the salary payments actually received were substantially less than the amount agreed upon. The worker's subsequent withdrawal from the project constituted a reduction in the recurrent input of his labor supply for which the "revenue surprise" was directly responsible.

This example is perhaps imperfect to the extent that a "correct" project design should have anticipated the difficulty of requiring the village to tax its members to support the village health worker. Nevertheless, the example underscores an important point: projects which are designed to cover some recurrent costs via <u>earmarked</u> user charges are particularly likely to experience reductions of recurrent inputs as a result of a "revenue surprise." Depending on the skill with which the project is designed, the exact amount of recurrent input reduction which results automatically from a given shortfall in earmarked revenue may or may not be optimal. Other things equal, it would clearly be a useful design feature of a project if earmarked revenue shortfalls were to automatically result in optimally reduced flows of recurrent inputs without the necessity for a conscious managerial decision. The possibility that an invisible hand could be introduced in this way into the management of development projects deserves further attention in the literature on applied project design.

5. Opportunity Cost of Public Funds. Marglin (1963) and Feldstein (1972) discuss in detail the variables that affect the opportunity cost of public funds used to finance the stream of project deficits, which in turn finance marginal units of recurrent input. If a surprise occurs which changes one of these variables so that the opportunity cost of the project deficit stream is larger than anticipated in the project design, then the result will again be an optimal reduction of the flow of recurrent input below the planned level.

For instance Marglin derives an expression for the relationship of the opportunity cost of funds used to finance a project deficit to the proportion of them that would have been invested in the private sector at the current private rate of return, and also to the proportion of the proceeds from these foregone investments that would in turn have been reinvested in the private sector (Ibid., pp. 290, 299). An increase in either of these proportions increases the opportunity cost of using these funds to finance the project deficit and thus in our model causes a surprising increase in the parameter s. On the other hand, he also shows that a policy of reinvesting a proportion of the benefits of the project at the private rate of return tends to decrease the social opportunity cost of the funds and thus diminish s.

Similarly, Feldstein examines the effect of the mixture of tax and debt financing of the project deficit on the social opportunity cost of the funds extracted from the private sector. A result of his analysis is that, under certain plausible conditions, the marginal dollar of project deficit incurs a higher social cost if it is debt financed than if it is tax financed.[21] Thus a surprising shift from tax to debt financing of a project deficit could raise the social cost of that deficit, increase the value of the parameter s, and lead to an optimal reduction of recurrent input below the planned level.

These considerations make it clear that a project designer must perform his analysis with great care if he is to properly capture the true social opportunity cost of the public funds diverted to financing the project deficit. One of his most difficult problems will be to guess how the project deficit stream will be financed over the course of the project lifetime. According to Little and Mirrlees,

> [s]ometimes [the project designer's] guess about [how a project will be financed] will be almost a value judgement: [he thinks] that a sensible government would plan [to finance a project in a certain way,] so [he] assumes that it will do so. Of course, if one of [his] assumptions required government action in order to be fulfilled, this should be brought to the attention of the appropriate authorities (1969, p. 106, as quoted in Sen, 1972).[22]

But as Sen points out,

> [i]t is not a question of <u>knowing</u> what is the "sensible" policy . . . but of being able to <u>ensure</u> that these policies will in fact be chosen. This would depend on [the project designer's] reading of the nature of the State of the Government and on [his] analysis of the influences that affect government action. And on this should depend the appropriate set of accounting prices for cost-benefit analysis (1972, p. 490, emphasis in original).

Thus a "correct" project design consistent with the limited power of a designer to ensure any government action, is one based on well-informed guesses regarding the most probable future government behavior.[23] Ideally the design should be parameterized with respect to those guesses of which the designer is least confident. This prescription clearly leaves room for a correct project design to err in predicting future government behavior regarding the financing of the project deficit. However the question remains whether there is any particular reason to believe that the errors in recent years might have consistently been in the direction of underestimating the opportunity cost of public funds.

A partial response to this question follows from the observation that many LDC's have continually modified their fiscal systems over the past two decades in order to accomodate demands that their tax efforts be increased and made more equitable. As a result of this constantly changing fiscal environment, project designers may have frequently been working in a context wherein increased tax revenues were expected to become available to finance recurrent inputs to development projects. But the number of ways in which attempts to increase tax revenues can be frustrated is so large that Harberger has developed the following typology to classify them:

(i) The affected factors of production may leave the country.

(ii) The affected factors of production may shift to other activities (in which lower taxes are paid) within the country.

(iii) The taxes in question may be evaded.

(iv) The taxes in question may be not levied in the first place.

(v) The taxes in question may be levied but not have the desired effect. (1977, p. 259)

Hence, even if the project designer discounts the revenue projections of the finance ministry as much as is consistent with assuring that his design be acceptable to the host country government, it seems likely that these "correct" projections will have proved to be overly optimistic. The result may be that the government is obliged to cover recurrent cost with a mix of financing that depends more heavily on debt than the designer had anticipated. Thus, according to the Feldstein result presented above, the opportunity cost of financing the project deficit turns out to be higher than expected, and the optimizing project manager accordingly reduces the flow of recurrent input to the project.

In a variation on the same theme, suppose that revenue projections are not met due to one of the adverse events on Harberger's list, and then it becomes apparent that additional public finances above the unexpectedly small quantity obtained are unavailable <u>at any price</u>. That is, the LDC in question is unable, for one reason or another, to extract another dollar from its taxpayers, to borrow another dollar from wary creditors, or to expand its money supply.[24] Clearly the effective opportunity cost of those funds that are available will increase dramatically. Even a sophisticated project design which has been carefully calibrated to be robust to minor increases in the s parameter in the event that the LDC shifts from tax- to debt-financed recurrent expenditures, is unlikely to be immune to such a sharp increase in s. The result will again be that the project manager must reduce the flow of recurrent input to the project in order to maximize social welfare.

A further problem that could arise to alter upward the value of s is similar to the fluctuation in national priorities discussed above. Suppose that the flow of development aid to a given LDC depends partly on whether the country in question is "in fashion" with the donor community for whatever reason. In that case it seems likely that some of the recurrent expenditure demands on the country's fiscal system are being met with foreign resources. If the designer is instructed to suppose that current levels of aid will continue or increase in the future, but this expectation turns out to be false, the designer's calculation of the opportunity cost of public funds in financing a given project's deficit will likewise be falsified.

Once again the question arises as to whether the designer is correct to ignore past cyclical behavior of donors with respect to individual countries in planning his project. However, given that the development bureaucracies of both the donor and host country have a vested interest in supposing that the flow of aid will continue, it is difficult to understand how the designer could elicit from the finance ministry a computation of the likely availability of public funds to finance the deficits of his project under any alternative assumptions about the inflow of foreign aid. In this situation the designer may follow Sen's advice and attempt to obtain "a reading of the nature of the State and of the Government and to analyze the influences that affect government action" in order to arrive at an independent prediction of the likely availability of public funds. But the designer's efforts to compute such an independent estimate are hampered by lack of resources and by the institutionalized optimism which conditions all of his sources of information. In view of his resource constraint, even the most skilled designer is unlikely to be able to purge his information of all optimistic biases. Thus his estimate of the opportunity cost of financing the project's future deficit, while less optimistic than it might be if he were an uncritical consumer of official predictions, will nevertheless be an underestimate. Again the result will be that the surprising increase in this cost will lead to an optimal reduction in the flow of recurrent input to the project.

In this section we have considered the possibility that the recurrent cost problem is the result of a sequence of three events which has repeatedly disturbed the course of project implementation. First, a project designer would produce a "correct" design. Second, an exogenous shock or "surprise" would occur. Third, the project manager would respond to the surprise by reducing the flow of recurrent input below the planned level in order to maximize the net present value of the project in the new situation. Throughout the discussion to this point we have assumed that the optimality of the recurrent input choice could be analyzed in relative isolation from the rest of the LDC's economy and particularly from other projects. In the next section we relax this last assumption in order to consider the problem of choosing the optimal level of recurrent input for one project when that same input is used by other projects within the country.

IV. Optimal Flow of Input When There Are Several Projects

In the last section we distinguished two varieties of exogenous "input supply surprise". First, the level of the supply price of the recurrent input might turn out to be higher than anticipated by the project designer. Second, the elasticity of recurrent input supply might be lower than anticipated. The first of these types of surprise is essentially an upward shift in the supply curve as perceived by the project manager as compared to that perceived by the designer. The second is a counter-clockwise rotation of the supply curve.

In this section we maintain the assumption that the supply curve is less than infinitely elastic and then alter the problem from that analyzed in the previous section by introducing two additional projects which use the same recurrent input as the project on which we focus. Since all three projects purchase their recurrent inputs in the same market, the upward sloping supply curve guarantees that the input decision of any one project designer or manager has external effects on the recurrent costs of the other two projects. We argue that the effect of these interactions is likely to be a sequence of supply surprises of the first of the two varieties mentioned above: the project manager of any given project will perceive an upward shift in the supply curve of recurrent input over time. Thus by expanding our perspective to include three projects in the same country we effectively endogenize one of the exogenous surprises of the previous section.

Suppose that three projects are undertaken seriatum during a period in the history of a specific LDC. All three projects are due to terminate on the same date which is T years after the present year, year zero. The first of the three projects was designed and began functioning in the past and has a total lifetime of $(T^1 + 1)$ years. The second of the three projects is currently being designed and will commence operations in year zero with a lifetime of $(T + 1)$ years. The third project is to be designed and implemented several years in the future and has a lifetime of $(T^3 + 1)$ years. These assumptions clearly guarantee that $T^1 > T > T^3$ and that the starting dates of projects one and three are year $(T - T^1)$ and year $(T - T^3)$ respectively. The time lines of the three projects are displayed in Figure 4. Our choice of origin on the time line reflects our desire to focus on project 2 in the context of two other projects, one past and one future.

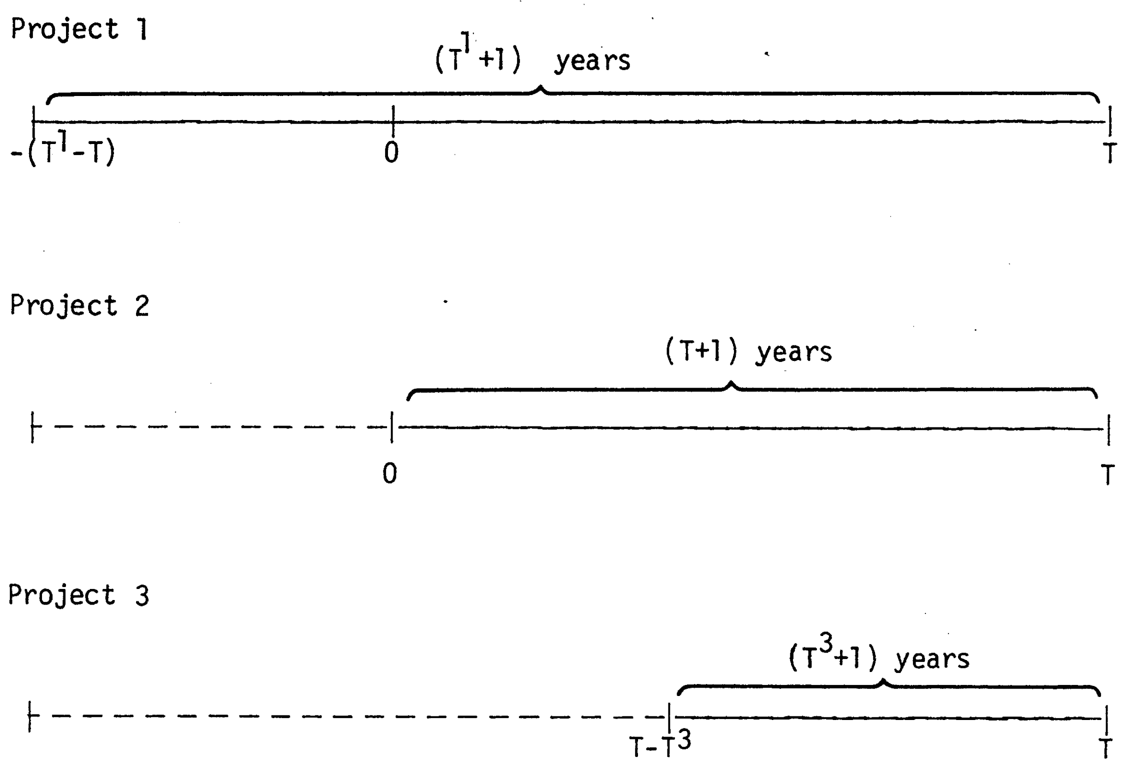

Figure 4. Time Lines of Three Projects from Perspective of Designer of Second Project.

Let W represent the sum of the net present values of the three projects computed at year zero. The global problem for the society is clearly to maximize W subject to all relevant constraints. However, for a number of reasons, the designer of project 2 is unlikely to be able to solve this global maximizing problem in order to design his particular project. First, project 1 has existed for $T^1 - T$ years and may have an articulate constituency which will prohibit the designer from considering recurrent input to project 1 as a choice variable. Rather the designer will be forced to take the level of recurrent input to project 1 as an exogenously determined constant just as is the amount of capital which was installed in project 1 as its inception. Second, the problem of designing a single project is difficult enough without adding to it the problems of designing other projects simultaneously. This fact may prohibit the designer from effectively considering the inputs to project 3 as choice variables. Instead he is likely to choose reasonable assumptions about the values of capital and recurrent input to project 3 and keep these figures fixed at those levels. These simplifications permit the designer to optimize his project design with respect to only the level of capital to be installed in project 2 and the level of recurrent input to project 2 in each year of its lifetime. If we further constrain the designer to consider only designs which use the same amount of recurrent input in each year, x^2, then the designer optimizes with respect to only two choice variables, K^2 and x^2.

By using superscripts to identify projects 1, 2, and 3, we can write the designer's problem as:

$$\max_{x^2,\, K^2} \qquad W = V^1 + V^2 + V^3 \tag{10}$$

where

$$V^i = B^i(y^i) - C^i(K^i, x^i, x) - (s - 1)\, D^i(K^i, x^i, x) \tag{11}$$

$$x = \bar{x}^1 + x^2 + \bar{x}^3 \tag{12}$$

and a barred variable is assumed constant. For simplicity, we assume that the supply of capital is perfectly elastic so that we need no adding-up constraint for capital similar to equation (12) for the recurrent input. Thus the choice of the quantity of capital to install in project 2 has no effect on projects 1 or 3 and the first-order conditions for problem (10) can be written

$$\frac{\partial W}{\partial K^2} = \frac{\partial V^2}{\partial K^2} = 0, \tag{13}$$

$$\frac{\partial W}{\partial x^2} = \frac{\partial V^1}{\partial x^2} + \frac{\partial V^2}{\partial x^2} + \frac{\partial V^3}{\partial x^2} = 0. \tag{14}$$

If the designer is to produce a correct design for project two, he must attempt an approximate solution to the first-order conditions (13) and (14). To do this he must calculate the approximate effects on projects one and three of a marginal unit of recurrent input used on project two. Only if the best information available to him given his budget constraints leads him to believe that these external effects are truly negligible should he ignore them completely in his project design, thereby implicitly assuming them to be zero. It is our contention here that many project designers fail to make even a cursory effort to determine whether external effects of this sort can be ignored - but they proceed to ignore them anyway. In the rest of this section we proceed under the assumption that the designer chooses levels of capital and recurrent input by solving (13) and (14) after setting the values of $\partial V^1/\partial x^2$ and $\partial V^3/\partial x^2$ to zero regardless of the true values of these two partial derivatives. Thus we have somewhat relaxed the assumption of the previous section that the project design itself is "correct" in favor of what may frequently be a more realistic view of the project design procedure.[25]

Under these assumptions about the designer's behavior, his design objective reduces to the more tractable problem of maximizing V^2. As a result, the first-order conditions for the problem that the designer actually attempts to solve are given by equations (3) and (4) of the previous section which we repeat here, appending the superscript 2 to indicate that all variables are specific to project 2:

$$\frac{\partial V^2}{\partial K^2} = \frac{\partial B^2}{\partial x^2}\frac{\partial y^2}{\partial K^2} - \frac{\partial C^2}{\partial K^2} - (s-1)\frac{\partial D^2}{\partial K^2}, \qquad (15)$$

$$\frac{\partial V^2}{\partial x^2} = \frac{\partial B^2}{\partial y^2}\frac{\partial y^2}{\partial x^2} - \frac{\partial C^2}{\partial x^2} - (s-1)\frac{\partial D^2}{\partial x^2}. \qquad (16)$$

where

K^2: physical units of capital installed at the commencement of project 2,

x^2: units of recurrent input flowing to project 2 in every year for $t = 0, 1, \ldots, T$.

