National Hydroelectric Power Resources Study

A Review of Economic Evaluation Criteria for Federal Hydroelectric Power Projects

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A Review of Economic Evaluation Criteria for Federal Hydroelectric Power Projects

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This report reviews and analyzes the principal economic (NED) evaluation criteria relating to Federal participation in hydropower development. The criteria studied include the alternative cost measure of benefits, the comparability test, economic and financial analyses, choice of alternatives, pricing policy, interest rates, relative price shifts and scheduling, evaluation of non-structural measures, and multiobjective aspects of hydropower evaluation. Recommendations are made with respect to the retention or modification of each criterion.

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A Review of Economic Evaluation Criteria for Hydroelectric Power Projects

by

David C. Major

Clark University

May 1981

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Abstract

This report reviews and analyzes the principal economic (NED) evaluation criteria relating to Federal participation in hydropower development. The criteria studied include the alternative cost measure of benefits, the comparability test, economic and financial analyses, choice of alternatives, pricing policy, interest rates, relative price shifts and scheduling, evaluation of non-structural measures, and multiobjective aspects of hydropower evaluation. Recommendations are made with respect to the retention or modification of each criterion.

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Summary of Recommendations

1. Benefit-Cost Analysis. Hydropower evaluation studies should utilize the basic structure of benefit-cost analysis as reflected in current Federal procedures. Progress should be made, however, in implementing guidelines permitting more complete NED benefit-cost accounting and more innovation in estimation techniques. (Ch. 2)

2. Alternative Cost. The alternative cost measure of benefits will continue to be appropriate in many cases. Where its assumptions do not hold direct measurement of willingness-to-pay benefits will be required, and much work remains to enable this to be done effectively at the field level. (Ch. 3).

3. Comparability Test. The comparability test (the application of Federal criteria to both a Federal project and its private alternative) is correct in principle, and should be kept. However, sensitivity analysis should be done regarding the recommendations that result from this test as a means of compensating for deficiencies in the current set of NED criteria. (Ch. 4).

4. Economic and Financial Analysis. In future evaluation studies the financial viability of projects that pass economic (NED) tests should be established as a guide to the future public/private mix of hydropower development. (Ch. 5)

5. Choice of Alternatives. The agencies' work on the utilization of systems techniques to examine alternatives should be continued and expanded, ideally to provide field level planners with a range of techniques appropriate for different circumstances. Further efforts should be made to insure the complete and accurate accounting of comparable effects as between hydro and thermal alternatives. (Ch. 6).

6. Pricing Policy. For near term planning efforts the current dichotomy between project design objectives (NED and EQ) and the objectives of pricing policy should be accepted, and recommendations should be based primarily on current design objectives. For the long term, it is appropriate to develop recommendations for pricing policies that permit the integration of pricing and project design. (Ch. 7).

7. Interest Rates. The best approach is to use a socially-determined interest rate for public projects, together with cost factors that reflect the real opportunity costs of public investment, and to use private financial rates of return to establish private viability of alternatives. Absent the use of a social rate of discount, sensitivity analysis on the interest rate should be used in studies of proposed Federal hydropower projects. (Ch. 8).

8. Relative Price Shifts and Scheduling. Relative price shift analysis should be used in hydropower studies, and the optimal scheduling criterion should be made a regular part of evaluation procedures. The forecasting problems involved should be dealt with in part through switching value analysis (Ch. 9).

9. Non-structural Measures. Current regulations require consideration of "non-structural" measures but very weak guidance is provided. Guidelines for individual project evaluation should be developed. Near-term broad planning efforts can deal with non-structural elements in two ways: first, through the use of load forecasts that take into account "without" elements, and second, for "with" elements, through the use of sensitivity analysis to bound the decision problem. (Ch. 10).

10. Multiobjectives. Current guidance is inadequate with respect to the multiobjective analysis of hydropower. A more complete range of design objectives is required, including energy independence objectives; and the current distinction between design and display objectives should be abolished. (Ch. 11).

Chapter 1: Introduction

This report is a study of economic evaluation criteria for hydroelectric energy projects. It was undertaken as part of the National Hydroelectric Power Resources Study. The National Hydroelectric Power Resources Study was authorized by the Congress in 1976 (P.L. 94-587). Subsequently, the study managers at the U.S. Army Corps of Engineers Institute for Water Resources established six objectives for the study:

"1. To analyze and define the nation's need for hydroelectric power;

2. To assess the physical potential for increasing hydroelectric power capacity and generation;

3. To analyze the current institutional and policy setting element of hydroelectric power planning, development, marketing and utilization;

4. To determine the feasibility of increasing hydroelectric generation capacity by development of new sites, by the addition of generation facilities to existing water resource projects, and by increasing the efficiency and reliability of existing hydropower systems;

5. To assess the general environmental and socio-economic impacts of hydroelectric power development;

6. To recommend to Congress a national hydroelectric power development program and any institutional and policy modifications which would increase the effectiveness of existing and future hydroelectric power development." (United States Army Corps of Engineers, Institute for Water Resources, 1979, pp. 1-2).

In order to accomplish these objectives, the work of the study was divided into two parts: a survey of the possibilities for developing hydropower at existing and new sites, and a series of policy and technical overview studies, of which this study is one.

The purpose of this review of economic evaluation criteria for hydropower is to provide a concise basis for applicable recommendations to the President and Congress from the National Hydroelectric Power Resources Study for use in future hydropower planning. The study was done on the basis of: a review of current criteria and procedures; analysis of project evaluation theory; and discussions with agency planners and other experts. The study is divided into 11 chapters, each dealing with an aspect of hydropower evaluation and each, with the exception of this introductory chapter, presenting recommendations. A summary of the recommendations precedes this introduction.

The chapters of the study are listed here. References are at the end of each chapter.

Chapter 2: Benefit-Cost Analysis for Hydropower. In this chapter the basic principles of benefit-cost analysis are described as they relate to hydropower evaluation. This material provides the elements of the theory that are required as groundwork for other chapters in the study.

Chapter 3: The Alternative Cost Measure of Benefits. In this chapter, the theoretical conditions under which the alternative cost measure should be applied in hydropower evaluation are described.

Chapter 4: The Comparability Test. This chapter describes the nature and significance of the comparability test as used in the evaluation of hydropower, and its proper application.

Chapter 5: Economic and Financial Analysis. In this chapter, the differences between economic and financial analysis are explained, and the relevance of the differences for project evaluation is described. In addition, differences between financial analysis and marketing analysis, where these are distinct for institutional reasons, are described.

Chapter 6: The Choice of Alternatives for Evaluation. This chapter deals with some principal aspects of choosing the system configurations alternative to proposed hydropower projects.

Chapter 7: Pricing Policy. In this chapter, basic principles for pricing policy, a complex matter for hydropower evaluation, are described.

Chapter 8: Interest Rates for Hydropower Evaluation. This chapter describes alternative approaches to the choice of interest rates for project evaluation as they relate to hydropower, including social, market, and financial rates of interest.

Chapter 9: Relative Price Shifts and Scheduling. This chapter describes the theory and application of relative price shift analysis, and also describes the problem of optimal scheduling, to which the analysis of relative price shifts leads.

Chapter 10: Evaluation of Non-Structural Measures. This chapter deals with the evaluation of non-structural alternatives, including demand management, from the standpoint of the NED account.

Chapter 11: Multiobjective Aspects of Hydropower Evaluation. This chapter deals with aspects of multiobjective evaluation that are particular to or new to hydropower evaluation.

Reference

United States Army Corps of Engineers, Institute for Water Resources, "National Hydroelectric Power Study: Plan of Study," Fort Belvoir, VA January, 1979.

Chapter 2: Benefit-Cost Analysis for Hydropower

This chapter is an introduction to benefit-cost analysis for hydropower. The topics covered include: the background of benefit-cost analysis; basic concepts for economic evaluation; the estimation of benefits and costs; the benefit-cost criterion and extensions; current procedures; and recommendations.

The Background of Benefit-Cost Analysis

Although water resources projects have been subjected to engineering and cost analysis in the United States since the 19th century, the beginnings of formal economic benefit-cost analysis as it is known today are to be found in the 1930's. The first explicit linking of benefits and costs for project evaluation in an easily accessible public document is in the Flood Control Act of 1936 (P.L. 74-738), in which it is said that, with respect to the projects undertaken under the authority of the act, "the benefits to whomsoever they may accrue [shall be] in excess of the estimated costs."

At about the same time, the long development of economic theories of demand and supply culminated in the elaboration of the model of economic resource allocation known as "welfare economics" (Bergson, 1938). In this model, the efficient production of the outputs most desired by individuals leads, under certain restrictive assumptions, to a clearly defined optimal allocation of economic resources. In the years immediately following World War II, the injunction in the Flood Control Act of 1936 and the welfare economics model became linked in the development of formal benefit-cost analysis. As it developed on the basis of the welfare econmics model, benefit-cost analysis became a technique to evaluate primarily the economic benefits and costs of projects, and to insure that only projects that were worthwhile in economic terms were recommended for implementation. (Other, non-economic objectives tended to be neglected until the development of multiobjective

theory; see Chapter 11). The most influential Federal presentation of this formal economic benefit-cost analysis was undoubtedly the "Green Book" (U.S. Inter-Agency River Basin Committee, 1958), originally issued in 1950.

Benefit-cost analysis in this form has seen extensive development in the United States and elsewhere for water resources and other public projects. The basic approach is the same, in principle, for all of the purposes of water resources development, including hydropower; but there are differences in application among purposes, due to differing technical aspects of the various purposes and to the different legal and institutional arrangements relating to them. There is a substantial literature on benefit-cost analysis. A brief historical review of the development of benefit-cost analysis, with references to the principal Federal documents, is in Major (1977, ch. 1). The model of economic resource allocation that provides the theoretical background for traditional economic benefit-cost analysis is described in Bergson (1938), Boulding (1952), and Graaf (1963). The assumptions of this model as they relate to project evaluation are considered in detail in Krutilla and Eckstein (1958) and Maass et al., (1962). A standard reference on economic benefit-cost analysis in theory and practice for water resources development is Eckstein (1958); chapter 8 of his work deals with hydropower. The extension of economic benefit-cost analysis to multiobjective analysis is presented in Maass et al. (1962), Marglin (1967), United Nations Industrial Development Organization (1972) and Major (1977). Among standard engineering and engineering economics texts dealing with hydropower are Creager and Justin (1950), Doland (1954), and Kuiper (1965). The principal recent U.S. Government documents dealing with the evaluation of hydropower include U.S. Department of Energy (1979) and U.S. Water Resources Council (1973, 1979, 1980).

Basic Concepts for Economic Evaluation

The basic idea of benefit-cost analysis for the economic objective, or the National Economic Development (NED) objective, as

it is referred to in Federal criteria, is that value is based on the evaluation of the "willingness to pay" of individuals for various outputs: efficient production of the most desired outputs leads to the optimal allocation of resources. The simplest case analytically is one in which there is a competitive economy, with numerous small producers and consumers free of externalities. The rule of benefit-cost analysis for public projects stemming from this simplest case is to analyze them using the same criteria that would be used to measure value privately in such an economy. (In the chapters to follow it will be seen that this simplest case is not, in general, adequate as a basis for the analysis of the merits of public projects). The analyst is concerned with the value of outputs, as measured by demands for these outputs; and with the economic value of inputs, as measured by their costs (that is, by their value in alternative uses). Economic analysis is concerned with the aggregate values of the outputs and inputs of a project; the distribution of benefits and costs from the project is the province not of economic analysis but of multiobjective analysis (ch. 11).

The demands for the outputs of hydroelectric energy projects depend on the willingness to pay of consumers for the energy. Consumers may be consumers of electric energy as a "final" good, such as householders who do not produce other goods with the energy but rather use it for personal consumption purposes such as lighting, heating, audio, and the like; or they may be consumers of electric energy as an intermediate good such as manufacturers who utilize the energy to produce other products.

Willingness to pay by consumers for energy is expressed as a demand function, or "demand curve," as illustrated in Figure 2-1. The output can be taken to be the quantity of kWh available during a specified time period with a specified probability. The demand curve, conventionally drawn with the independent variable, price, on the vertical rather than the horizontal axis, shows the amount that the potential consumers of the energy would be willing to purchase at each price per kWh.

FIGURE 2-1 HERE

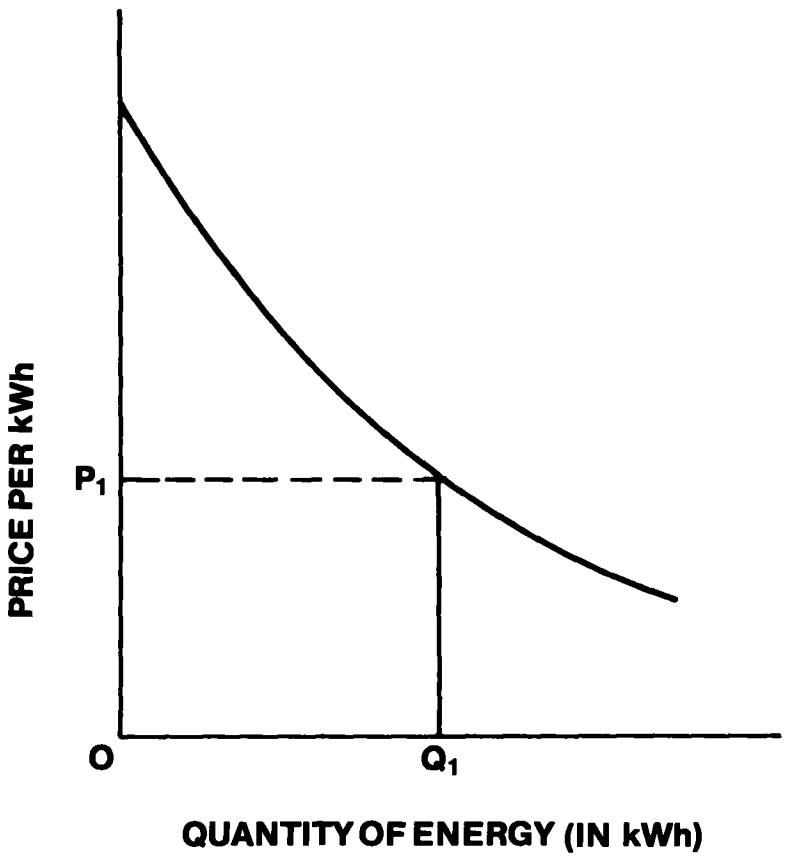

FIGURE 2-1: DEMAND OF USERS FOR ENERGY

For projects whose outputs are large relative to their markets, and which therefore affect output price, willingness to pay is estimated by the area under the demand curve. For example, in Figure 2-1, for an output of Q_1 kWh, the total willingness to pay of consumers can be estimated by measuring the area under the demand curve from $Q = 0$ to $Q = Q_1$. The market clearing price for Q_1 kWh is P_1. The difference between total willingness to pay and the revenue from selling Q_1 units at the market clearing price, or $P_1 Q_1$, is called "consumers' surplus." For projects whose outputs are marginal to their markets, i.e., projects that do not contribute sufficiently to total output to affect price, willingness to pay per unit is appropriately estimated by using the existing price of output.