Holding K^2 fixed at the value which satisfies equations (15) and (16), the optimal value of x^2 must satisfy equation (16). Figure 3 again depicts the determination of optimal recurrent input, but the definitions of the MSCX and MCX curves are somewhat altered to account for the fact that the demand for the recurrent input increases discontinuously at time $t = 0$ (from $\bar{x}^1$ to $\bar{x}^1 + x^2$) and then again at time $t = T - T^3$ (from $\bar{x}^1 + x^2$ to $\bar{x}^1 + x^2 + \bar{x}^3$).[26] The optimal level of recurrent input from the perspective of project 2's designer is determined as in Figure 3 by the intersection of a marginal value product curve, MVP^2, and the marginal social cost curve constructed from the revised versions of the two marginal cost functions of recurrent input to project 2, $MSCX^2$ and MCX^2. In Figure 5 the MVP and MSC curves from Figure 3 are redrawn with superscripts indicating that they are specific to project 2. Their intersection at $x^2 = \alpha$ determines the level of recurrent input that the project designer would choose following the decision process described in this section.

Although the project designer has been able to complete his work under the assumption that the terms $\partial V^1/\partial x^2$ and $\partial V^3/\partial x^2$ are zero, the project manager may find this assumption difficult to maintain. As soon as the project is constructed and begins operation,

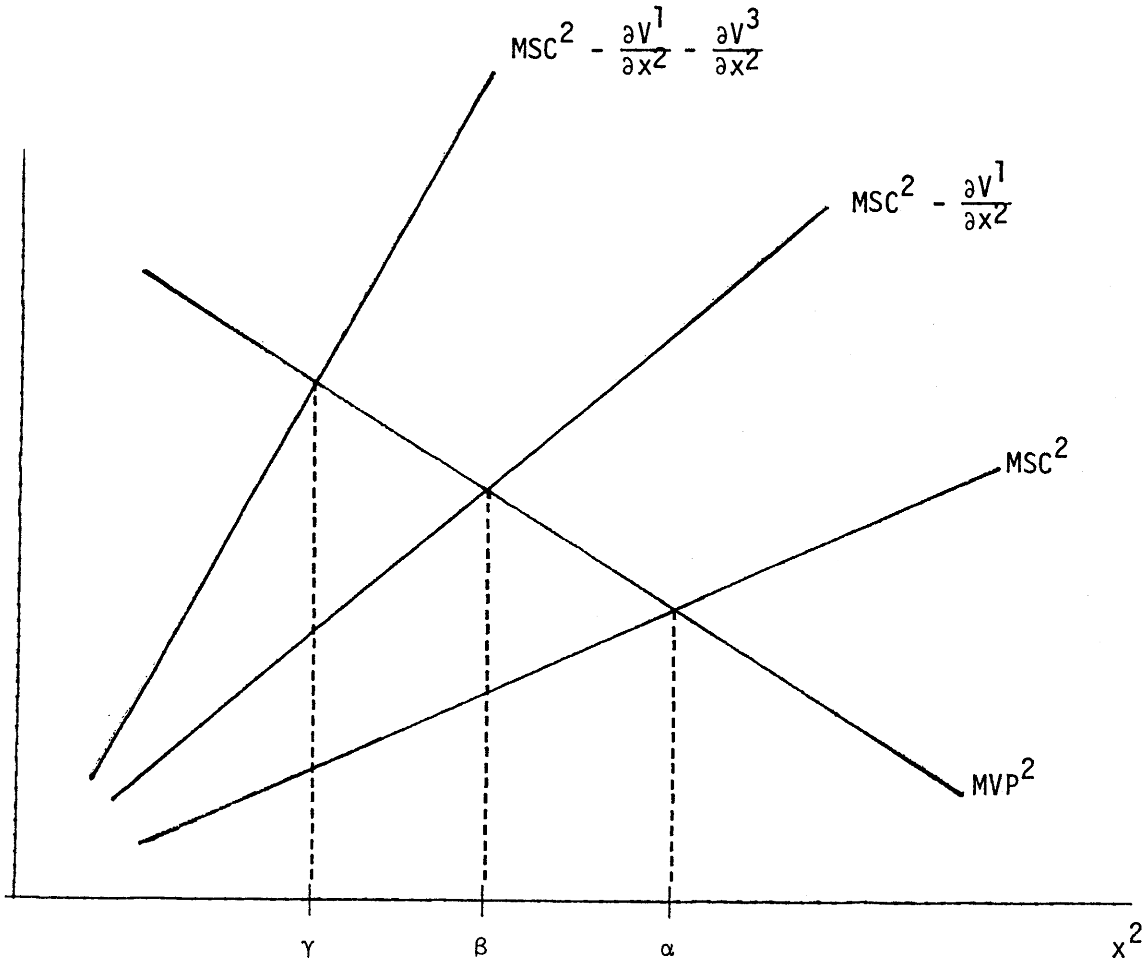

Figure 5. Three Different "Optimal" Levels of Recurrent Input to Project 2.

the fact that project 2's demand for the recurrent input drives up its price will cause the costs of project 1 to rise. It is reasonable to suppose that project 1 has a constituency which will complain bitterly at any attempt to require them to reduce their use of the recurrent input and will insist that their budget be increased to permit them to continue using the same quantity of that input at the higher price. If they succeed in retaining their claim on

$\bar{x}^1$ units of recurrent input flow, as we will assume, then the entire adjustment to the externality must be made by project 2. Implicitly project 2's manager must recompute the "optimal" level of recurrent input to his project by adding the external cost, $-\partial V^1/\partial x^2$, to the marginal social cost of x^2 computed by the project designer, MSC^2. Unless the demand for project 2's output as represented by its marginal value product curve is extremely inelastic, the result will be to reduce the flow of recurrent input to project 2 from α to β units per period as shown in Figure 5. The donor country which observes the project begin operation at a level of recurrent input that is already below the "optimal" level chosen by the project designer will perceive a "recurrent cost problem," when the host country is in fact maximizing its social welfare given the inappropriate project with which it has been endowed by a mistaken project design.[27]

Thus project 2 begins operation using β units of recurrent input per period. The situation is unaltered for a few years. But then project 3 is designed, constructed, and begins operation in year $(T - T^3)$. If project 3 had not been expected by project 2's designer, the result would be a further reduction of the recurrent input supply to project 2 unless project 2's constituency is as articulate and effective at defending its interests as was project 1's constituency. But we have assumed that project 2's designer and later its manager did expect project 3 and computed the optimal level of recurrent input to project 2 on the assumption that project

3 uses $\bar{x}^3$ units each year after it begins operation. The problem with the computations of project 2's designer and manager was the more subtle omission of the external cost of recurrent input used on their project to the net present value of project 3, which we represented by $\partial V^3/\partial x^2$ in equation (14). It is not until project 3 begins to operate that these externalities are appreciated and project 2's constituency must make a case for its continued use of β units of recurrent input per period. If they are less successful than was the constituency of project 1, project 2 will be forced to bear some or all of this external cost. In the extreme situation, project 2's manager would be obliged to recompute the optimal level of recurrent input use by his project by adding the term $-\partial V^3/\partial x^2$ to the marginal social cost of x^2 as he had previously computed it, $MSC^2 - \partial V^1/\partial x^2$. The new lower optimum of γ units per period is given by the intersection of this doubly revised cost curve with the MVP^2 curve in Figure 5.

Figure 6 below displays the time profile of the recurrent input to project 2. The dotted line at $x^2 = \alpha$ is the level of recurrent input prescribed by the project designer. However, in the scenario we have described, recurrent input begins to flow to project 2 at the lower level of β and then, at the inception of project 3, drops still lower to γ units per period. One can easily imagine the consternation of project 2's donor as it observes this pattern. Unaware of the degree of external costs of its project on other projects financed by other donors, the donor of project 2 compares the actual recurrent input profile with the prescribed level and is led

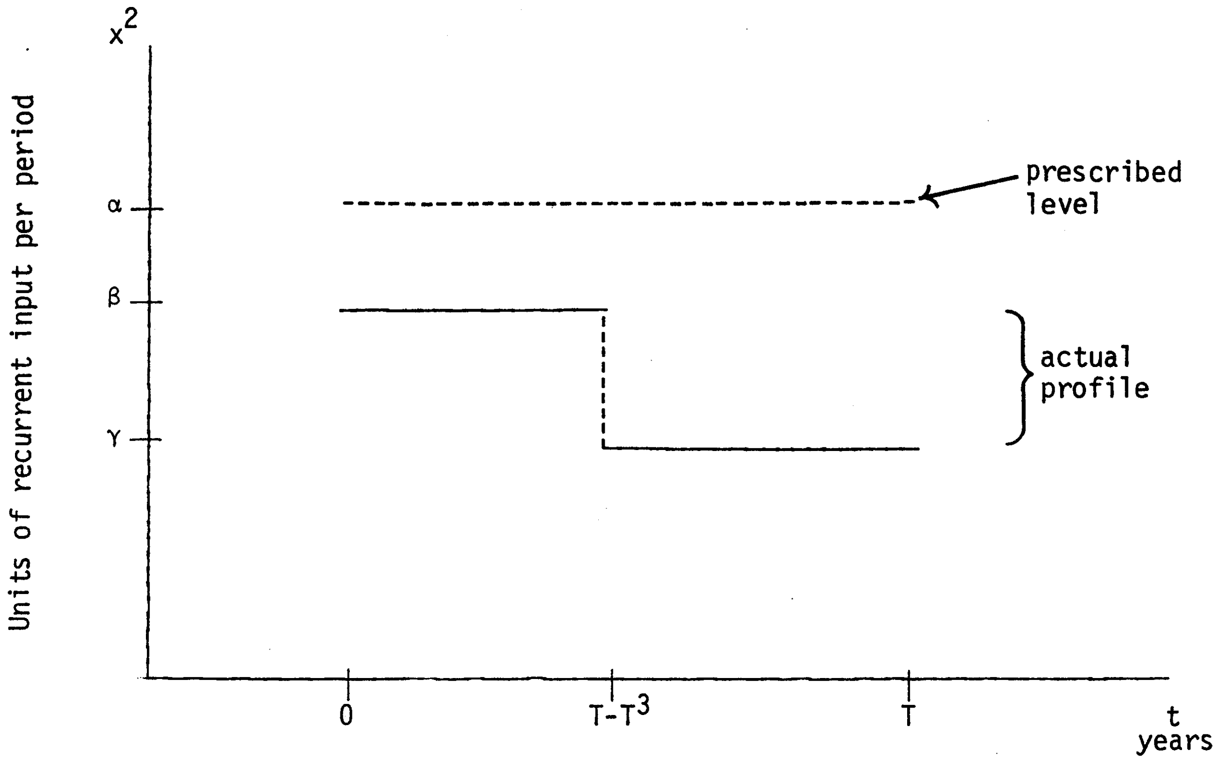

Figure 6. Time Profile of Recurrent Input to Project 2.

to suspect ineptitude or malfeasance. However, this discussion suggests that a donor should make a careful search for external costs of its project omitted from the original design as well as for the surprises listed in the previous section before giving credence to alternative less benign explanations of the recurrent cost problem.

V. A Model Which Predicts Biased Project Designs

A. Overview

If a project design is correct *ex ante* in the sense of the previous two sections of this paper, then the welfare maximizing project manager would restrict the flow of recurrent input to his project only in response to a "surprise" similar to those we have described. If, on the other hand, a given project design is *wrong ex ante*, calling for more than the welfare maximizing flow of recurrent input, then, even in the absence of "surprises", the project manager has an incentive to choose a flow of recurrent input to the project below the flow prescribed in the project document. The frequency of instances of the recurrent cost problem, together with the scarcity of examples of a significant and sustained *increase* in the flow of recurrent input above the planned amount, suggest that "surprises" may be insufficient to explain the problem. Rather it seems likely that the process of project design is systematically biased towards the prescription of more recurrent input than will in fact be forthcoming.

To explain why such a bias might appear, we must enter more deeply than heretofore into the motivation of the donor and the LDC, the two parties to the implicit contract that is codified in the project design document. In previous sections we have assumed that the donor is motivated to approve and finance project designs which are correct *ex ante*, without inquiring as to the source of that motivation. But a "correct" project design purports to maximize LDC welfare subject to the LDC budget constraint as modified by concessionary financing. The assumption that the design which is "correct" in this sense is also correct from the donor's perspective suggests that the donor's social preferences and resource endowments are so similar to those of the LDC that the solution it would choose to the welfare-maximizing project design problem tends to be identical to that of the "correct-to-the-LDC" design. In view of the vast differences which in fact distinguish the situations of the donor and the LDC, this assumption could be rendered plausible only through specific argument. However, the literature on project evaluation rarely recognizes the possibility that the donor's interests might diverge from those of the LDC with respect to the choice of project design.[28]

The minimal requirement for a successful model of donor motivation is that it predicts that the donor and LDC first share an interest in designing the project and then subsequently have different interests regarding project operation. The subsequent divergence in their interests would lead one of the parties, the donor, to complain of a recurrent cost problem. There are at least four models which fulfill this requirement. In this section we analyze one of these, which we call the "merit good model", assuming the preferences of both parties are known to both. Then in section VI we compare the merit good model with the three alternatives and we explore the possible implications of relaxing the assumption that each party knows the other's preferences.

After this introductory part, this section presents the merit good model in part B, and then uses it in part C to predict, first, that donor and LDC both have an incentive to agree to a biased project design, and, second, that the LDC subsequently has an incentive to reduce recurrent input flow from that prescribed by the design. As a result of both parties' responding to these incentives, the donor perceives a recurrent cost problem. Then in part D of this section we characterize a subset of the solutions to the perfect information merit good model as the cells of a payoff matrix in a two-person, non-zero-sum, iterative game in order to model a donor-LDC relationship which could include multiple projects designed and implemented over several years.

B. The Merit Good Model of Donor-LDC Interaction[29]

A possible explanation of the donor's interest in funding a development project is that the output of that project in the LDC directly enters the donor's welfare function as an argument. If the donor derives value from the project output through rivalrous consumption of that output, then this hypothesis simply reduces to a version of the exchange model which we will discuss in section VI. However, many projects produce outputs such as health care, subsistence crops, or military defense, which are not exportable to the donor, and others produce outputs like peanuts, beef, or grain which the donor may desire to exclude from its domestic markets to protect domestic producers of the same products. We hypothesize that the donor obtains welfare from the output of one of these projects, not through importing it for direct consumption, but rather from its knowledge that the citizens of the LDC are consuming it.

In the case of goods which are said to be "basic human needs", the preference of the donor may be based on its fundamental ethical beliefs. At the opposite ethical extreme, project output might strengthen the military defense of the LDC and thereby serve some strategic purpose of the donor. In either case it would be the project output, rather than the welfare the LDC derives therefrom or the act of donating resources, that yields welfare for the donor.

Suppose that the project output entering the separate national welfare functions of the donor and the LDC is a purely private good according to the usual definition. Once that output is produced and privately consumed by citizens in the LDC, both nations obtain social welfare from that consumption and neither can exclude the other from the enjoyment of that welfare. If we focus on the relationship between the two nations, the output of the development project has an attribute which is analagous to the conventional property of nonexcludability. Furthermore, since all project output enters both welfare functions, the good has an attribute analagous to the conventional property of nonrivalrous. Goods like this project output which are nonrivalrous and nonexcludable between (or among) nations, regardless of whether they are public or private within the boundaries of given countries, constitute a class of collective goods which we shall term pure "internationally collective goods." When the preference of one country for consumption of the good by citizens of the other is due to the ethical belief by the donor that the good is a "basic human need" or "should" be consumed more than it is, we call the good an "internationally meritorious good." For simplicity we call this fourth model the "merit good model" of donor motivation, although we recognize that the model may apply equally well to internationally collective goods that are not internationally meritorious.

In the merit good model of donor motivation towards the project design process, the donor and the LDC separately seek to maximize their own welfare functions, W_D and W_L. The fact that both welfare functions contain the output of a given development project implies that they share an interest which may induce them to collaborate in the production of that output. We assume that production of an annual flow of project output, y, is achieved by combining K_y units of capital, all provided at the beginning of the project, with an annual flow of recurrent input, x_y. As in previous sections, we assume that all capital is provided by the donor and all recurrent input is provided by the LDC. Because provision of the "merit good" y is achieved through cooperation of two parties and because neither can exclude the other from its consumption once it is produced, the way is prepared for the appearance of the free-rider problem. In section VI we will return to a discussion of the nature of that problem in this situation once we have presented the model in more detail.

In addition to (the flow of) project output, y, the welfare function of the donor contains (the flow of) another good, q_D, which is also produced with capital. Thus the opportunity cost to the donor of giving capital to the LDC for use in the development project is represented by the marginal value product of that same capital in producing this other composite good in its welfare function. We write the donor's welfare function as

$$W_D\ (y,\ q_D). \qquad (17)$$

Just as allocation of capital to the development project has an opportunity cost for the donor, allocation of recurrent input to the project has an opportunity cost to the LDC. That cost is given by the marginal value product of recurrent input in producing (the flow of) a second composite good in the LDC welfare function, q_L. The LDC welfare function is

$$W_L\ (y,\ q_L). \qquad (18)$$

The production functions which represent the technologies by which the three goods are produced are given by:

$$y = f(K_y,\ x_y), \qquad (19)$$

$$q_D = g(K_q), \qquad (20)$$

$$q_L = h(x_q). \qquad (21)$$

We impose adding-up constraints on the two scarce resources:

$$K_y + K_q = \overline{K} \ , \tag{22}$$

$$x_y + x_q = \overline{x} \ , \tag{23}$$

where $\overline{x}$ and $\overline{K}$ are fixed constants and x_y, x_q, K_y and K_q are nonnegative. We assume that the two welfare functions and the three production functions are all nonnegative over their respective nonnegative domains. They have strictly positive first partial derivatives, strictly negative second partial derivatives, and the first partial derivative of any of them with respect to one of its arguments approaches positive infinity as that argument approaches zero. Furthermore, in order to derive unambiguous results, we assume that the two welfare functions and the production function for project output are all homogeneous of degree one in their respective arguments.

Since the value of y to the donor lies in its production and consumption within the LDC, it is natural to assume that it is a nontraded good. Furthermore, the opportunity cost to the LDC of supplying recurrent input to a development project is typically measured in the foregone consumption of other nontraded goods such as the output of other development projects or of general government services. Even where the opportunity cost might be measured in terms of a traded good, exchange controls, established trade and consumption patterns, and other rigidities of the structure of a developing country often impede the free flow of goods between them and other countries at a market determined exchange rate. In recognition of these features of a developing economy and in order to focus attention on the interaction of donor and LDC around the development project, we assume that q_L, and hence q_D, are also untraded goods.[30] Thus the only form of "exchange" available to the two countries is their agreement to jointly produce the output of the development project.

The structure of this model is similar to that of the standard duopoly model.[31] As in that model, each of two parties seeks to maximize its own welfare through manipulation of the instrumental variable under its control. However, each party's actions affect not only its own welfare, but also that of the other party. Because the two parties have different welfare functions and different resource constraints, their interests do not perfectly coincide. Various solutions to the duopoly problem have been proposed which depend on different assumptions regarding the degree to which the two parties are willing and able to coordinate their decisions. At one extreme the classic Cournot solution to the duopoly problem posits that each party behaves as if it believes the value of the other's instrument is fixed. Each party maximizes its own welfare without regard to possible responses by the other party. At the other extreme, the pareto optimal solution to the duopoly problem posits that each party behaves as if it fully considers the effects of its behavior on the welfare of the other when it chooses a value of its own instrument. For example, if the two parties agree to jointly choose the values of their two instruments in order to maximize the weighted sum of their welfare functions subject to all the constraints on each of them individually, the instrument values so chosen will be pareto optimal.

However, the present model differs from the standard duopoly model in one important respect. Whereas the two actors in the standard model are assumed to choose the values of their respective instruments either simultaneously or in an arbitrary sequence, here those decisions are naturally ordered by the fact that in reality the donor's contribution is usually committed fairly early in the project lifetime, while the LDC has the opportunity to revise annually its decision on the flow of recurrent input to commit to the project. In our model, we represent this feature of the project design process by assuming that K_y is determined before the project begins by the project designer, while x_y, the flow of recurrent input, is independently chosen by the project manager who may or may not pick the value of x_y prescribed by the project design. This natural, technologically determined, timing introduces an assymmetry between the two actors that is absent from the standard duopoly model.[32] We explore the implications of that assymetry below.

Because this model of the design and management of a development project is so similar in structure to the classical duopoly model, we will have repeated occasion to borrow terms and concepts from the duopoly model for application to our problem. However, differences between this model and the standard duopoly model of the microeconomic textbooks imply that a concept occasionally acquires a somewhat different connotation in our application than it may have in the familiar literature. An example of such a difference occurs when we refer to the Cournot behavioral assumption.

Whereas it is generally believed that the Cournot assumption is "rather artificial and weak" as a description of duopolist decision rules (Henderson and Quandt, 1980, p. 205), it may be a relatively realistic description of the LDC's decision process in the present model. Since the donor's capital input to the project K_y is assumed to be fixed by the technology of project construction at the time the LDC decides how much recurrent input to actually commit, the LDC that is looking no further than the current project is quite justified in adopting the Cournot assumption as it seeks to maximize its own welfare from the project.

Once the donor has chosen and installed an amount of capital at the beginning of the project, the LDC's decision problem is to choose that value of its own instrument, the recurrent input x_y, which maximizes its welfare function (18) subject to constraints (19), (21), and (23). The first-order condition for this constrained maximization problem can be written

$$\frac{\partial W_L/\partial y}{\partial W_L/\partial q_L} = \frac{dq_L/dx_q}{\partial y/\partial x_y} . \tag{24}$$

The left-hand-side of equation (24) is the marginal rate of substitution between the other goods in the LDC's welfare function and project output. Our assumptions assure that, for fixed K_y, this quantity is a declining function of project output. We denote it MRS_L and interpret it as the marginal social benefit of project output or as the LDC's social demand curve for y. The right-hand-side of equation (24) is the marginal rate of transformation between other goods and project output as determined by the technologies of producing q_L and y. We denote this quantity by MRT_L, interpret it as the marginal social cost of project output and note that our assumptions guarantee it to be an increasing function of project output.

The LDC which maximizes its own welfare subject to its own constraints and given a fixed level of capital input chooses that rate of flow of project output that equates its demand with its marginal cost. In Figure 7 we depict this solution of the LDC's optimization problem as it is defined by equation (24). Panel (a) of the figure displays the determination of the nationally optimal rate of production of project output, y*, as the value of y at which the declining MRS_L curve intersects the rising MRT_L curve.

Panels (b) and (c) relate the story told by panel (a) to the determination of optimal recurrent input by the methods of section III and Figure 3 above. Given fixed capital input $\overline{K}_y$, the production function displayed in panel (b) of Figure 7 provides a one-to-one correspondence between rates of flow of project output y and rates of flow of recurrent input to the project x_y. Thus once the optimal rate of flow of project output, y*, is determined by the curves of panel (a), that value determines in turn an optimal rate of flow of recurrent input to the project, x_y^*. But both x_y^* and y* could equally well be determined from the curves in panel (c) which

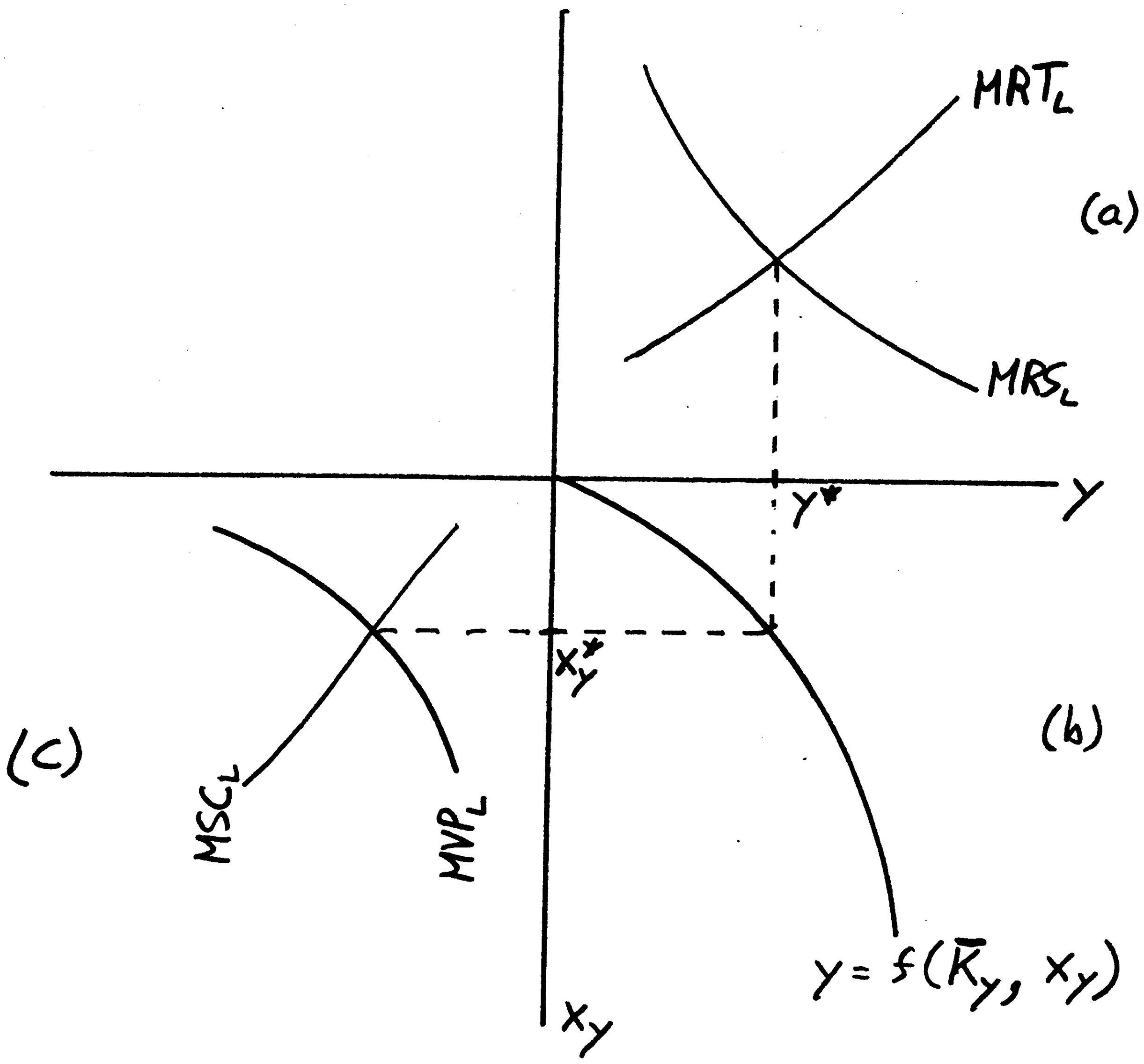

Figure 7. Determination of LDC's Nationally Optimal Level of Recurrent Input

is analagous to panel (c) of Figure 3 above. In panel (c) of Figure 7, x_y^* is the flow of recurrent input to the project which, given $\overline{K}_y$, equates the present marginal value product of an additional unit of recurrent input flow, MVP_L, to the (present) marginal social cost of that unit, MSC_L. The optimal flow of recurrent input x_y^* in turn determines the optimal flow of project output y*.[33]

An alternative characterization of the LDC's decision problem which is less familiar but more useful can be obtained by substituting producton functions (19) and (21) and adding-up constraint (23) into the LDC's welfare function to obtain its reduced-form welfare function in terms of the two project inputs x_y and K_y. If we denote this function $U^L(K_y, x_y)$, then the LDC's choice problem can be written:

$$\max_{x_y} U^L(K_y, x_y) \qquad (25)$$

subject to:

$$K_y = \overline{K}_y.$$

Using subscripts on U^L to indicate partial differentiation, the first-order condition for a solution to problem (25) is:

$$U_x^L(x_y ; \overline{K}_y) = \frac{\partial W_L}{\partial y}\frac{\partial y}{\partial x_y} - \frac{\partial W_L}{\partial q_L}\frac{dq_L}{dx_q} = 0 \qquad (26)$$

It can be shown that the function U^L is strictly quasiconcave in a neighborhood of any solution to first-order condition (26) so that such a solution is indeed a constrained maximum.

This formulation of the problem leads to the definition of isowelfare loci in x_y and K_y. The slope of these LDC indifference curves is determined by fixing U^L to a given value, totally differentiating, and solving for the derivative dK_y/dx_y. We find that

$$\left.\frac{d\,K_y}{d\,x_y}\right|_{dU^L=0} = -\frac{U^L{}_x}{U^L_K} \quad . \tag{27}$$

The denominator of this derivative is given by

$$U^L_K(\,K_y,\,x_y\,) = \frac{\partial W_L}{\partial y}\;\frac{\partial y}{\partial K_y} \tag{28}$$

which is strictly positive and approaches positive infinity as K_y approaches zero. Therefore, the sign of expression (27) is determined by its numerator which is defined by the first equation in (26).

These characteristics of the function U^L allow us to picture its isowelfare loci in input space. In Figure 8 we have used the adding-up constraints to define the feasible project input space as a rectangle reminiscent of the Edgeworth-Bowley box diagram. The vertical dimension of the box is defined by $\overline{x}$, the total amount of recurrent input available to the LDC each year for allocation between the production of project input and other goods. Similarly, the horizontal dimension of the box is defined by the total capital to which the donor is constrained, $\overline{K}$. In view of the adding-up constraints, any point in the box such as point A represents the quadruple $(x^a_y,\ K^a_y,\ x^a_q,\ K^a_q)$, where x^a_y and K^a_y are measured from the $(K_y,\ x_y)$

origin in the usual manner while x_q^a and K_q^a are respectively defined as $\overline{x} - x_y^a$ and $\overline{K} - K_y$ are measured from the top and right of the graph. The assumptions regarding the three production functions f(.), g(.), and h(.) guarantee that a move northeast within the box increases project output and decreases the outputs of other goods in each of the two countries and the reverse is true of a move southwest. On the other hand a move southeast, such as that from point A to point B in the figure, has an indeterminate effect on project output although it must increase other good production by the LDC while it decreases such production by the donor.