With respect to the costs of projects, the value of resources used in the construction and operation of a project is also measured by willingness to pay; in this case, the willingness to pay of those who wish to use the resources in alternative ways. The estimation of the value of inputs requires an analysis of whether the project being considered uses amounts of inputs that are marginal or non-marginal to the input markets. If the amounts of inputs used are large relative to the markets for inputs, then an estimating procedure equivalent to estimating the demand curve for outputs is required (United Nations Industrial Development Organization, 1972, pp. 54-57). In practice, projects are usually assumed to be marginal to the input markets, and thus it is possible to estimate the value of inputs at their current market prices. A water resources project that produces quantities of outputs that are non-marginal (say irrigation water for a previously arid region) may use inputs (construction materials, labor, machinery) in quantities that are marginal in relation to the markets for these inputs. In such a case costs would be easier to estimate than benefits.

The benefits and costs attributable to a project from users' willingness to pay for outputs and the value of inputs are the traditional benefits and costs of benefit-cost analysis. There are,

however, other possible sources of benefits and costs on the economic account resulting from departures from the simple assumptions of the basic competitive model. These include benefits from the use of otherwise unemployed resources; benefits and costs from externalities; multiplier effects; departures from competition in further processing of project outputs; price changes in consumer goods resulting from the use of project outputs; and effects arising from the divergence of private and social rates of interest. Descriptions of these can be found in Marglin (1967) and Major (1977); detailed expositions are given in Maass et al. (1962) and United Nations Industrial Development Organization (1972). These other benefits and costs, although not associated directly with the willingness to pay of users of outputs and the value of inputs, are all ultimately expressions of willingness to pay, which is the fundamental expression of value in the economic model that underlies benefit-cost analysis.

Estimation of Benefits and Costs

The estimation of demand curves is difficult. A demand curve is defined as the amount that would be purchased at each price, at a given time, all other things being equal. Because the demand curve is instantaneous, the estimation of demand curves is not a simple matter of looking at historical price and quantity series. There have been some attempts to estimate demand curves for the outputs of water resource systems from data sets that have been fairly large. Two notable examples are those of Merewitz (1966) and Linaweaver and Howe (1967). Merewitz (1966) derived demand curves for recreation at Lake of the Ozarks, Missouri, based on a census of attendance at the lake and using a method that interprets the costs of traveling to a recreation site as a surrogate for price; thus, demand curves are derived that indicate fewer recreation days consumed as the price (cost of travel to the site) increases. Linaweaver and Howe (1967) estimated demand curves for water supplied to residential users, employing a large data set collected at the Johns Hopkins University for the Federal Housing Administration. These curves

show the typical shape of a demand curve: buyers are willing to purchase more units as the price per unit at which the commodity is offered decreases.

The difficulty of estimating demand curves has given impetus to the use of two simpler methods of calculating benefits for hydropower. The first is to assume the marginality of the outputs to the power market, and to use price as the estimate of value per unit, as noted above; the second is to use the alternative cost measure of value (or benefit) which, because of its importance in power benefit estimation, is explained in detail in the next chapter.

Supply curves, strictly defined as instantaneous, are also difficult to estimate, but are somewhat more tractable than demand curves because of the possibilities of conducting actual or statistical experiments on sometimes copious data dealing with production. An excellent brief discussion of the practical difficulties of estimating demand and supply curves is in Dorfman (1972, ch. 2).

A demand curve or a supply curve estimated for one project or situation will only be strictly appropriate for that project or situation, and only for the time period specified. However, it is sometimes reasonable to use curves developed for one project as indicators of value at other, similar projects.

The Benefit-Cost Criterion and Extensions

The application of the benefit-cost criterion requires that benefits and costs be compared (on a discounted basis--see Ch. 8), and that a project be recommended if discounted benefits exceed discounted costs. (This assumes the absence of budget constraints--see Major, 1977, pp. 43-47). Benefits and costs are estimated for different possible sizes of a project; the size that yields the greatest (positive) net benefits is the optimal design. The point of maximum net discounted benefits provides the greatest incremental contribution to overall economic product, based on the willingness to pay measure that is the basis of all of the benefit and cost

calculations made for the economic objective. (It is sometimes thought that the proper design is that which maximizes the benefit-cost ratio, but this is incorrect; see Eckstein, 1958, pp. 65-66.) Normal benefit-cost practice has been to make point estimates of benefits and costs for each of several sizes of a project; the size recommended for implementation is described by these point estimates, usually presented as a benefit-cost ratio.

All estimates of benefits and costs are, of course, subject to uncertainty, and this suggests the need for approaches to benefit-cost analysis that are more flexible than the use of single point estimates and optimization based on them. One such approach is perhaps of special interest in screening studies, although it is relevant also for detailed project design. This is to do sensitivity analysis on the principal forecast variables and parameters of a project, in order to develop a range of benefit and cost estimates for each different project size. Good investment strategy might then be to settle upon project designs that appear to be reasonably good choices over a range of reasonably likely future outcomes, rather than to choose the design that is optimal for a single set of point estimates of benefits and costs. With this approach, some projects that might not have passed muster under a single set of point estimates of benefits and costs might appear to have potential when ranges are considered, and thus would be kept in a list of potential projects rather than discarded.

A second way of using benefit-cost analysis that, like the use of ranges, is less rigid than the normal single point estimation procedure is the "switching value" approach (United Nations Industrial Development Organization, 1972, pp. 247 ff.). This requires the determination of the minimum (or maximum, depending upon the variable) numerical value of a key forecast variable (or parameter) at which a given project would yield positive net benefits. For example, the rise in relative fuel costs for thermal alternatives to public hydro projects must be considered in applying the alternative cost measure of benefits (chs. 3 and 9). The increase in real fuel prices that would be required to insure that a

given hydro project would yield positive net benefits can be determined. This value is called the switching value; it is the value of a variable or parameter at which a project switches from negative to positive net benefits and therefore can be recommended for implementation. When the switching value of a forecast variable has been determined, it is not necessary to forecast the future level of the variable on a point or even a range basis in order to determine whether a project should be recommended for implementation; it is only necessary to estimate whether or not the value is likely to exceed the switching value, an easier although still difficult task. This technique, like the use of ranges, is perhaps particularly useful in screening studies, although it is also important in detailed project assessments.

Current Procedures

Present Federal procedures for evaluating hydropower and other water resource projects include the entire basic structure of economic benefit-cost analysis, including the willingness to pay measure of benefit (a demand curve is shown on p. 24798 of U.S. Water Resources Council, 1973) and the net benefit criterion. There is authority for calculating several types of benefits (externalities and benefits from otherwise unemployed resources) in addition to users' willingness to pay for direct system outputs (U.S. Water Resources Council, 1979, pp. 72965-72970); authority for the use of the alternative cost measure of benefits, the application of which to hydropower is described in detail in the 1979 Manual (U.S. Water Resources Council, 1979, pp. 72938 - 72943); provision for sensitivity analysis (U. S. Water Resources Council, 1979, p. 72915); as well as many other detailed applications of the basic benefit-cost technique. The principal ways in which current procedures for economic analysis differ from a full text in economic benefit-cost analysis are, first, they omit certain types of benefit and cost categories and procedures (for types of benefits omitted see above and see Marglin, 1967, pp. 80-82 or Major, 1977, pp. 22-27);

and, second, because of the legal implications of the rule procedure, the current standards lack the flexibility for innovation in detailed detailed project evaluation that they ought to have.

Recommendations

Hydropower evaluation studies should utilize the basic structure of benefit-cost analysis as reflected in current Federal procedures. Progress should be made, however, in implementing guidelines permitting more complete NED benefit-cost accounting and more innovation in estimation techniques.

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Chapter 3: The Alternative Cost Measure of Benefits

This chapter describes the alternative cost measure of benefit for hydropower evaluation. The sections of the chapter include explanations of the principles of the method and several examples; a description of the role of the method in current government regulations; and recommendations.

The Alternative Cost Measure of Benefits: Principles and Examples

The alternative cost measure of benefit is based upon, and is a special case of, the willingness to pay criterion that is central to benefit-cost analysis for the economic objective. Given its assumptions it is a theoretically correct measure that is relatively straightforward to apply, and this is its appeal. The method is appropriate as an evaluation criterion for public hydropower projects when two assumptions are met: first, that there is a private alternative (e.g. a thermal plant) to the public project and this private alternative will be constructed if the public project is not undertaken; and second, that the gross benefits of the private alternative are equal to the gross benefits of the public project. The first assumption applies reasonably well to many cases of public hydropower development in the United States; the validity of the second assumption, on the other hand, often must be carefully examined by with and without analysis using systems modeling techniques (ch. 6). (On alternative cost, see Steiner, 1965; Maass *et al.*, 1962, p. 215; and, for multiobjectives, Major, 1977, pp. 35-36).

Under these assumptions, the alternative cost measure of benefits says that the benefits of the government project are limited to the costs of the private alternative, and that, as a result, the benefit-cost evaluation of the public project consists of comparing the costs of the private alternative to the costs of the public project, and choosing the less costly for implementation.

A simple example of the alternative cost method of benefits follows. Assume that there is a public hydro project to be evaluated on the basis of economic benefits and costs; and that there is a private alternative to this project that yields the same gross benefits. The values of costs and benefits are assumed to be as shown in the table. These values are real NED values, rather than financial values (see chapter 5); and it is assumed that the value of gross benefits is known. (In fact, the gross benefits need not be known precisely for the evaluator to be assured that they are equal; it is enough to know, for example, that the outputs of the two projects are the same and will be delivered to the system at the same time.)

Alternative	Public Project	Private Project
Gross benefits	100	100
Gross costs	70	80

If the government project is not built, the private alternative will be constructed and will supply outputs with gross benefits of 100.

Consider then the economic evaluation of each project.

For the private project, the benefits are 100, and the costs are 80, for a net benefit of 20. The private project reaps the full willingness to pay benefits for output; and incurs costs of 80 to do this.

For the public project, the positive economic effect is limited to the avoidance of the economic cost of the private project, since willingness to pay benefits will be captured in any case. Thus, the benefits of the public project are 80. The costs of the public project are 70, for a net benefit of 10. Since the public project has positive net benefits, it should, in the absence of budget constraints or negative multiobjective considerations, be implemented.

It might be supposed that, given the figures, the private project should be implemented rather than the public project, since its net benefits are 20; however, these benefits are reaped in any

case, and by building the public project an additional 10 of net benefits is obtained. If the public project is built, total net benefits will be 30; but of these only 10 are dependent on the decision to build the public project.

The alternative cost method thus depends on the important principle in economic evaluation that only the incremental positive and negative effects on the economic system of a project should be evaluated as benefits and costs. (United States Water Resources Council (1979, p. 72938, sec. 713.603a) is thus incorrect in holding that the alternative cost measure of benefits is to be used for hydropower evaluation only if ".... direct measures of marginal willingness to pay" for energy are not available). Effects that would occur whether or not the project is undertaken are not evaluated; this is the familiar with and without principle applied to the problem of alternative cost as a measure of benefits. Applying this principle to the construction of the private alternative, it can be seen that the benefits of the private alternative will be the gross benefits of the output, and the costs will be the costs of implementing the project. The incremental effects of the public project are the result of the assumption that, if the public project is not built, the private project will be constructed. Given this assumption, the benefits of the government project are not the gross benefits of the output, since these will be reaped in any case (the with and without principle); rather, the benefits attributable to the public project (the incremental positive effects on the system) are the costs of the alternative private project that are avoided if the public project is built. The costs of the public project are the costs of its implementation (the resources used in its construction and operation).

The key to the empirical simplicity of the alternative cost measure of benefits is that, given the assumption of a viable private alternative with equal gross benefits, there is no incremental effect on gross benefits if the public project is constructed; and therefore these benefits need not be estimated to evaluate the public project. (It is for this reason that this

method is called the alternative cost measure of benefits, or, put another way, it is sometimes said that the benefits of the public project are "limited by the costs" of the private alternative). The willingness to pay for the output of the projects is the same no matter which project is built; and since the private project will be built if the public project is not, the decision to construct the public project has no effect on willingness to pay for the output.

The last point helps to explain a confusion about the alternative cost measure that is sometimes encountered. It is sometimes said that the real benefits of the public project are not the costs of the private alternative, but the full willingness to pay for the outputs, that is, the gross benefits. (The argument is sometimes phrased in terms of the existing market price of output, which is taken to be a lower bound on willingness to pay). This misunderstanding is a misapplication of a correct insight. It is entirely correct that the total benefits of the output (of either project) are the willingness to pay for the output by users of the output. However, the assumption that there is a viable private alternative to the public project means that building the public project has no effect on whether or not these willingness to pay benefits are reaped; they will be obtained whether or not the public project is built, and therefore they cannot be included in an analysis of the incremental positive and negative effects of the public project. The with and without principle, applied to alternative costs, says that the total willingness to pay for output will be captured with or without the public project, and that therefore it is not relevant to an evaluation of the public project. The irrelevance of the total willingness to pay for outputs (the gross benefits) is entirely due to the assumption of a viable private alternative with equal gross benefits. This can be seen by considering the situation when these assumptions do not hold. If there is no viable private alternative, then there is no escape from the necessity to measure the gross benefits (the willingness to pay) of the public project and to compare these to the costs of the project.

As an example, suppose that a potential hospital project is available to the government, and that, for regulatory or other reasons, there is no viable private alternative to the project. The willingness to pay benefits for the hospital are assumed to be 100, and its costs are assumed to be 70, as shown in the table. Both values are taken to be real NED values.

	Hospital Project	
Alternative	Public	[Private]
Gross benefits	100	[--]
Gross costs	70	[--]

In this case, the benefits of the government project are the full willingness to pay benefits of the hospital, since there is no viable private alternative. The net benefits of the project are 30; in the earlier example of the public hydro plant with the private thermal alternative, the net benefits of the public project are 10. As a way of gaining insight into the meaning of alternative cost, it is instructive to compare the two examples under the assumption that the government has a limited capital budget of 70 available for such projects. Under this condition, which project would the government choose? Those who would argue that the real benefits of the hydro plant are 100 would have to say that the government would be indifferent as between the hydro plant and the hospital; whereas in fact the government should clearly build the hospital.