For any given value of capital input, the LDC's optimal choice of recurrent input is given by the point of tangency between a vertical line constructed at that value of K_y, and the indifference curve representing the LDC's highest attainable welfare level. Points A and B give the LDC welfare maximizing choice of recurrent input for each of two different values of donor-determined capital input to the development project, K_y^a and K_y^b. They are two of an infinite number of points on the curve CC which graphs the value of x_y determined implicitly by equation (26) for every value of $\overline{K}_y$.

Because the curve CC gives the value of x_y that the LDC would choose for any given value of K_y, it is the LDC's reaction function and is analagous to the Cournot reaction function of the standard duopoly model. Aside from the fact that it intersects the left and and right margins of Figure 8 at some distance away from the corners and that it proceeds smoothly from left to right without doubling back on itself, its shape over the interval $0 \leq K_y \leq \overline{K}$ is arbitrary

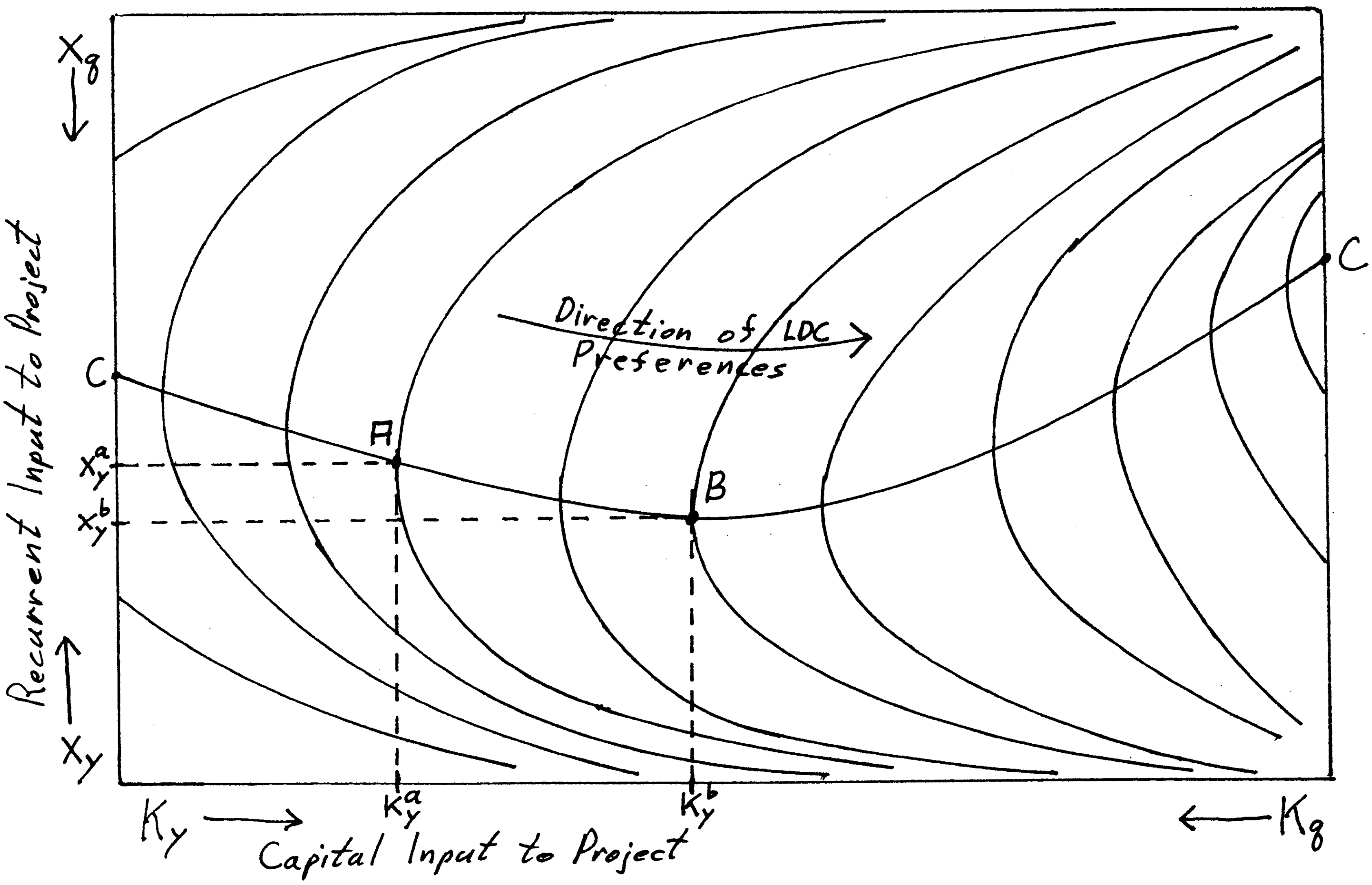

Figure 8. LDC Indifference Curves and Reaction Curve

and depends on the nature of the functions which comprise U^L. The reaction function's slope at any value of K^y can be found by totally differentiating the implicit function (26) to obtain.

$$d\, U_x^L = U_{xx}^L\, dx_y + U_{xK}^L\, dK_y = 0 \tag{29}$$

and solving for.

$$\left.\frac{dx_y}{dK_y}\right|_{dU_x^L = 0} = \frac{-\ U_{xK}^L}{U_{xx}^L} \ . \tag{30}$$

It can be shown that the sign of U_{xx}^L is strictly positive so that the sign of the slope of the reaction curve depends on the sign of the cross partial derivative of U with respect to the two inputs. But that sign in turn depends on the elasticities of substitution characterizing two of the functions which comprise U^L. Define σ to be the elasticity of substitution between the two inputs x_y and K_y in the production of project output and λ to be the elasticity of substitution between project output and other goods in the LDC's welfare function W_L. In this general equilibrium context we can also interpret λ as the elasticity of LDC demand for the output of the development project evaluated at a certain pair of values of y and q_L. Then by using the linear homogeneity of the functions W^L and f(.), it can be shown that

$$\text{sgn}\left[\frac{dx_y}{dK_y}\right] = \text{sgn}\ (\lambda - \sigma). \tag{31}$$

Thus the particular shape of the reaction function depicted by the curve CC in Figure 8 corresponds to a situation in which the elasticity of LDC demand for project output is less than the elasticity of substitution characterizing the project production process for values of capital input up to K_y^b. As the figure is drawn, for greater values of donor input than K_y^b, the magnitudes of the two elasticities are apparently reversed, perhaps because at these large values of project output LDC demand becomes more elastic.

Relation (31) bears an interesting economic interpretation. If either the substitution elasticity that characterizes the production process is very small or the elasticity of LDC demand is very large (or both), the reaction function will tend to be positively sloped.[34] Thus, in these situations, incremental amounts of capital provided by the donor will elicit positive increments in the contribution of the LDC to the project <u>without any policing by the donor</u>. On the other hand, in situations where inputs are highly substitutable or LDC demand is quite inelastic, incremental amounts of capital will elicit reductions in recurrent input supplied by a welfare maximizing LDC. An implication is that donors concerned that their inputs to certain LDC endeavors be matched by increasing LDC contributions to those activities should seek the former situation and shun the latter.

While the Cournot behavioral hypothesis may not be unreasonable to describe the LDC's behavior, the same characteristic of the problem that makes the Cournot hypothesis unusually acceptable for the LDC renders it entirely untenable as a description of donor behavior.

In view of the timing of project inputs, no project designer or donor can reasonably be supposed to treat the recurrent input to be supplied by the LDC as an exogenous parameter unaffected by the design decision. In fact, donor participation in the project design process might be partially motivated by the donor's desire to estimate the LDC's reaction function. Since the ability of the LDC to adjust its recurrent input decision after the donor has irrevocably committed most of its capital input is a recognized fact of the project design and implementation process, the donor can be presumed to know that the LDC can ignore donor reactions to its recurrent input supply decision - at least in the context of this project. Thus the donor can avoid the infinite regression that can occur in plotting duopolist strategy when each party must conjecture on the other's beliefs regarding its own and the other's reaction functions.

If the donor is perfectly informed regarding the LDC's welfare function and the technologies for producing both project output and the LDC's other good, then it can derive equation (26), the LDC's reaction function in implicit form. One donor strategy might then be to simply choose the level of concessionary project financing which maximizes its own welfare subject ot its own resource constraint, project technology, the opportunity cost to it of that grant capital, and, in addition, its knowledge of the LDC reaction function. Formally, the problem is

$$\max_{K_y} \quad W_D(y, q_D) \qquad (32)$$

subject to constraints (19), (20), (22), and the LDC reaction function as given implicitly by equation (26). If the donor follows that strategy, its behavior is analagous to that of the "Stackleberg leader" of the classic Stackleberg solution to the duopoly problem (ibid., pp.205-207).

The first-order condition for problem (32) can be written in the form:

$$MRS_D = MRT'_D \, , \tag{33}$$

where MRS_D is defined analagously to MRS_L. MRT'_D is a modified form of the marginal rate of transformation that would obtain if the LDC's choice of recurrent input were exogenous. The modified marginal rate of transformation is defined as

$$MRT'_D = \frac{d\, q_D \,/\, d\, K_q}{\frac{\partial y}{\partial K_y} + \frac{\partial y}{\partial x_y}\,\frac{dx_y}{dK_y}} , \tag{34}$$

and is related to the unmodified marginal rate of transformation by the inequalities

$$MRT'_D \begin{Bmatrix} > \\ = \\ < \end{Bmatrix} MRT_D \text{ as } \frac{dx_y}{dK_y} \begin{Bmatrix} < \\ = \\ > \end{Bmatrix} 0 \, . \tag{35}$$

The quantity dx_y/dK_y is the response that the donor conjectures will be forthcoming from the LDC in response to a unit increment in K_y by the donor. Following conventional terminology, we refer to this quantity as the "conjectural variation." If the donor has perfect information, the conjectural variation is given by equation (30).[35]

In order to depict the donor's choice problem on our box diagram, we replace maximand (32) by the donor's reduced form welfare function, U^D, which we obtain by substituting equations (19), (20), and (22) into the donor's welfare function, W^D. The slope of the donor's isowelfare loci is given by an equation analagous to equation (27),

$$\left.\frac{d\,x_y}{d\,K_y}\right|_{dU^D=0} = -\frac{U^D_K}{U^D_x}, \tag{36}$$

and the slope of the donor's Cournot reaction function, which joins the points at which its indifference curves are horizontal, is given by

$$\left.\frac{d\,K_y}{d\,x_y}\right|_{dU^D_K=0} = -\frac{U^D_{Kx}}{U^D_{DD}}. \tag{37}$$

The shape of the donor's reaction function, like that of the LDC's, depends on the relative magnitudes of two elasticites. Define δ to be the donor's elasticity of demand for project output as given by the elasticity of substitution between y and q_D in the function W^D. Then it can be shown that

$$\text{sgn}\left[\frac{d\,K_y}{d\,x_y}\right] = \text{sgn}\,(\delta-\sigma). \tag{38}$$

In Figure 9 we superimpose a set of donor indifference curves upon a set of LDC indifference curves different from those displayed in Figure 8. The downward sloping LDC reaction function represents a situation in which the LDC's demand for project output is less elastic than the project production technology ($\lambda<\sigma$) over the entire domain of feasible input combinations. On the other hand, the positively sloped donor reaction function corresponds to a situation in which the donor's demand for project output is more elastic than the production technology ($\delta>\sigma$) over the entire domain. Combining these assumptions, we have the relationship

$$\delta > \sigma > \lambda \tag{39}$$

which characterizes the preferences and technology of Figure 9.

The superposition of the two preferences maps graphically displays the fact that the donor and LDC share a common, but not an identical, interest in project output. The southwest corner of the figure represents zero inputs to the project and thus zero project output. Since any move away from that point increases both welfares, the two nations share an interest in moving away from that point toward positive production of y. On the other hand the directions of preferred movement are not identical. The donor will prefer moves towards its bliss point above all others, while the LDC will prefer moves towards its bliss point.

Given knowledge of the technology and preferences as summarized by Figure 9, the donor's decision problem is to choose a point on the horizontal axis representing an amount K_y of capital which it

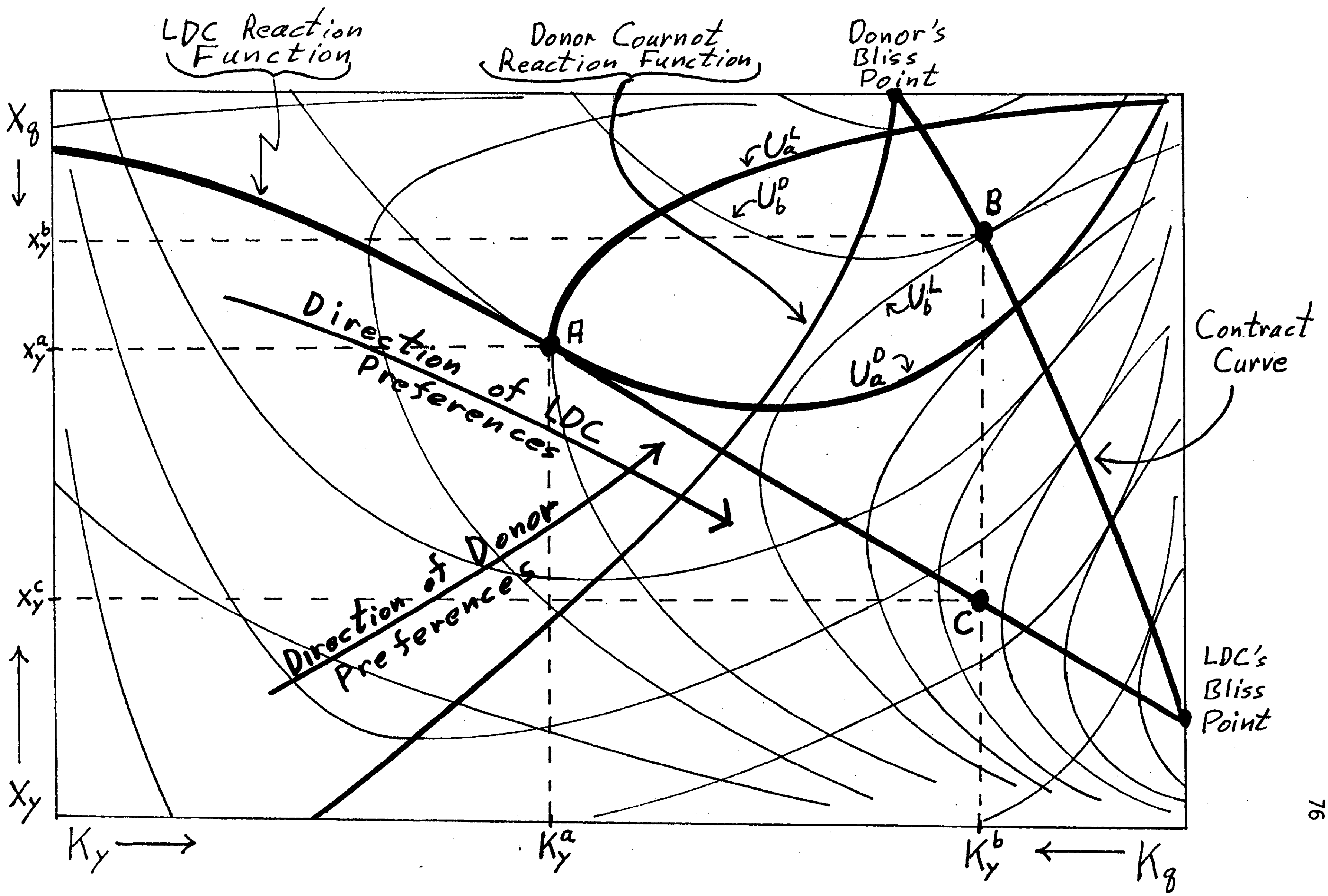

Figure 9. Preference Mappings of Donor and LDC in Project Input Space ($\delta > \sigma > \lambda$).

will provide to the development project. As we pointed out above, one option that the donor has is to behave as a Stackleberg leader. In this case the donor uses its knowledge of the LDC's reaction function to simply choose the point on that function that the donor most prefers. In Figure 9 this most preferred point is point A, which is a point of tangency with a donor indifference curve and yields a higher donor welfare than any other point on the LDC reaction function.[36] This point is analagous to the Stackleberg equilibrium of duopoly theory. Note that it improves the LDC's welfare relative to any point west of A on the LDC's reaction function.