Another possibility is the existence of viable private alternatives to public projects that are partial alternatives. Rather than producing exactly the same levels of energy, delivered to the system at the same times, these alternatives might produce different levels of energy or deliver energy to the system at different times than the public project. In these cases, the alternative cost procedure cannot be used in its simplest form, since the gross benefits of the public and private projects cannot be assumed to be equal. However, the presence of a partial alternative may help to avoid some benefit measurement. For

example, consider the case in which a private alternative yields lower amounts of energy, with the same timing of deliveries to the system, than a proposed public hydro project of given design. Here, the (unknown) gross benefits will differ in favor of the public project. Then there are two possibilities. If the NED costs of the public plant are less than or equal to the costs of the private alternative, no further analysis is required to decide upon the public plant. Its benefits are greater than, and its costs less than or equal to, those of the private alternative. However, if the costs of the public plant are larger than those of the private plant, the situation is one in which larger (unknown) gross benefits are obtained for larger (known) costs. In this case, it is not necessary to estimate the total gross benefits of the two projects, but rather only the incremental benefits of the public project over the private project. If these extra benefits exceed the extra costs, then the public plant is chosen; if they do not, then the private plant is superior. (Steiner, 1965, p. 425). While this procedure is more complicated than the simple use of alternative cost, it is likely to be easier to implement than the case of no viable alternative, in which total gross benefits must be estimated.

The Question of Benefit Estimation

Above, it was said that the precise benefits of the public project and its alternative need not be known--that, for the alternative cost rule to be applied, it is enough to know that the gross benefits of the projects are equal. If the benefits are not known, the analyst is faced (to use the NED cost figures from the first example) with the following:

Alternative	Public	Private
Gross Benefits	X	X
Gross Costs	70	80

where X represents the unknown gross benefits. The application of the alternative cost measure of benefits will insure that the less

costly alternative is chosen, and the rule is optimal in this sense. In the simplest version of the welfare economics model of resource allocation (ch. 2), the private financial revenues and costs of a private investment project are equal to the true NED benefits and costs of the project; and it is assumed that private firms are rational, so that they would not undertake a project that had negative net financial benefits. If these assumptions held in the example, NED benefits would be at least 80, so that both private and public projects would be worthwhile. The only choice to be made is the one made by the alternative cost rule, namely, the selection of the less costly of the projects. However, in real economies, where taxes, subsidies and other transfers prevail, and, particularly in the power industry, where pricing is often determined not by the market but rather administratively, it is entirely possible that a project that is privately viable (private financial revenues exceed private financial costs) will not be worthwhile from the NED point of view. For example, if the (unknown) real NED benefits in the preceeding case were 60, the situation would be:

Alternative	Public	Private
Gross benefits	[60]	[60]
Gross costs	70	80

(The private financial revenues and costs are not shown, but they can be assumed to be positive on a net basis, since the private project has been proposed by a firm.) The alternative cost rule yields the correct choice, in the sense that the public project is the less costly of the two, but it can be seen that this is not the best choice from the standpoint of the NED net benefit criterion. On the basis of that criterion neither project should be built. However, this cannot be known unless at least a preliminary estimate of gross benefits is made; and it is the avoidance of direct benefit estimation that makes the alternative cost rule attractive in practical planning applications.

Current Procedures

The role of the alternative cost measure of benefits for hydropower evaluation in current Federal criteria is a substantial one. Alternative cost is one of the general measures of NED benefits permitted by the Principles and Standards; its application for hydropower evaluation is discussed on pp. 24798-9 and 24801-2 of the Standards (U.S. Water Resources Council, 1973) and also in the FERC manual (U.S. Department of Energy, 1979, ch. 3). In the 1979 Water Resources Council manual, there is a general reference to willingness to pay as the conceptual basis of benefit measurement for hydropower but it is the alternative cost procedure that is treated in detail, rather than direct benefit measurement (U.S. Water Resources Council, 1979, pp. 72938-72943). Neither the need for direct benefit measurement in cases of partial alternatives, which may in fact be common, or in the case of the general problem of knowing whether benefits exceed costs, is adequately confronted in current Federal procedures. Thus, while there is provision for the correct use of the alternative cost measure of benefits, it is not certain in every case either that the test is fully appropriate (partial alternatives) or that the benefits of hydro projects that pass the alternative cost test in fact exceed the costs. There is, therefore, a need to develop methods for direct benefit estimation for hydroelectric power evaluation.

Recommendations

The alternative cost measure of benefits is correct where its assumptions are met, and it should continue to be an important part of project evaluation for hydropower. However, the question of direct estimation of benefits in cases of partial alternatives, and of gross benefit estimation to insure that benefits exceed costs, should be pursued vigorously. It is possible that adequately confronting these questions may require the devotion of substantial additional resources to hydropower planning, and that a fairly large shift to direct benefit measurement may result.

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Chapter 4: The Comparability Test

This chapter describes the comparability test, an aspect of the alternative cost measure of benefit. The chapter includes a description of the test; a discussion of its status; and recommendations.

The Comparability Test: Description and Illustration

The comparability test arises as part of the alternative cost measure of benefits. The proper use of the alternative cost measure of benefits requires two assumptions: that gross benefits of the public project and the private alternative are equal, and that the private alternative is a viable alternative. The viability of the private alternative is established with financial analysis, as described in chapter 5. Given these two assumptions, the choice between the public and private projects depends on a comparison of their costs. The costs of the public project are, of course, evaluated using public economic criteria; and the use of these criteria to examine the private alternative as well is called the comparability test. It reflects the injunction that the public project it should not be recommended unless there is no more efficient alternative available, evaluated on a comparable basis.

As an illustration, consider the case of a public hydroelectric project with a viable private alternative, say a thermal project. (In actual practice alternatives are likely to be a mix of investment and operating changes; this creates more detail but does not change the principle). Suppose that the government project passes relevant marketing tests; that the gross benefits of the two projects are equal at 100; and that the following values obtain:

Public Project	Private Project
Economic Costs: 70	Financial Costs: 90

This does not permit a comparable evaluation, since, as described in chapter 5, there are many reasons why financial costs

and economic costs might be different in a real economy. The costs of the private alternative have to be estimated according to public (NED) criteria. The financial costs might include, for example, taxes that are treated as transfers in NED accounting and that thus do not count as true economic costs. Correcting for such factors might yield:

Public Project	Private Project
Economic Costs: 70	Economic Costs: 80

Since gross benefits are equal on the economic account, and since the private alternative is viable (by assumption), the alternative cost measure of benefits can be applied. The costs of the government project are 70, its benefits (the costs of the private alternative) are 80, and its net benefits are 10. The project should, absent budget or other constraints, be implemented. If the cost figures on the economic account were, say, Public = 70, Private = 65, the government project would fail the comparability test and would therefore not be recommended for implementation.

The use of the comparability test--that is, the use of NED criteria to evaluate both public and private projects--is thus, in principle, the correct method of applying the alternative cost method of benefit estimation. The test properly is not, as its name implies, an additional or separate test, but rather is central to the evaluation procedure. Its previous use as an additional test came about because agencies in some instances compared public hydro projects to private alternatives using the accounting methods of each sector to evaluate that sector's project. The public project was evaluated using economic (NED) criteria, and the private project was evaluated using private financial criteria. It was, however, recognized that a public project, lower in costs than a private alternative according to this procedure, was not necessarily suitable for implementation because it would not necessarily have lower costs according to public (NED) criteria. An additional test, comparing the two projects on the basis of public economic criteria, was applied, and this became known as the comparability test.