At the other extreme from the uncooperative Cournot and Stackleberg solutions to the duopoly problem lies the set of Pareto-optimal choices of instrumental variables which can be achieved by the two parties if they cooperate. In our problem it can be shown that the locus of Pareto-optimal input combinations must lie above and to the right of both the donor and the LDC reaction functions in the interior of the input space and it must join the two bliss points. In Figure 9 the locus of Pareto-optimal input combinations or "contract curve" is shown connecting the two bliss points and passing through the points of tangency of the two sets of indifference curves.

Just as the Stackleberg equilibrium in duopoly theory is Pareto-inferior to many cooperative solutions, here also both the donor and the LDC could gain from cooperation. If we think of point A as their starting position, both parties' welfares would be higher if they were to move off the LDC's reaction function to a point within the lens-shaped area outlined by the heavy portions of indifference curves U_a^L and U_a^D. If they are able to agree on a point like point B, which is both on the contract curve and within the lens shaped area, then both will have more welfare than at point A and neither could improve its welfare except at the expense of the other's welfare.[37]

C. The Merit Good Model and Biased Project Designs

Now that we have developed a merit good model of donor-LDC interaction we are prepared to apply it in an attempt to explain how project designs might be systematically biased in the direction of "too much" recurrent input. We continue to assume that both the donor and the LDC have perfect information about technology and preferences. Suppose that preferences and technology define indifference curves in project input space like those of Figure 9. Now consider Figure 10 where key features of Figure 9 have been traced without the confusing detail of the earlier figure. The donor could choose its Stackleberg equilibrium capital donation to the LDC of K_y^a units of capital, thereby attaining a welfare level of U_a^D for itself and U_a^L for the LDC. Since the donor need not accept a welfare level lower than this one which it obtains from a noncooperative solution to its decision problem, point A represents the donor's "threat strategy." However, both the donor and the LDC are aware of the superiority to both of them of points like point B, which are both on the contract curve and within the "lens." Thus they have an incentive to design the project with input combination (K_y^b, x_y^b).

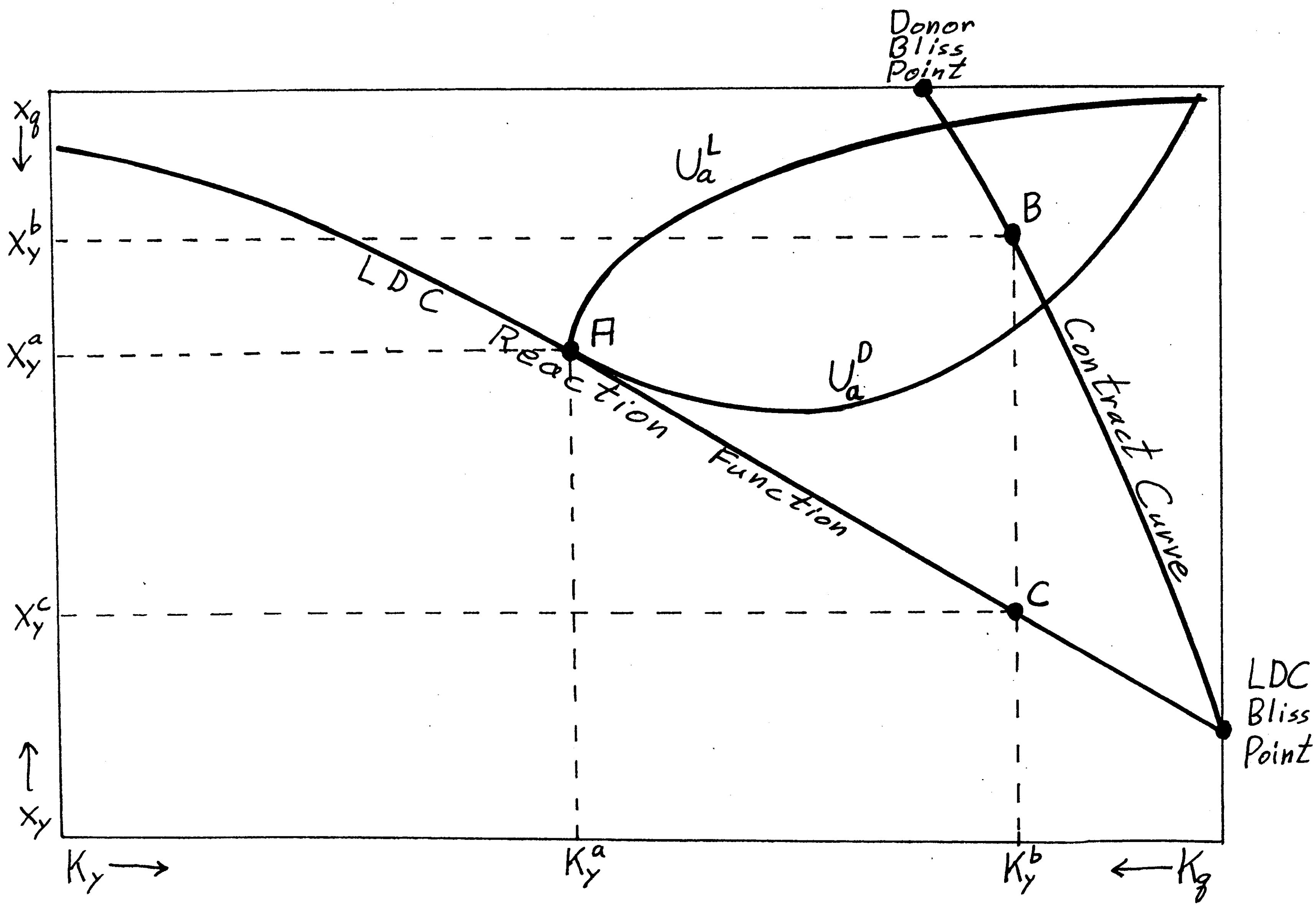

Figure 10. Project Design Bias Predicted by the Merit Good Model ($\delta > \sigma > \lambda$).

In order to attain point B, the project must be designed to maximize a weighted sum of both nations' welfare functions, W^L and W^D, subject to technology and to both resource constraints. However, the purported objective of project design is the maximization of only the LDC's welfare, subject only to the resource constraints which apply to the LDC. Thus at first glance actual project design practice seems to conflict with the requirements of a move from point A to a point on the contract curve in Figure 10. Instead the practice seems to lead unambiguously to a point on the LDC's reaction curve.

However, suppose that the donor's desire to see its capital inputs "properly" valued leads project designers to consistently assign positive shadow prices to donor-supplied capital goods which in fact have a vanishingly small opportunity cost to the LDC. Furthermore suppose that the project designer implicitly assigns a value to the merit good to be produced by the completed project which is in excess of the LDC's national willingness-to-pay for that good. The combined effect of these two "mistakes" in project design practice will lead to a project design which is biased away from the LDC's reaction function and towards the contract curve.

It is important to note that both nations have an incentive to escape from point A towards a point like B and therefore both have a strong incentive to ignore any errors in project design which allow the designer to produce a design more like point B than point A. If we supplement this argument with the observation that both types of overvaluation do seem to occur in practice, the possibility that actual project designs are often closer to a Pareto-optimal input combination like B than they are to a point on the LDC's reaction curve seems quite plausible.

The implicit agreement between the donor and the LDC could then be summarized as follows: the donor agrees to provide K_y^b units, rather than just K_y^a units, of capital input to the project on condition that the LDC agrees to increase its recurrent input committment from the x_y^a units it would supply in its own self-interest at point A to the x_y^b units that will permit the donor and the LDC to jointly attain a Pareto-optimum. In fact the "project agreement" signed by donor and LDC prior to project implementation often contains language very similar to this except that no reference is made to the donor's "threat strategy" at point A.

Once the project has been constructed and K_y^b units of capital have been installed, the project manager assumes control and must maintain a flow of x_y^b units of recurrent input per period in order to keep the project at point B. While it is certainly true that the LDC will attain a higher welfare level at point B than it would have received at point A, the project manager is likely to soon become aware that he can do even better than point B. If the manager restricts recurrent input to the project from x_y^b units per period to the much smaller level of x_y^c units per period, LDC welfare will be even higher than it is at point B. The fact that donor capital is an exogenously fixed constant from the viewpoint of the LDC's project manager, means that he can maximize LDC welfare by picking an input combination on the LDC reaction function. Since a move directly south from point B to point C decreases x_y while leaving K_y unchanged, this welfare maximizing move unambiguously decreases project output relative to point B and increases the LDC's production of its other goods, q_L.

We have said that the project manager is likely to realize that point C is better from the LDC's perspective than point B. In a sense it is more correct to say that the manager is forced to realize that point B is worse than point C. This realization occurs as the manager becomes aware of the high opportunity cost of the marginal unit of recurrent input used to maintain the project at B, in terms of the foregone productivity of this input in alternative uses. The manager who attempts to maintain "his" project at its design parameters in the face of the outcry from the constituency that would benefit from the alternative uses of the recurrent input is likely to quickly lose the support of his superiors. The fact that point B is better than point A will no longer be relevant. The pressing reality will be that point B is worse than point C.

While input combination C is obviously better than combination B from the LDC's perspective, the fact that B is a Pareto-optimum implies that a move from B benefiting one party, like that to point C, must necessarily harm the other. Thus the donor receives less welfare at point C than it would receive at B. But the situation looks even worse from the donor's perspective when we notice that the donor's welfare at point C is less than the donor could have achieved at point A with no effort to cooperate at all. While the LDC project manager may forget point A in his struggle to satisfy the constituencies that demand other goods, q_L, the donor is likely to remember point A with poignant regret. Indeed congressional critics of U.S. aid policy have been heard to complain that the U.S. Agency for International Development has chosen to build an immense and very costly project which exceeds the managerial capacity of the host country, when a smaller project would have been within the capacity of the host-country and thus would have been operated more efficiently. If we interpret the phrase "within the managerial capacity of the host country" as a description of a project that makes smaller demands on managerial recurrent input with a high opportunity cost to the LDC, then this complaint does sound like an expression of nostalgia for point A in Figure 10.

The fact that the project output is an internationally collective good means that it is not exchanged on an explicit market. Thus there is no way for the donor to purchase it directly. Instead it attempts to purchase it indirectly by engaging in the project design process with the LDC. Here the technologically determined timing of capital and recurrent inputs acts to divorce the donor's demand for project output from the moment to moment decisions regarding the allocation of the recurrent input. Since the donor's demand for project output is not operationally relevant to the project manager while the demands for recurrent input in alternative uses are omnipresent, the project manager allocates recurrent resources away from the project and towards the production of those alternative goods.

If donor-LDC interaction is confined to a single development project, the sovereignty of the LDC implies that the donor will find it difficult or impossible to enforce the implicit contract represented by point B in Figures 9 and 10. Although the donor has paid its agreed share of the cost of producing a Pareto-optimal quantity of the internationally collective good, the LDC fails to contribute its agreed share. As a result the amount produced is less than a Pareto-optimum and the LDC becomes a "free-rider" on the donor's contribution.

VI. The Recurrent Cost Problem as a Free-Rider Problem

In the last section we demonstrated that the perfect information merit good model of donor-LDC interaction predicts that the LDC has incentives, first to cooperate with the donor in choosing a Pareto-optimal design for a development project and, subsequently, to renege on this "agreement" with the donor by unilaterally restricting its recurrent input to the project below the level prescribed in the project document. It would not be surprising if the donor were to accuse the LDC that responds to these incentives of taking a "free-ride" on the donor-provided capital input to the development project - and on the donor's "good will."

In this section we first define the free-rider problem in part A. Then in part B we demonstrate that the perfect information merit good model can be characterized as a certain game form in which the free-rider problem is known to arise. Hence the recurrent cost problem, to the degree that it is explained by the perfect information merit good model, is a version of the free rider problem and is amenable to solution by the same approaches that have been used to solve the general free-rider problem.

In part C of this section, we consider three alternatives to the perfect information merit good model of donor motivation. Our purpose is to explore the possibility that another model might succeed as well as, or better than, our chosen one at predicting that the LDC would "free-ride" on the donor or otherwise behave in a way that would cause the donor to perceive a recurrent cost problem.

We discover that one of the three models, the altruism model, could generate a recurrent cost problem if LDC's can misrepresent their preferences. This discovery leads us in turn to notice that, even if an LDC desires to reveal its true preferences, to do so may be extremely costly to it. In section D we discuss the probable severity of this additional barrier to a solution of the free-rider problem in the context of the merit good model without perfect information.

A. The Free-Rider Problem

In an excellent survey of the literature on the free-rider problem, McMillan states that the problem of attaining a Pareto-optimum in an economy with a public good is "not one, but three separate problems" (1979, p. 96). The three component problems McMillan cites can be paraphrased as follows:

1) individuals may not be willing to contribute without coercion to the production of the collective good such that aggregate contributed resources suffice to produce it at the Pareto-optimal level;

2) individuals may not be willing to reveal their true preferences for the collective good, thus preventing the computation of the optimal quantity to produce;

3) even if a mechanism can be constructed which overcomes problems 1) and 2), the incentives it brings to bear on the individual may not dominate the substantial participation cost to the individual of acquiring sufficient information on the utility he derives from various quantities of the collective good so that he can truthfully reveal his preferences.

It has long been known that the "first of these three problems can be overcome by assuming the existence of another economic agent, the government, with power to pass laws (to define the rules of the game) and to collect taxes" (ibid., p. 97). Ten years ago there existed no known solution to the second component problem, that of truthful preference revelation. However, two separate sets of solutions have recently been proposed to the preference revelation problem which are distinguished from one another according to whether or not the existence of a governmental agent is assumed.

If such an agent does exist to solve problem 1), then the solution to problem 2) is given by any of several demand-revealing tax structures or, if the collective good is an intermediate rather than a final output, by observing the degree of complementarity between the collective good and other factors of production.[39]

On the other hand, in the absence of a governmental agent possessing both the power to tax and an interest in Pareto-optima, a solution to the free-rider problem must simultaneously solve problems 1) and 2). McMillan cites both experimental and real-world examples where individuals appear to have solved this seemingly difficult problem (ibid., p. 104). To explain why individuals might sometimes have an incentive not to free-ride, McMillan cites his own unpublished work in which he has characterized the free-rider problem as an iterative game (ibid. p. 102).

It is well known that free-riding and its opposite, cooperation, can be modelled as two possible moves (or choices) available to a player of a particular type of non-zero-sum game called the "prisoner's dilemma."[40] When two players play this game only once, as in the scenario involving two prisoners which gives the game its name, non-cooperation (or free-riding) dominates cooperation for both players. Since the cooperative solution requires that neither play his dominant strategy, free-riding is likely. However, in even the earliest discussions of the prisoner's dilemma game, it was noticed that the knowledge that the game was to be repeated and that both players would remember their opponents' moves on previous iterations might induce players to choose the cooperative solution.[41] More recently, as the theory of the iterated game or "supergame" has begun to be developed in the literature, McMillan and others have suggested specific mechanisms whereby iteration and memory could make cooperation a dominant solution to the iterated prisoner's dilemma.[42] These mechanisms thus potentially solve problems 1) and 2) of the free-rider problem even in the absence of demand revealing taxes and the governmental authority to administer them.

However a true solution to the free-rider problem must overcome its component problem 3), the participation cost problem, as well as 1) and 2). Unfortunately solutions to 1) and 2) that use government-administered demand-revealing taxes, as well as those that use the properties of supergames, depend on incentives to individuals for them to participate in the public choice problem which tend to evaporate as the number of individuals grows. In reviewing the literature on this problem, McMillan points to some promising work towards its solution (ibid, p. 103). However in the case of any specific free-rider problem with a given number of individuals for which a specific solution to 1) and 2) is proposed, it must be demonstrated that preference revelation by the individuals is not so costly to them as to negate incentives for cooperation created by the solution mechanism.

B. The Iterative Game as a Possible Solution to the Recurrent Cost Problem

The analysis of the perfect information merit good model presented in section V suggests a specific set of possible moves and outcomes for the donor and the LDC that together define the payoff matrix of a game. By assigning numerical measures of donor and LDC welfare to the two sets of indifference curves in Figure 9, we obtain the specific payoff matrix displayed in Table 2. The donor, which must play first, chooses between two moves, K^a and K^b. The donor selects move K^a if it decides to behave as a Stackleberg leader and choose the point on the LDC's reaction function that it prefers to all others. The donor would only select K^b if it hoped to induce the LDC to select x^b and thus achieve a Pareto-optimal input allocation.

If the donor selects move K^a, the LDC will maximize its utility by choosing move x^a, just as the donor would predict. A Stackleberg equilibrium would result. On the other hand, if the donor selects move K^b, the LDC has an incentive to choose move x^c which maximizes its own utility but inflicts punishing losses on the donor relative to what it could have obtained with K^a. Thus the safe pure strategy for the donor in this game is clearly to choose move K^a where its maximum loss (minimum gain) is five units and it will probably gain ten units.

Table 2. Game Representation of the Merit Good Model

		LDC's Moves		
		Small x (x^c)	Medium x (x^a)	Large x (x^b)
Donor's Moves	Small K (K^a)	50 5	100 A 10	70 12
	Big K (K^b)	200 C 2	170 10	150 B 15

*In each cell, lower left number is payoff to donor and upper left number is payoff to LDC measured in units of their respective welfares, W^D and W^L. Cells containing the letters A, B, and C correspond to points A, B, and C in Figures 9 and 10.

If the LDC has reason to believe that this project design game will only be played once or twice, then it has an incentive to do everything in its power to convince the donor to play the donor's second move, K^b, and then respond with x^c, yielding two hundred units of utility for the LDC in our example and only two units for the donor. However, suppose that the game is played repeatedly over an extended period of time on successive development projects. It is no longer obvious that the LDC's best strategy in this "super-game" is to play x^c every time the donor plays K^b. For if the donor "loses faith" in the LDC's willingness or ability to carry through on agreements to play the Pareto-optimal move, then the donor will play move K^a every subsequent iteration of the game and the LDC will be forced to forego the opportunity to attain the higher utilities in the second row of its payoff matrix. Thus the LDC might instead decide to respond to K^b with the pareto optimal move x^b in order to reinforce the donor's choice of K^b. Many repetitions of the move (K^b,x^b) would, after all, yield the LDC more utility than many repetitions of (K^a,x^a). However as the end of the supergame approaches and only a few iterations of the game remain, this argument for the LDC to respond to K^b with x^b no longer holds. Anticipating little or no future benefit to offset the foregone advantage of x^c over x^b, the LDC may then begin to respond to K^b with x^c.[43] At this point cooperation would cease and the recurrent cost problem would reappear.

When two agents assign conflicting rankings to a set of outcomes which are a function of their joint behavior, it is rational for them to treat the situation as a "game" and to behave strategically. Where possible and useful their strategic behavior might include misleading messages to one another, such as the hypothetical message to the donor from the LDC: "if you choose K^b, I will choose x^b." Although diplomats expect strategic behavior in international relations, donor agencies seem to have assumed that the act of providing development financing automatically guarantees that the interests of the donor and recipient will be roughly the same so that the possibility of strategic behavior can be ignored. When evidence accumulates that host countries may be behaving strategically, donors react with surprise and occasionally with bitterness.[44] It seems more appropriate to recognize the inherent differences between the interests of the donor and those of the LDC and that a free-rider problem is inherent in any joint production activity which requires the donor to provide its contribution before the LDC is required to provide its share.

This game theoretic discussion, aside from providing an alternative value-free perspective on the strategic behavior of the donor and LDC in the context of the merit good model, also suggests some policy options which could encourage Pareto-optimal projects. The LDC's incentives to respond to move K^b with move x^b will be larger, other things equal, to the extent that the LDC is assured of a continued relationship with a donor that both remembers and acts on past LDC behavior.

Thus any institutional modifications which guarantee future availability of project financing to an LDC, while simultaneously ensuring that donors maintain accurate institutional memories of LDC behavior, will tend to encourage the LDC to respond to move K^b with move x^b rather than x^c. Furthermore if the donor's possible moves are expanded to include "Quit Playing," and if the LDC knows that donors that stop playing cannot be replaced, the LDC's incentives to take seriously its recurrent input commitments will be increased even further.

C. Three Alternative Models of Donor Motivation and The Recurrent Cost Problem

Perhaps the simplest of the three alternative models we consider is one we shall call the "exchange model." It posits that the donor's "gift" is not really a gift at all, but only the donor's half of an exchange contracted with the LDC to the mutual benefit of the two countries. In return, the LDC is either explicitly or implicitly expected to provide some service which enters directly into the welfare function of the donor nation. Examples of such a service might include a specific vote in the United Nations, general support of donor interests in world forums, or just abstention from active criticism of donor policies. Certainly some donors use their development programs in this way.[45]

While incontrovertible examples of this kind of exchange undoubtedly exist, the model is less than totally satisfactory because it fails to explain why donors should continue to be concerned with the operation of funded projects long after any explicit exchange can be presumed to have been consummated. To elaborate the exchange model by suggesting that the specific <u>quid pro quo</u> desired by the donor is the continued provision of recurrent input seems rather artificial. The operation and maintenance of most projects yield little or no pecuniary benefits to citizens of the donor country. Therefore this elaboration begs the question, because one would still be obliged to explain why the donor would value continued provision of the input.

A second model of donor motivation might be termed the "philanthropy model." In this model, the donor obtains welfare from the very act of giving. The argument in the donor welfare function could be either the amount of the gift or a binary variable equal to unity if gifts exceed a certain magnitude and zero otherwise. This model shares the defect of the exchange model in failing to explain without further elaboration the observed fact of continued donor concern with the result of a gift. In particular, if the value of K_y enters as an argument in the donor's welfare function, it is not clear why the donor would become as deeply involved with the project design process as it in fact does. According to this second model, donor welfare could be maximized most effectively by simply donating budgetary resources to LDC's with no concern for the use made of those resources. Except in isolated cases, casual observation of actual donor practice directly contradicts this prediction of the philanthropy model.[46]

A third model of donor motivation is that the donor obtains welfare from the welfare of the recipient nation. We call this model the "altruism model" of donor motivation because it posits that, from the donor's perspective, the ultimate purpose of concessionary project financing is to permit the LDC to attain a higher welfare level than would otherwise be available to it. More than the exchange or philanthropy models, the altruism model is consistent with the fact that donors express intense concern when they observe instances of the recurrent cost problem. For the donor might interpret a deviation from the project design as evidence that the LDC is receiving less welfare from the project than the donor thought the project would supply.

The altruism model predicts that the donor will seek to "purchase" a commodity it values called "LDC welfare" by paying for it with grant capital. But when one purchases a commodity, one is naturally concerned to know that commodity's price. Thus, the altruism model would explain more successfully than the exchange or philanthropy models the tendency of donors to attempt to ensure that funded projects are well designed by directly employing the project designer and subsidizing the project design process. This behavior is explained as the donor's effort to gauge both the elasticity of project output with respect to grant capital and the elasticity of LDC welfare with respect to project output in order that the donor may know in advance how much it must "pay" in grant capital for each unit of incremental LDC welfare.

While the altruism model is more successful than either the exchange or philanthropy models at predicting donor concern when recurrent inputs are reduced below planned levels, the model must be further elaborated to predict that actual levels of recurrent inputs tend to be less rather than greater than the levels prescribed in project documents. If donor and LDC both have perfect information regarding the other's preferences and about the technology of producing the three outputs, then input deviations should be randomly distributed on either side of planned levels. However, a reasonable modification of the altruism model is the assumption that the donor is ignorant of LDC preferences and must depend on messages from LDC decision-makers regarding these preferences in order to choose its optimal strategy.

Just as the altruism model predicts the donor would make every effort to learn the "price" to it of LDC welfare before commiting itself to a project, the model also predicts that the LDC has an incentive not to reveal to the donor the true magnitude of that price.[47] For if the donor's demand for LDC welfare is at all price elastic, the perception by the donor that increments to LDC welfare can be acquired less expensively(in terms of grant capital) than is actually the case will lead the donor to make larger grants. The fact that the donor typically employs the most expert project managers it can find implies that there may be relatively little the LDC can do to help or hinder the donor's efforts to learn the productivity of grant capital on the project. However, the project designer and donor must largely depend on the unsupported assertions of LDC decision-makers and other informants in forming their judgment of the elasticity of LDC welfare with respect to project output.

If the LDC responds to its incentive to exagerate the marginal value product of capital on a development project and thus to understate the true "price" to the donor of LDC welfare, the result will be a biased project design. Projects will tend to be "too big" and call for "too much" recurrent input relative to the level of recurrent input that will in fact maximize LDC welfare for a given level of capital input. As a result, the donor will be repeatedly "surprised" to learn that the project output is apparently less valued relative to other uses of LDC recurrent input than the donor had believed. In terms of section III, the altruism model can be viewed as a mechanism for endogenizing the "National Priorities" surprise and for explaining why it tends to occur more frequently in the direction of a reduction of recurrent inputs rather than in the opposite direction.

However, without elaboration the altruism model shares the failure of the exchange and philanthropy models to explain the tendency of donors to fund specific development projects rather than simply to provide general budgetary support. Many recent development projects produce outputs like health care or subsistence crops that the donor asserts to be "basic needs." The donors' observed preference for projects which produce certain specific products, even when those products are not clearly valued by the host country as much as, say, certain luxury consumer goods, is evidence against the altruism model and in favor of the merit good model of donor motivation which we have analyzed above.

The fact that the altruism model as we have presented it includes the possibility that designs are biased because the LDC misrepresents its preferences may at first glance appear to be an advantage of the altruism model with respect to the merit good model. However, it is quite possible to modify the merit good model in the same direction. The effect would be to exagerate the bias in project design predicted by the merit good model with perfect information. In our analysis of the merit good model, we have abstracted from the second and third components of the free-rider problem by assuming perfect information. But the discussion of the altruism model raises the possibility that preferences are not necessarily reliably revealed to the project designer and the donor at the time of the project design. In the next part of this section we briefly address the preference revelation and the participation cost components of the free-rider problem as possible contributors to the recurrent cost problem.

The nature of donor motivation may, of course, differ from project to project. For this reason, the merit good model and the three models described here are not mutually exclusive; each may explain some portion of the donor grant activity. However, in many if not most of the actual instances where the recurrent cost problem has arisen, it seems to this author that the merit good model is more appropriate than any of the others. It's advantage over the other models seems to be even larger if it is extended to include the possibility that the LDC may exagerate the welfare it gets from the project.

D. Participation Cost and the Merit Good Model Without Perfect Information

In the merit good model with perfect information, the recurrent cost problem is explained by the inability of the donor to require the LDC to stick to the planned level of recurrent input. For if the donor could enforce project agreements as if they were contracts, donors and LDC's would still have an incentive to agree to pareto optimal designs like point B in Figure 9 rather than a Stackleberg equilibrium like point A. But if we admit the possibility that LDC's misrepresent their preferences to donors, then preference revelation and participation cost are added to the problem of enforcing the pareto optimal operation of the project.

In part B of this section we suggested that knowledge by the LDC that the design game will be repeated and that the donor will remember whether the LDC provides projects with prescribed levels of recurrent input can create an incentive for the LDC to stick to prescribed input flows in the perfect information version of the merit good model. But even if we relax the assumption of perfect information to permit the LDC to misrepresent its preferences, iteration of the game should provide an effective enforcement mechanism. For in the iterated merit good model, the donor will attend to the level of project output and the level of recurrent input to produce that output, not to alleged LDC welfare levels. Thus if the LDC wishes to encourage the donor to play a cooperative Pareto-optimal move in future iterations of the design game, it must reward the donor's choice of a cooperative move on previous iterations by meeting the recurrent input flow prescribed in the project document and expected by the donor. As a result, the LDC has an incentive to reject project designs which misrepresent its own preferences and thereby exagerate the amount of recurrent input it will supply.

If it were costless for the LDC to reveal its preferences regarding project output, then iteration of the project design might suffice to solve the recurrent cost problem. However, even for a single person it is not usually costless to determine and reveal preferences for a collective good. Regarding the individual voter, Downs (1957) has argued:

> [e]ven if people do decide to vote, they are not normally motivated to give any serious study to their vote in collective decision processes, because the probable gain from acquiring further information or simply reflecting on the information already at hand is usually less than the cost. Thus ill-informed voting is to be expected.[48]

The incentives on individual voters created by most solutions to problems 1) and 2) diminish as the number of voters increases. Since the participation cost of each individual voter can be assumed to remain constant (or perhaps to increase) as the number of voters increases, there will generally be a critical population size above which these mechanisms fail to solve the free-rider problem. In societies where the participation cost is relatively high, for example because of low education levels, the critical population size may be quite small.

The same principle applies when the individuals in question are nations rather than individual voters. Since determining the welfare function of a nation is inherently much more difficult than determining the preference ordering of an individual, the participation cost of a nation in a collective decision process requiring preference revelation is extremely high. Unless incentives for truthful revelation are correspondingly powerful, participation cost for a nation could dominate them even when there are only two players in the design game, the donor and the LDC. The result would be "ill-informed voting" or misrepresentation of LDC preferences.

If the participation cost problem simply introduced a random error to LDC preference revelation, then preferences would be understated as frequently as they would be exagerated and the donor might disregard such errors as unavoidable. However, consider the actual process by which the designer is likely to elicit the LDC's preferences. The designer's informants are typically employees of the ministry which will eventually administer the completed project and thus may honestly perceive the benefits of the project to be very high indeed. In fact, these ministry informants may be the LDC citizens who are most likely to overestimate the benefits of this particular project and underestimate the benefits from alternative uses of recurrent inputs on projects controlled by other ministries. The result is a systematic bias in the project design toward "too big" a project requiring "too much" recurrent input.

But it is frequently the case that several projects are designed simultaneously, all to be eventually controlled by different ministries. If all designs are biased by the same systematic forces, the net result will be a large excess demand for recurrent inputs. Although this excess demand would be due to misrepresentation of LDC preferences, note that no individual citizen of the LDC has intentionally misled a project designer. Rather the perceptions of the various informants in the various ministries are systematically biased by their necessarily narrow perspectives.