Current Status

The current status of the comparability test is that it is required for the calculation of the benefits of Federal hydropower projects by the alternative cost measure. The rule stated in the 1979 NED accounting manual of the Water Resources Council (U.S. Water Resources Council, 1979, p. 72940) is:

"...The calculation of alternative costs to be used as a measure of NED benefits shall be on the following basis: (A) all interest and amortization costs charged to the alternative shall be calculated on the basis of the Federal discount rate; (B) no costs for taxes or insurance shall be charged to the alternative; and (C) all other assumptions and procedures used in calculating the costs of the alternatives, including external diseconomies, shall parallel those used in calculating the costs of the proposed project."

One source of controversy with the comparability test has been the idea that using public criteria to evaluate the private alternative implies that the alternative is really a public thermal plant. (See U.S. Department of Energy, 1979, p. 3-3). Since the government (excepting the TVA) does not build thermal plants, it is argued that the alternative is therefore illusory and that the comparability test is not a correct test as applied under these circumstances. This line of argument is not correct. Using the government's criteria for the economic account to evaluate a financially viable private alternative is not tantamount to assuming that the private alternative is suddenly transformed into a public alternative. It is merely to examine someone else's decision (that of the private company) with our own (the public's) criteria, a common situation both in private and in public decision-making.

A more substantial problem with the comparability test in practice has to do with the completeness and correctness of the government's NED evaluation criteria. The description of the comparability test and its use given in the first section of this chapter assumes that the Federal government's criteria are the complete set of economically correct criteria. This assumption

transforms the injunction that there shall be no more efficient project evaluated on a comparable basis into the injunction that there shall be no more efficient project evaluated according to complete and correct criteria. The comparability test, to give the right results, requires both the use of the same set of criteria for the public hydro project and its private alternative, and the use of complete and correct criteria. Completeness and correctness are required to insure the right results because, in general, public and private projects are different with respect to the proportion of costs from different inputs and with respect to the time distribution of costs. They are thus affected differentially by the omission or incorrect estimation of evaluation criteria. For example, suppose that both projects are evaluated on a comparable basis with respect to negative externalities, but that this evaluation is not a comprehensive evaluation of externalities. If the projects differ in the extent to which they generate different types of externalities, the project that tends to generate more of the unevaluated negative externality will be favored by the application of the (incomplete) comparability test. Thus, it may be that private thermal or nuclear projects will look better, as compared to hydro projects, given the incomplete extent to which negative externalities are currently evaluated, than they would were a complete evaluation of such externalities applied. Similarly, if positive externalities are incompletely evaluated, the alternative that generates more of these will be disadvantaged by the incompleteness of the evaluation.

The current requirements for the application of the comparability test assure that the same criteria will be used to evaluate both a public project and its alternative. However, it is not clear that current Federal criteria are the complete and correct set of economic criteria; and so, when the comparability test is used, it is no doubt biased, but in an unknown direction. It would be helpful to have some investigation into this question; if the nature and direction of the biases inherent in the current use of the test could be discerned it would be possible to be more certain of the meaning of its application. Absent such investigation the most reasonable approach is to do sensitivity testing on the key

parameters used in the current version of the test; this would yield some knowledge of whether modest biases would or would not alter project choice. Among the criteria on which sensitivity testing ought to be done are the interest rate, which might be either too high or too low depending on the theory of the interest rate that is chosen as correct; and externalities, which are not fully accounted for in current practice (although there is permission to do this accounting where it can be done).

Recommendations

The comparability test should be kept, but sensitivity analysis should be done regarding the recommendations that result from this test as a means of compensating for deficiencies in the current set of NED criteria. Work on improving the current set of NED criteria, in order to make these criteria both more correct and more complete, should be encouraged.

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Chapter 5: Economic and Financial Analysis

In this chapter, economic, financial, and marketing analyses for hydropower are discussed and compared. The sections of the chapter include descriptions of the meaning of each of these types of analysis; their relationship to government decision-making in current practice; and recommendations.

Introduction

In the simplest version of the theoretical model of economic resource allocation that is at the basis of traditional benefit-cost analysis all economic benefits and costs are captured in the private market; all economic flows are therefore also financial flows. Thus, private decisions based on financial flows give the "right" results from the national income point of view since they are the same as purely economic decisions. In this system, there is no need for the separate accounting of economic and financial flows. By the same token, all marketing is competitive; marketing is not constrained institutionally, so that where there is a demand for goods this demand is met on the free market. Hence marketing is taken care of automatically in the allocation of goods and services and need not be treated separately.

In real economies, however, economic, financial, and marketing aspects of economic decisions are generally not coincident, and so it is necessary to consider the role of each type of analysis in considering a particular economic decision by the government, such as an investment in hydropower.

Economic Analysis

The economic analysis of projects is undertaken to examine their impacts on the traditional objective of benefit-cost analysis, the national income (NED) objective (chapter 2). Economic analysis is designed to estimate the real income (that is the real productivity) effects of proposed projects and programs, as measured by the

willingness to pay of individuals for the outputs of projects and for their inputs in alternative uses. These real income effects are taken to be one important measure of social welfare and are thus normally included in the objective function for government investment. In the simplest theoretical model of the market economy, without non-market effects and with all decisions marginal, these benefits and costs can be estimated by the market (financial) prices of outputs and inputs. In a real economy, a fairly elaborate set of rules serves as a guideline for economic benefit-cost analysis (see Marglin, 1967, or Major, 1977, ch. 3) and, of course, the application of these rules results at best only in an approximate estimate of economic effects because of the complexity of the real system. Since economic effects and financial flows differ in a real economy, projects that are economically good according to the NED criterion might be financially unprofitable, and vice versa. If financial viability is an important consideration in the evaluation of government projects this must be analyzed separately from and in addition to the economic analysis. Profit-making private firms cannot be expected to use economic as opposed to financial analysis for their own investments, of course, unless induced to do do by appropriate government policies.

Financial Analysis

The financial account includes revenues and financial costs, and it is the account used as the basis of decision-making by private firms and by government agencies concerned with the financial viability of projects. Where design is on the basis of financial criteria, the project will be, in general, different from the project designed on the basis of NED criteria. And, for the identical project, analyses with the two sets of criteria will ordinarily yield different results.

Differences between the economic and the financial accounts can be thought of as arising from two general sources: transfer payments of various kinds, and real economic flows not captured by the market.

Transfer payments are, in economic parlance, all of those many financial flows that represent taxes, subsidies, grants, and the like. These flows are pervasive in a real economy. They are an important part of financial accounting, but they are not taken into account in the economic analysis of government projects because they represent simple transfers of funds rather than economic productivity changes. (Or, at least, so it is usually assumed; in fact transfers of sufficient magnitude can effect economic magnitudes. To the extent that these effects occur, they must be taken into account in economic analysis).

Differences between financial flows and economic flows can also arise from economic effects that cannot be captured in the marketplace. Externalities are such flows; a private firm might undertake an action in its own interest that helps other firms, as for example by cleaning up pollution; but there is no way through the market that the firm taking the action can force other firms to help pay for the benefits that they receive; the benefits are real, and are thus included in the economic account; but they are not financial in terms of the accounts of the firm that undertakes the action. Similarly, a firm might take an action that imposes economic costs on others (as for example disposal of waste) that are not fully accounted for in the financial accounts for the firm and thus do not affect its financial decision making. As a result of such effects, a private project that might be worthwhile from the NED point of view might not pass financial tests; and, conversely, a privately profitable plant might fail NED tests. (Other examples of economic flows not captured by the market include public goods; for a discussion of these and externalities, see Maass et al. 1962, ch. 2).