To pursue this scenario further, suppose that realistic estimates of the relative values to the LDC of the outputs from a set of proposed projects are <u>only</u> obtainable as the revealed outcome of the actual struggle among the various LDC constituencies to win the allocation of recurrent input to "their" projects. This struggle, which constitutes the participation cost referred to above, is likely to be painful and quite expensive for the political leadership of the country. The LDC has every incentive to postpone a political conflict of this magnitude as long as possible. As a result, unless the donors bring to bear extremely strong countervailing incentives, each constituency within the LDC is likely to continue to overstate the quantity of scarce recurrent input it will be able to command from the government at large. Only when the projects are installed and operating must these conflicting claims be reconciled. Some donors will inevitably feel their projects have been "unjustly" starved of recurrent input and will complain of the recurrent cost problem.

In view of the cost to the LDC of determining its own preferences for the output of a project, it is unlikely that any single donor will be able to construct sufficiently powerful incentives to induce an LDC to alter its behavior in this respect. It is conceivable, however, that a coalition of donors acting jointly could induce an LDC to reconcile the claims on recurrent inputs by various projects with projected supplies of those resources. There seem to be two fundamental questions that would need to be answered before an individual donor would choose to join such a coalition, however. First, will it work? In view of the fact that the Unites States Congress has only begun reconciling individual expenditure items with an aggregate budget in the last few years and still performs this operation crudely and for only a year at a time, it may be utopian to hope for a greater degree of political and budgetary sophistication in an LDC. Second, if it does work, would it be worth the cost in terms of political instability in the LDC and likely accusations of imperialism aimed at the donors. Only if all the individual donors who frequently give to a given LDC were to answer both these questions in the affirmative, would such a coalition be likely to be stable.

If an LDC were willing and able to implement a planning system which reconciled projected demands for recurrent inputs with projected supplies at market equilibrating prices, note that such a reconciliation would not guarantee accurate preference revelation on individual projects. It would guarantee, however, that overestimates of recurrent input supply to some projects would be offset by underestimates to other projects. If the LDC computes these estimates to maximize its own welfare subject to the merit good welfare functions of the various donors, it has an incentive to overestimate the effective "price" of project output to those donors whose demands are relatively inelastic and to underestimate the effective "price" to the other donors. This strategy will require a specific pattern of misrepresenation of LDC preferences, which would in turn lead to a recurrent cost problem for some of the projects and a "surprise" in the other direction for other projects. The fact that only some projects would suffer from a shortage of recurrent inputs while others would seem to benefit would probably console the donors. If the donors are encouraged to give more capital more often by this outcome, then the LDC's might be the long term beneficiaries of such a policy.

VII. Summary and General Policy Suggestions

To the extent that the recurrent cost problem is caused or exacerbated by either the surprises of sections III and IV or the biased project designs of section V, the policy recommendations must be different than they would be if the problem were entirely due to the kind of institutional rigidities and inefficiencies emphasized by Heller and reviewed in section II above. For whether the LDC's reduction of recurrent inputs is an optimal response to a surprise or a welfare maximizing move in an iterative game, the fact that the response is driven by an optimization procedure implies that it may be modified by appropriately structured incentives.

If project designs are *ex ante* correct, and observed recurrent input reductions are optimal responses to surprises, then there is some question whether the donor that is aware of this situation would desire to alter it *ex post*. Since the assumption of sections III and IV was that the donor's and the LDC's interests are essentially identical and both seek the maximization of LDC welfare subject to LDC constraints, it would be inconsistent with these assumptions to suggest that the LDC's optimal decision be modified to take account of the disutility that the donor incurs due to the cutback of inputs to its project.

Hence the only consistent policy recommendations implied by sections II and III are *ex ante* ones which argue for better, more flexible project design. One implication of these sections is that project designs should be parameterized with respect to a range of possible scarcity values or shadow prices of selected crucial recurrent inputs. In cases where a substantial probability must be assigned to scenarios involving extreme values of these shadow prices, the designer should explore the possibility that an alternative design which is more robust with respect to these prices should be preferred. In section IV we pointed out that project designs which are substantially correct in other ways may systematically underpredict the external cost of one project which is imposed on other projects as an increased marginal social cost of recurrent input. Since planners will never have perfect information on future projects, they will never predict future demands for recurrent inputs with perfect accuracy. However, it is not unreasonable to expect that planners budget a growth rate of the supply of crucial recurrent inputs in anticipation of an as yet uncertain increase in demand for those inputs.[49] Then that forecast supply is available to be allocated by future project designers.

By budgeting an increase in the supply of government produced recurrent inputs in excess of currently foreseen growth in demand for those inputs, part of the problem of the successive agglomeration of projects is solved. Another possible procedure would be to predict as a matter of course that the shadow price of recurrent input is likely to rise faster than the most pessimistic predictions suggest, and to give substantial weight to this scenario to the project analysis, rejecting those projects which fair poorly in this light.

But the frequency of the recurrent cost problem suggests that random surprises or exogenous shocks are insufficient to explain it.

In Section V we develop a model in which it is in the interests of both the LDC and the donor to move away from a project design that maximizes LDC welfare for a given level of capital provided by the donor. Instead the donor and LDC have an incentive to negotiate the choice of a design that is Pareto-superior to the one that would occur without negotiation. However, since the donor's input is fixed after the beginning of the project, while the LDC's input is a choice variable, the LDC can then reduce recurrent input to the project below the level agreed upon with the donor.

The search for policy proposals in this situation must begin by valuing the outcome as it stands. The move away from the Pareto-optimum succeeds in maximizing the LDC's welfare although it disappoints the donor's hopes for substantial project output. If the policy objective is to maximize LDC welfare from a single project, then the recurrent input reduction is not a problem. However, our discussion of the donor LDC negotiation as an iterative game suggested that this outcome would not be indefinitely repeated because the disappointed donors will cease to trust the LDC's to fulfill bargains after many similar bargains have been broken in the past. Since the areto optimal position is Pareto-superior to the solution that is likely to occur if trust entirely breaks down, we believe that the goal of policy should be to facilitate the achievement and maintenance of Pareto-optimal solutions to the donor-LDC negotiations.

But the fact that the project design is iterated may offer the best hope for achieving a stable Pareto-optimal solution to each individual iteration of the game. An important ingredient of such a stable situation is donor memory and therefore a sharing of information among the donors who fund projects in a given country. Furthermore donors must act on their memories, only accepting Pareto-optimal designs in LDC's that have kept their bargains in the past.

In section VI we discuss the implication of the fact that budgeting recurrent input among projects years in advance is likely to be administratively and politically costly to the LDC. In fact, the extent of that cost may be such as to effectively prohibit such a budgeting exercise from taking place unless the donors are able to bring strong countervailing incentives to bear on the LDC. For example, if donors were able to form an effective coalition and agree as a group to withhold aid until a recurrent input budgeting system is in place, much of the political cost of establishing such a powerful group within the LDC government would be borne by the donors. Such a coalition of donors could also serve as a repository of information on past recurrent input performance by the LDC. In order to assure the continued operation of the budgeting system once it is installed, the donors would probably be obliged to maintain their coalition and to continue to threaten to withhold aid unless the system is continually used.[50]

On the other hand, a situation exists in which the establishment of an effective recurrent input budgeting system, as part of a general system of continual project surveillance and evaluation, might be to the net benefit of the LDC, even in the absence of any donor pressure. Robert Klitgaard makes this argument in an interesting article entitled "On Assessing A Gift Horse" when he asks "[w]ill [aid projects] be tempting gifts that lure countries away from their national goals and into dependency and subservience?" (1975, p. 15). Only by carefully determining its long term as well as its short term goals and the relationship of each project's output to those goals, will an LDC be able to judge the "gift horses" it is offered. Thus, if there exists a perceptible danger that a given LDC will be lured away from its national goals, it may be willing to endure the participation cost of preference revelation in its own self-interest.

All of the discussion to this point assumes that the donor's capital input is entirely installed at the beginning of the development project, while the LDC's recurrent input is allocated thereafter. In its news release of May 3, 1979, the Development Assistance Committee of the O.E.C.D. suggests that donors begin to consider ways in which they can provide recurrent inputs as well as initial capital requirements for a project (OECD, 1979). If the donor feels unable to enforce an agreement to operate the project at a Pareto-optimal point, it may want to work with the LDC's reaction function. According to the analysis of section V, the LDC's reaction function is entirely flat with respect to donor capital when the LDC's elasticity of demand for project output is equal to the elasticity of substitution between capital and recurrent input in the project production function. When LDC demand is quite inelastic or, alternatively, the elasticity of substitution is quite high, the LDC's reaction function is negatively sloped as in Figures

9 and 10 and the LDC responds to incremental capital gifts with decrements in its recurrent input contribution. In these situations a system whereby the donor matches recurrent input purchases by the project might achieve more gains for the donor than equivalent expenditures on additional capital. On the other hand if the production function is extremely inelastic and/or LDC demand is quite elastic, a donor constrained to the LDC's reaction function may find that its own welfare is better served by increments in capital alone than by matching contributions to recurrent input purchases. For in this case the LDC will respond to increments in capital donation with increments of recurrent input supplied to the project.

In the latter situation, where the LDC reaction function is positively sloped, rather than match recurrent input purchases the donor may want to increase the value to the LDC of the donor's capital gifts by increasing the opportunity cost to the LDC of grant capital. In the model of section V, capital was assumed to be scarce only to the donor. This situation could be altered if a coalition of donors were to fix the total amount of capital available to a given LDC for a certain period of (say) five years. Then the LDC would be permitted more freedom in disposing of this capital than it presently has. If the quantity of capital granted were no smaller than it would otherwise be, the LDC's welfare would be unambiguously increased by its greater freedom in the allocation of this resource among alternative uses.

In section II we reviewed Heller's list of possible causes of the recurrent cost problem, and we pointed out that they could be characterized as institutional and informational impediments to rational LDC and donor decision-making. An implicit assumption behind Heller's list is that, if these impediments could somehow be removed, donors and LDC's would both find it in their interest to avoid the recurrent input shortfalls responsible for the donor's perception that there is a recurrent cost problem, and the problem would disappear.

The central purpose of this paper has been to argue that a reduction in recurrent input to a project could occur due to rational welfare optimizing behavior by the LDC rather than to the absence thereof. In sections III and IV we explored the possibility that recurrent cost reductions could be caused by "surprises" or unanticipated events to which the LDC optimally responds by reducing recurrent input flows. In sections V and VI we considered the alternative possibility, that project designs are systematically biased in the direction of "too much" recurrent input so that LDC's repeatedly find it prohibitively expensive to meet the flow of recurrent input prescribed by the project design.

Certainly some of the inefficiency in any bureaucracy could be eliminated to the benefit of the nation it serves. However, if the arguments of sections V and VI of this paper are correct, then some of the impediments to information flow and "proper" allocation of recurrent inputs may serve the short-run national purpose of the LDC rather than hinder it. For to the extent that donors forget past LDC recurrent input supplies to their own and other projects, it may be in the interest of an LDC to hide the fact that it is rationally choosing to exagerate its preferences for a project output during the design stage or to reduce recurrent input to a project below the Pareto-optimal level during the operation stage.

Thus we urge those who work to solve the recurrent cost problem to attend not only to the removal of institutional rigidities and informational impediments, but also to the creation of incentives that will guide donors and LDC's alike to avoid re-creating these rigidities and impediments. For these institutional obstructions can engender errors in project design which in turn provide the preconditions for the recurrent cost problem.

Notes

1. Montigny and Martens (1978, p. 35, my translation) give this version of the hypothesis which they credit to Kamarck (1971) and Zimmerman (1975).

2. For present purposes the cause of this donor preference is immaterial. Nevertheless, it is interesting to speculate on reasons for its existence. Possibly donors are solely motivated by an altruistic (and paternalistic) desire to encourage developing countries to develop their own autonomy and independence. Alternatively, we can point to the influence of special interests within donor countries that directly benefit from capital cost financing but not from recurrent cost financing. A third possibility is that donor agencies, well aware of the annual funding cycle on which they operate themselves, recognize the impossibility of committing their domestic legislatures and political authorities to the funding of costs that endure beyond the shortest possible start-up period. A fourth possibility is that donors implicitly recognize the "moral hazard" inherent in a commitment to fund a portion of "needed" costs, especially if the apparent "need" for such funding is substantially under the control of the recipient country. (The analogy here is with the health insurance beneficiary who demands more care and thus spends more money if the marginal price to him of that care is reduced by the insurance policy.) A final possibility is that donors implicitly recognize the difficulty to be discussed in section VI of inducing the recipient countries to reveal their true preferences regarding a given project.

Thus donors hope that by committing the host country to substantial recurrent expenditures, the donor can be sure that the recipient has not exaggerated its view of the benefits to accrue to it from the project.

3. An interesting earlier source that touches briefly on the recurrent cost problem, and thereby demonstrates that the problem is not new, is Hirschman (1967, pp. 56-59, 113-127). See also Hirschman (1958, pp. 141-143).

4. This and subsequent quotes in this paragraph are from Heller (1979, p. 38).

5. The effort to curb recurrent expenditures is facilitated by a system of national accounts which clearly distinguishes them from capital expenditures.

6. There are several examples of studies in which the authors verbally recognize the malleability of the r-coefficient, but treat it as a fixed constant for the purpose of their analysis. Montigny and Martens (1978) elaborate and refine Heller's (1974) model in many ways without modifying Heller's assumption that the project specific r-coefficient is a fixed number. Beazer and Pulley (1978) and Burki and Voorhoeve (1977) use fixed r-coefficients to characterize the recurrent input "requirements" of entire sectors and nations and to project those "needs" far into the future. While the degree to which the authors' discussions recognize the variability of r-coefficients differs from author to author, there is one example of an author who apparently did not notice Heller's footnotes and qualifications. In his projections of recurrent

expenditure "requirements" of Malawi, Hansen asserts that each of the r-coefficients he estimates "defines a real relationship which should be equally applicable to future investments" (1978, p.7).

7. When Heller implies that countries should "identify when serious losses in project productivity may occur" as a result of insufficient recurrent inputs, he presumably refers to this feature of a recurrent cost profile (Heller, 1979, p. 38).

8. We relax these assumptions in sections V and VI.

9. Some implications of the possibility that x is supplied with less than perfect elasticity are explored in sections III and IV.

10. Hirschman (1958, pp. 141-143) argues that in some cases a robust project design should actually be avoided in favor of a design which may appear to have a lower NPV but which is more sensitive to the level of recurrent inputs. He hypothesizes that "underdeveloped countries will do best in activities where maintenance is inescapably imposed" by a project design with a steep-sided, quite pointed profile.

11. Our model differs from theirs in distinguishing capital and recurrent inputs as separate factors of production.

12. The fact that, in a world of imperfect capital markets, the opportunity cost of public funds might be larger than their current value in consumption was first developed in detail by Marglin (1963) and Feldstein (1964), although the idea was expressed in Eckstein (1958, 1961). Later Feldstein

(1970, 1972) extended this framework to analyze the choice of technique for a given project and the distinction between debt and tax financed deficits. For an alternative view see Baumol (1968, 1969) or Harberger (1969). Boadway (1979, pp. 186-187) provides a useful textbook exposition of the approach adopted here.

13. Following Marglin (1963), s is greater than unity by a proportion of the ratio of the private marginal rate of return to the social time preference rate, where the proportion is a function of the method used to finance the deficit. In the simplest case the proportion is the fraction of each dollar of deficit financing that would have been invested at the private rate of return rather than consumed. Thus s would equal unity if either all project resources are drawn from consumption or the private rate of return equals the social rate of time preference. For convenience we assume s is constant over time.

14. The function w(x) can be thought of as an "intertemporal supply function." It is related to the conventional recurrent input supply function for period t, $w'(x_t)$, by

$$w(x) = \sum_{t=0}^{T} w'(x_t)/(1 + d)^t$$

where x_t is the number of units of recurrent input used in time t, d is the social discount or time preference rate, and we assume that $x_t = x$ in every period.