The differences between economic analysis and financial analysis have led to the institutionalization, by some international lending agencies, of the use of two separate analyses for each proposed project: an economic analysis and a financial analysis. The latter analysis is designed to provide an indication of whether a project that might be good in an economic sense will be financially viable in

the sense that the loans required to finance it can be paid off. The World Bank follows this approach; an example is given in Gittinger (1972, ch. 7).

In addition to uses of financial analysis at the project level, financial analysis can be utilized to estimate the impacts of alternative programs of hydropower development on the Federal budget. For example, if two programs were considered, one emphasizing Federal hydro development and one emphasizing non-Federal development, the total impacts of the alternative programs on the Federal budget could be estimated by examining not only direct Federal expenditures but also the impacts of the range of loan guarantees, grants, and other taxes and subsidies relating to both Federal and non-Federal development.

Both economic and financial analyses take place in the context of a complex system of Federal and non-Federal regulation of electric power production (as well as of departures from competition more generally). Thus, an economic analysis reflects the economic gains and losses brought about by a project within this system of control; it does not represent the economic gains and losses of that project within a purely competitive system. Similarly, a financial analysis reflects the financial gains and losses brought about by a project within the system of regulation; it does not represent the financial effects that would have occurred within a free market. Because the system of regulation is so complex and pervasive, it can be supposed that both economic and financial analyses of a project would yield quite different results absent the system. In some instances, it will be useful to do economic or financial analyses of projects assuming that one or another constraint in the regulatory system is relaxed; this permits an estimate of the economic or financial costs and benefits of the constraint to be made.

Marketing Analysis

Marketing analysis is the consideration of whether the energy from a particular hydropower site can be marketed. This can be taken as either marketing in a general sense, or marketing by particular marketing organizations, i.e. those with which a production agency has marketing agreements.

There are several differences between marketing analysis and financial analysis. Marketing refers only to sales, whereas financial analysis covers all financial flows relating both to sales and to costs. In addition, some "sales" might actually be trades of energy or facilities usage that may or may not result in financial flows or effects. Finally, marketing is subject in practice to various institutional constraints, such as price controls or guidelines, marketing area restrictions, and the use of designated sales agents. The Corps of Engineers, for example, the largest hydro producing agency, does not market any of the power produced at the projects that it controls; the TVA however, markets its own power. Thus, it is convenient to think of marketing analysis as distinct from or at least a distinct part of financial analysis.

Economic, Financial and Marketing Analyses in Government Decision-Making

There are two general reasons why financial flows and marketing in addition to the economic objective and other multiobjectives might be taken into account in government decision-making for hydropower.

The first reason is that finance and marketing might be taken as objectives in themselves, or as representing other objectives. For example, the financial aspect might be taken as an objective; it might be thought appropriate that government projects should cover their financial costs, perhaps for moral or other reasons of principle. Similarly, it might be held that it is an objective in itself that government-produced power should be marketed through

government agencies. In cases such as these, where finance and marketing are treated as objectives, the multiobjective approach of chapter 11 should govern methods of analysis.

A second reason why finance and marketing might be taken into account in government decision-making for hydropower is that these two aspects might be considered as instrumental in the achievement of the economic (or other) objective. For example, the use of financial analysis for private alternatives is an instrument in the calculation of NED benefits, since it is necessary to know, for the alternative cost rule to apply, that the private alternative is privately (i.e. financially) viable. Here the financial analysis is purely instrumental in the calculation of NED benefits, and is not an objective in itself. The marketing analysis of a government project might also be used instrumentally as a check on or substitute for economic analysis. In the 1979 NED manual (U.S. Water Resources Council, 1979, p. 72938) a marketing analysis is suggested as a substitute for a forecast of need in evaluating small hydropower projects.

Economic, financial, and marketing analyses currently are undertaken as follows in relation to the evaluation of potential Federal hydroelectric power projects. The explicit objective of analysis (in addition to the environmental quality objective--see chapter 11) is the economic (NED) objective, and it is according to this objective that the current standards require that both the government project and its likely alternative be evaluated. (However, private energy projects that are not alternatives to Federal projects are not subject to Federal NED analysis. It is possible that such analysis should be required for these projects if, for example, they receive a government subsidy or other assistance). In addition, there is an analysis at some level of detail of the financial viability of the alternative, since it is this that establishes the alternative as a likely alternative and thus permits the use of the alternative cost measure of benefits. The marketing analysis of the alternative, in the sense of covering costs and normal returns to capital, is implicit in the financial analysis, since without adequate marketing the alternative would not

be likely. In addition, a marketing test is required for the Federal project, since Federal hydropower expenditures are reimbursable according to statutory requirements (Kirkpatrick, 1980).

In matrix form, the use of economic, financial, and marketing analyses for the evaluation of a potential Federal hydropower project and its private alternative is:

Alternative	Economic (NED)	Private Financial	Marketing
Public	X		X
Private	X	X	X

An X indicates that the analysis is, at some level of detail, undertaken.

Thus, potential public projects are not evaluated in terms of whether they might be suitable for private (or, more generally, non-Federal) development except to the extent that projects under study have been taken into account in the forecast of the alternative system. This is an area in which expansion of analysis may well be justified. In surveys such as the National Hydroelectric Power Resources Study, the outcome is the estimation of the set of projects that, at the screening level, would be feasible from the Federal standpoint. However, since overall energy policy will be made taking into account alternative possibilities for the development of energy sources, it would be of interest to know, on a level of detail consistent with the assessment for Federal development, the size of the set of projects that would be feasible for non-Federal development, and the extent to which this set overlaps with the set of potential Federal projects. (Analysis of non-Federal projects could also be done in multiobjective, as well as NED-only, terms). This information could be produced relatively easily by simple adaptations in the use of screening models such as that used for the Study. Such analyses will be particularly useful in formulating policy to the extent that time lags in the implementation of projects, an important factor in determining net

NED benefits, differ substantially as between Federal and other projects. It appears that this is the case (Franklin Pierce Law Center, 1981).

Recommendation

In future evaluation studies an effort should be made to establish the approximate financial viability, for private and other non-Federal development, of the projects studied for Federal development. This will provide a means of guiding future Federal budgeting decisions on hydropower and an indicator of the future public/private mix of hydropower development.

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Chapter 6: The Choice of Alternatives for Evaluation

This chapter deals with the choice of alternatives for evaluation. While this is not strictly speaking a problem of economic evaluation criteria, it is dealt with here because of the importance of the alternative cost measure in hydropower evaluation. The chapter includes a discussion of some principal aspects of choosing alternatives; current procedures; and recommendations.

Introduction

In the simplest and most abstract version of the alternative cost principle, a government project is thought of as having as an alternative a private project that is viable by private criteria. This project is required in order for the alternative-cost method to be applied in the conventional way. While the alternative need not have the same operating and output characteristics as the hydropower project in order to have equal gross benefits, it is simplest to approach the question of the exact equivalence of gross benefits by assuming that the operational and output characteristics of the alternative are the same as those of the government project. In this case gross benefits will be the same.

This approach, where there is a single alternative project with the same characteristics as the government project, is a valuable simplification for purposes of explication. However, for the actual evaluation of alternative costs, it is necessary to examine an entire power system, both with the government hydro project under consideration and without the government hydro project. In the without situation the government hydropower project will, in general, be replaced by a system change including both construction and operation and affecting several or many projects over time. This is evidently a complex systems problem that will require substantial analysis for large hydropower projects; for smaller projects that are marginal to large systems, simpler approaches may be appropriate.