15. A direct definition of the discounted stream of operating deficits is:

$$\sum_{t=0}^{T} [w'(x_t)\ x_t \ - \ p_t'\ y_t]\ (1 + d)^{-t}$$

where p_t' is the per-unit output price in period t, y_t is the number of units of output in period t, and the other terms have been previously defined. Assuming that $y_t = y$ in every period, defining $p = \sum_{t=0}^{T} p_t'/(1 + d)^t$, and using the previous footnote, this expression reduces to the second two terms of equation (7). We distinguish our treatment of factor prices from our treatment of output prices by permitting the former to vary as a function of the quantity of input used by the project, while requiring the latter to be fixed and independent of the quantity of project output. This distinction reflects our belief that the relative tightness of the markets for locally produced recurrent inputs is an important possible cause of the perception by donors that there is a recurrent cost problem. We expand on this theme in section IV of this paper. On the other hand, for our present purposes, it seems unnecessary to permit a downward sloping demand curve for the project's output. Of course, a model which permitted the user charge p to also be an instrumental variable subject to the designer's plan and the manager's manipulation might benefit by relaxing the assumption of an infinitely elastic demand curve for the product of the project. However, consideration of p as a choice variable is beyond the scope of this paper.

16. The figure assumes that $1<s<2$ which need not be the case.

17. If we assume that the level at which the capital stock is held constant to construct the recurrent input profile of Figure 1 is the optimal level as computed by the project designer K*, the optimal level of recurrent input determined by Figure 3 is identical to that determined in Figure 1. In this case the slope of Figure 1 is represented by the difference between the MVP and MSC curves of Figure 3, and Figure 1 could be derived from Figure 3 up to a constant of integration.

18. In other words, we must explain why the behavior of project designers has not conformed to a "rational expectations" hypothesis. That this is so is supported by comments like that of Kermit Gordon, who wrote that "little has become known about the truly formative experiences which are due to the behavior--and misbehavior--of development projects" (1967, p. vii).

19. A relevant question is whether the project designer who fails to discount current "fashions" in evaluating the benefits of a project has in fact produced a "correct" design. However, it is hard to imagine a designer second-guessing his superiors in order to discount the stream of benefits under the presumption that current desire for the project is partly a fad. Sen's discussion of the role of the project designer who operates under political and bureaucratic constraints is relevant here (1972). See the discussion below of the opportunity cost of public funds.

20. The next section of this paper considers the possibility that this type of "surprise" results from the sequential, incompletely coordinated, project design activities of several donors in the country.

21. From Feldstein's equations (14) and (16) it is straightforward to show that debt financing incurs a higher social cost at the margin than tax financing if and only if

$$\frac{MPC_b}{MPC_t} > 1 - \frac{r}{d}$$

where MPC_b and MPC_t are the marginal propensities to consume of bondholders and taxpayers respectively, r is the private rate of return, and d is the social time preference rate (1972, pp. 328,9). Note that when MPC_b/MPC_t exceeds .75 and r/d exceeds .25, the condition is fulfilled. These conditions seem likely to obtain in most applications.

22. The project designer in Little and Mirrlees actually is required to guess whether the government will choose to import or produce locally a certain intermediate input to the project being designed.

23. This observation also applies to the four types of surprises previously discussed, but especially to the first surprise, a change in national priorities. In section V the concept of a well-informed guess about future behavior of the LDC government is formalized using the concept of a "reaction function" from duopoly theory.

24. For instance, countries in the Franc Zone lack control of their own money supplies. The possibility that public finances are supplied inelastically is emphasized by Clark (1965, pp. 22-29) who treats the difference between target development expenditures and the sum of borrowed and tax-derived revenues as a "gap" in the tradition of the "two-gap model" of Chenery and Strout (1966). Just as in the two-gap models, unless this additional fiscal gap is filled, the speed of development will be constrained below that which would fully utilize other resources.

25. Despite constraints on his time and other resources, the project designer should attempt to guess the external effects of x^2 on other projects, especially in situations where the supply curve of x may be upward sloping. To explain why many designers fail to consider external effects of their design decision, we might appeal to the literature on bounded rationality or on myopic decision-making (where we interpret "myopia" in its ordinary spatial sense as well as in the temporal sense that economists usually use it.) Alternatively perhaps the fact that the project designer's mandate is likely to be "to design project two" rather than "to maximize social welfare using K^2 and x^2 as instruments" establishes a "frame" or "context" for the designer's problem-solving activity which reduces the likelihood that he will consider external effects. See Grether and Plott (1979) for evidence that the context of a question can condition the rationality of an individual's response.

26. If we use subscripts a, b, and c to denote the three time periods of interest, such that a refers to the period from year $T - T^1$ through year -1, b refers to the years from zero through $T - T^3 - 1$, and c refers to the years from $T - T^3$ through year T, then we can write the marginal social cost of x^2 to project 2 as

$$MSCX^2 = \frac{\partial C^2}{\partial x^2} = w_b(\overline{x}^1 + x^2) + w_c(\overline{x}^1 + x^2 + \overline{x}^3) \qquad (n.1)$$

where underlined variables have been assumed constant,

$$w_b(x) = \sum_{t=0}^{T-T^3-1} w_t'(x)/(1 + d)^t \qquad (n.2)$$

$$w_c(x) = \sum_{t=T-T^3}^{T} w_t'(x)/(1 + d)^t \qquad (n.3)$$

and $w_t'(x)$ is defined (as in note (14)) to be the conventional supply function of the recurrent input at time t as a function of the quantity of recurrent input purchased that period. Since

$$w(x) = w_b(x) + w_c(x) , \qquad (n.4)$$

these definitions of $w_b(x)$ and $w_c(x)$ are consistent with the definition of $w(x)$ given in note (14).

The analagous expression for the marginal cost of x^2 to project 2's budget, MCX^2, is given by

$$MCX^2 = w_b(\overline{x}^1 + x^2) + w_c(\overline{x}^1 + x^2 + \overline{x}^3) \qquad (n.5)$$
$$+ [d\, w_b(\overline{x}^1 + x^2)/dx + d\, w_c(\overline{x}^1 + x^2 + \overline{x}^3)/dx]x^2.$$

Note that despite the discontinuous jumps in the demand for x, there need not be any discontinuities in either $MSCX^2$ or MCX^2 as a function of x^2. Thus the depiction of these functions in Figures 3 and 5 remains valid.

27. Note that there is a lack of symmetry in the information available to the designer and the manager regarding the magnitude of the external effects of one project to another. The project designer does not compute $\partial V^1/\partial x^2$ because the information required to estimate it is unavailable to him and the host country has neither the motivation nor the resources to provide it. The project manager is forced by the politics of his position to estimate $\partial V^1/\partial x^2$. The intensity with which project 1's constituents complain gives him some information that was unavailable to the designer and that can be used to arrive at a guess for the magnitude of this affect. Thus to overly criticize the project designer for not doing what the project manager later is able to do would be to ignore this extreme disparity in their situtations.

28. For an interesting paper that does recognize potentially different interests, see Klitgard (1975).

29. Rodgers (1974) constructs a typology of models to explain income redistribution among individuals within a country and thereby provides an excellent review of the literature on such models. The model presented here and the three models we descirbe briefly in section VI all have their counterparts in one of the models described by Rodgers. In particular the model we choose to develop at some length in this section is formally similar to one version of the type called "interdependent preference" models by Rodgers (ibid., p. 181-3) and was first developed as an explanation of interpersonal income redistribution in a paper he wrote with Hochman (1969). The application of these models to governmental

entities rather than individuals is in the tradition of the literature on local public goods. See for example Williams (1966) and Shibata (1971). Other antecedents of the present work include Davis and Whinston (1962) and Dolbear (1967) who analyzed interdependent preferences and optimal externalities for firms and consumers, respectively.

30. Independently, we might argue that the immediate opportunity cost to the donor of K_y is the use of capital on <u>other development projects</u> in other countries. The output of these other projects would also be untraded.

31. Shibata (1971, pp. 13-17) has previously pointed out that the problem of determining the optimal expenditure on, and the optimal distribution of the tax bill for, a conventional public good is homeomorphic with aspects of the duopoly problem. However, neither in Shibata's public good model nor in the present one does the interdependence between the agents depend on the existence of any third agent or group of agents analagous to the consumers whose demand is the source of the interdependence between duopolists. Thus neither public good model is structurally identical to the duopoly model.

In both Shibata's model and the present public good model, the two agents are assumed to bargain overtly in an attempt to move from a given initial position to a pareto optimum. But duopolists are usually constrained to reach agreements only through "tacit understanding;" it is bilateral monopolists who must bargain overtly. Because the structural similarities of his model to the duopoly model were less important in Shibata's context than the bargaining aspects of the problem, he was led to use the perspective of the bilateral monopoly model rather than that of the duopoly model. In our application, however, the relative usefulness of the two perspectives is reversed. To avoid the complication of two perspectives, we choose to ignore that of the bilateral monopoly model and instead discuss overt bargaining between the LDC and the donor as analagous to the overt bargaining that duopolists would engage in if free to do so.

32. When assymetry is introduced to the duopoly or bilateral monopoly models, it often enters as unequal bargaining power of the two parties caused, perhaps, by unequal initial endowments of wealth or "influence." If bargaining power is unequally distributed between the donor and the LDC in this sense, certainly the donor is likely to have more of it than the LDC. However, the assymetry introduced to the relationship between donor and LDC by the technologically determined timing of their respective inputs to development projects is of a different variety. We shall see below that there is a sense in which this assymetry works in the opposite direction from any possible inequalities of endowed "influence" and may bias the outcome of potential bargaining toward the LDC rather than toward the donor.

33. To see the equivalence between the two concepts of the LDC's optimum, rewrite equation (24) as:

$$\frac{\partial W_L}{\partial y}\frac{\partial y}{\partial x_y} = \frac{\partial W_L}{\partial q_L}\frac{dq_L}{dx_q}$$

The left hand-side represents the marginal value product of x_y in the production of project output, MVP_L. The right-hand-side is the marginal value product of $x_q = \bar{x} - x_y$ in producing other goods which can be interpreted as the marginal opportunity cost to using recurrent input on the project, MSC_L.

34. In terms of Figure 7 the increment in capital can be pictured as a rightward shift of the MRT_L curve in panel (a) combined with a northeastward rotation of the production function in panel (b). While the effect of these maneuvers unambiguously increases project output, their net effect on optimal recurrent input x_y^* depends on the relative magnitudes of the two effects. When λ is greater than σ, the shift of the production function dominates the shift of the MRT_L curve and the net effect is to increase x_y^*.

35. It is straightforward to construct a figure which depicts the donor's decision problem using curves analagous to those displayed in Figure 7 above for the LDC. If conjectural variation is negative (positive), the effective supply curve to the donor of project output as given by the MRT_D' curve lies to the northwest (southeast) of the MRT_D curve that obtains for the Cournot assumption. Thus the effect of the inclusion of negative (positive) conjectural variation in the donor's decision problem is unambiguously to reduce (increase) the donor's chosen project output level compared to the level it would choose if conjectural variation were zero. The effect of conjectural variation on the level of

concessionary project financing chosen by the donor is less clear, however. Depending on the nature of donor preferences and technology, the donor may provide either less or more K_y with a negative (positive) conjectural variation than when that variation is zero.

36. If the LDC reaction function is U-shaped as in Figure 8, there may be two such Stackleberg equilibria. This complication, while interesting, would not affect the analysis to follow.

37. The locus of pareto optimal input combinations is the set of (K_y, x_y) pairs which satisfy the first-order conditions to the following problem:

$$\max_{K_y,\, x_y,} \quad U^L(K_y, x_y)$$

subject to

$$U^D(K_y, x_y) = \bar{U}^D.$$

In terms of the reduced form welfare functions, the first-order condition is:

$$\frac{U_x^L}{U_K^L} = \frac{U_x^D}{U_K^D}.$$

It can be shown that both U^L and the constraint are strictly quasi-concave in the neighborhood of any point satisfying the first-order condition so that this condition is sufficient as well as necessary for a maximum. The first-order condition can be expressed in terms of the marginal rates of substitution and transformation of the underlying functions as:

$$\frac{MRS_L}{MRT_L} + \frac{MRS_D}{MRT_D} = 1.$$

Comparison of this condition to the first-order condition for the LDC's nationally optimal choice, equation (24), reveals that the pareto optimal production of output will always be greater than the LDC's chosen output level for any given level of $\overline{K}_y$.

38. This result depends on the assumption that $\lambda < \sigma$ in the region $K_y^a < K_y < K_y^b$.

39. See McMillan (1979, pp. 97-102) for a discussion of these "solutions" and their weaknesses.

40. See Chapter 2 of Mueller (1979) and the references cited there.

41. For a lucid presentation of the prisoner's dilemma game and a discussion of some early conjectures on the effect of repetition on the players' behavior, see Luce and Raiffa (1959, pp. 94-102).

42. McMillan's recent work adopts this approach to solve the free-rider problem in the context of a public good economy, while Friedman (1971, 1977) and Marshak and Selten (1978) have made pathbreaking contributions to the theory of the super-game in the duopoly context where cheating on a collusive agreement can be interpreted as "free-riding". Also see Shibata (1971), Berman and Schotter (1979), and Schotter (1981).

43. Friedman (1971) and Marshak and Selten (1978) formalize the concept of a response in one iteration of a game to moves by the other player in previous iterations. For an alternative model of the evolution of a cooperative behavioral norm in a duopoly super-game, see Cyert and DeGroot (1973).

44. A citizen of one donor country was recently quoted in the Wall Street Journal as saying: "[s]ometimes people think that just because we're [insert nationality], we are suckers" (quoted by Vicker, 1980).

45. In a variation of the exchange model, the LDC might simply promise to purchase project inputs from firms located in the donor country. In this case the donor would be using a development grant to an LDC to redistribute income from its taxpayers at large to a subset of its citizens. The *quid pro quo* provided by the LDC would be its willingness to act as a conduit for that transfer payment.

46. France regularly grants unrestricted budgetary support to former colonies, but not to other LDC's. If France were motivated by the pure "joy of giving," as suggested by the philanthropy model, it would be hard to explain why it would discriminate in this way according to the identity of the recipient nation. Instead it seems likely that the mixture of motives that guides France's foreign aid varies according to whether the potential recipient is a former French colony. France's behavior towards LDC's which have never been French colonies seems more consistent with either the exchange model or the merit good model, depending on the circumstances, than with the philanthropy model. On the other hand, France's behavior towards former French colonies may occasionally be explicable by the altruism model which posits that the donor is motivated by the value it attaches to the *welfare* of the recipient nation, because this assumption seems more likely to apply when the donor and recipient nations share the same language and much of the same culture as do France and

its former colonies. The altruism model is discussed in subsequent paragraphs of the text.

47. We assume that the donor's welfare is not an argument in the LDC's welfare function.

48. This quote is a paraphrase of Downs' argument by Tideman and Tullock (1976, p. 1149) who also provide a lucid demonstration of the destruction of one of the demand-revealing tax mechanisms by the phenomenon of participation cost as the number of voters becomes arbitrarily large (ibid., p. 1156).

49. In order to explicitly plan for growth in the supply of a recurrent input in advance of predictable demand, it is important to permit or encourage the creation or expansion of private markets for that input which will establish a reservation wage against which government projects will be forced to bid.

50. Of course LDC's may be expected to object strongly to such coalitions of donors. In the summer of 1979 one Sahelian country objected in writing to a proposed meeting of donor representatives to discuss current projects in that country. Donors that attended the meeting would be refused the right to offer more aid. The meeting did not occur.

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