In principle this problem consists of projecting the whole trajectory of the system over the relevant time period both with the hydropower project under consideration and without the project under consideration. In order to do this, a breakdown is needed of the types of energy demand (peak, intermediate, base); the types of plants that will be constructed; and the operational characteristics of the system. It is also necessary to consider the replacement of plants and equipment alternative to the hydropower project over the life of the project, possibly with new technologies.

The analysis of the hydropower project thus requires determining what portions of what types of demands will be met, during which time periods, during the life of the project; and examining the alternative costs that will be incurred in the system that would be required to meet these demands absent the hydropower project. This is, on the one hand, a simulation problem (simulating the expected system at each future time period), and on the other, an optimization problem, since it is desired to choose the best use of the hydropower in the sense of avoiding the greatest amount of alternative cost. It can be seen immediately that for systems of even moderate complexity there will be a likely necessity for mathematical modeling approaches in order to make the necessary data manipulation tractable. (The current state of mathematical modeling for hydropower system alternatives is discussed in U.S. Army Corps of Engineers and U.S. Water and Power Resources Service, 1980).

Several factors act to complicate the required analyses because the systems alternative to hydropower are not identical to hydropower in the production and delivery of energy and in their cost and other characteristics.

One such factor is the capacity value adjustment. Hydropower plants differ from thermal plants in their operating characteristics and in particular in having greater flexibility and reliability. Thus, the capacity equivalent to a given hydro plant is represented not by thermal plants with the same capacity, but rather by thermal plants with greater installed capacity. The difference is dependent on the actual system in which the plants would operate, and thus in

principle would need to be determined by a separate analysis for each hydropower project. In current practice adjustments of from 5% to 10% of the hydro plant's capacity are added to the alternative thermal plants to yield equivalent capacity. (U.S. Water Resources Council, 1979, p. 72940; U.S. Department of Energy, 1979, pp 3-6).

A second capacity factor relates to the value of intermittent capacity, and is the product of the way in which the dependable capacity of a hydroplant is conventionally defined. This capacity is usually defined as the dependable capacity of the plant under the most adverse flow conditions of record (U.S. Department of Energy, 1979, pp 3-5). In fact, a hydro plant may have substantially dependable capacity for a much larger fraction of the time than is suggested by this definition; the energy produced will have value and this needs to be credited to the hydropower plant in making alternative cost calculations.

A third systems factor is the question of the costs of energy production in a system with hydropower as compared to a system without. Depending on the hydro plant and alternatives, the total system energy costs might increase or decrease with the implementation of the hydro plant, and these costs have to be taken into account in the alternative cost calculations. (Examples of cases in which costs might increase and decrease with hydro as compared to alternatives are given in U.S. Department of Energy, 1979, pp 3-7). The 1979 NED manual (U.S. Water Resources Council 1979, p. 72940) recommends the use of a systems analysis to determine the appropriate adjustment. (With sufficiently complex systems models, this and the previous adjustments can be made directly as part of the with/without analysis).

A factor that must be taken into account in assessing the NED costs of the forecast alternative system is the range of negative effects that are incurred by certain alternative methods of energy production, such as coal and nuclear, that are not currently accounted for in Federal evaluation procedures. These externalities include health and environmental effects capturable in the NED account. The current NED guidance (U.S. Water Resource Council, 1979, p. 72974) on negative externalities refers only to those

effects pertaining to projects or plans, not to alternatives, although the hydropower section (p. 72940) requires parallel treatment. Negative externalities such as these have, as yet, been estimated only very approximately, so that the appropriate approach for alternative cost assessment is to estimate in detail the components of the alternative cost that can be estimated, and then to do switching value analysis using the available approximate estimates of negative externalities as a guide.

Another factor that must be taken into account in estimating the costs of alternatives is that costs must be adjusted to account for the impacts (positive or negative) of alternative energy generation on multipurpose uses of water. The construction and operation of a hydropower facility can increase or decrease benefits for other purposes. Similarly, for alternative power sources, the operation of a thermal plant can, because of cooling water demands, have a negative impact on other water uses; or, the change in the temperature of a river as a result of cooling water use can in some cases have positive impacts on other uses. While multipurpose analysis of this type is well developed for hydropower evaluation, it is not currently well integrated into alternative cost estimation procedures and this should be done.

The size of the project to which alternatives are being considered is also a factor in the analysis; this is the question of marginality. For small hydropower projects that are marginal to the system (in the sense of providing very small proportions of various types of power) good results can probably often be achieved by taking generalized values for capacity and energy without a detailed systems analysis for each project. The reason is that the system will change so little after the implementation of a marginal project that the changes incumbent upon the implementation of the project cannot be determined accurately given the large range of error in data and assumptions for the system as a whole. Given the available analytic techniques and data, system changes for one as opposed to another small project cannot be distinguished, and so it appears

sensible to use generalized estimates for them. For large projects, on the other hand, systems changes may be distinguishable, and systems studies will have to be used.

Current Procedures

The current guidance on NED evaluation procedures for hydropower (U.S. Water Resources Council, 1979) makes provision for taking into account the complexity of analyzing alternative systems in general (p. 72939, sec. 713.607) and with respect to capacity and energy (pp. 72940-41). The main lack is of guidance on the particular circumstances in which various analytic techniques might be employed. Work on these questions is underway in the agencies (U.S. Army Corps of Engineers and U.S. Water and Power Resources Service, 1980). Differences in externalities between hydro and thermal are not explicitly accounted for in the current guidance, although the requirement for parallel treatment provides for this (p. 72940); and there is no explicit requirement for analysis of the multipurpose effects of water requirements for alternatives.

Recommendations

The agencies' work on the utilization of systems techniques to examine alternatives should be continued and expanded, ideally to provide field level planners with a range of techniques appropriate for different circumstances. (The extent to which the use of systems techniques is expanded should, of course, be governed by the relationship between the value of resulting improvements in decision-making and increased costs of analysis). Further efforts need to be made to insure accurate accounting of comparable effects as between hydro and thermal alternatives, including negative externalities and effects on the multipurpose uses of water.

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Chapter 7: Pricing Policy

This chapter deals with pricing policy for hydropower. The chapter includes sections on the principles of pricing; the current situation; and recommendations.

Pricing Principles

The correct pricing policy for a public project depends, as does project design, on the objectives of investment. For example, the proper policy to insure optimal economic allocation is not in general the proper policy to achieve another objective, say increasing regional income. However, most discussions of power pricing have, until recently, centered on a rule derived from the welfare economics model that is the theoretical basis of economic benefit-cost analysis (ch. 2). This is the rule that price should equal marginal cost, a rule designed to optimize the economic allocation of resources. This approach has been widely discussed in theory but less commonly attempted in practice.

The relationship of price to objectives can be seen by considering a simple case of demand for energy. This is shown in Figure 7-1. In the figure, the demand curve for energy in a given period is shown as D. (Omit questions of cost for the moment.) If the quantity of energy Q_1 is produced, what is the price that will distribute this energy to consumers so that the maximum NED benefits from the production of Q_1 will be realized? The correct price will be P_1. This is called the market clearing price, since if the quantity Q_1 is supplied to the market, exactly Q_1 units will be demanded at the price of P_1. P_1 is a suitable price for NED purposes because selling energy at this price will insure that only those demanders whose willingness to pay is represented in the demand curve to the left of Q_1 will purchase energy at this price. These are the demanders with the largest willingness to pay. Other demanders (or the same demanders, where their demands for additional, lower-valued units are concerned) with lower willingness

FIGURE 7-1 GOES HERE

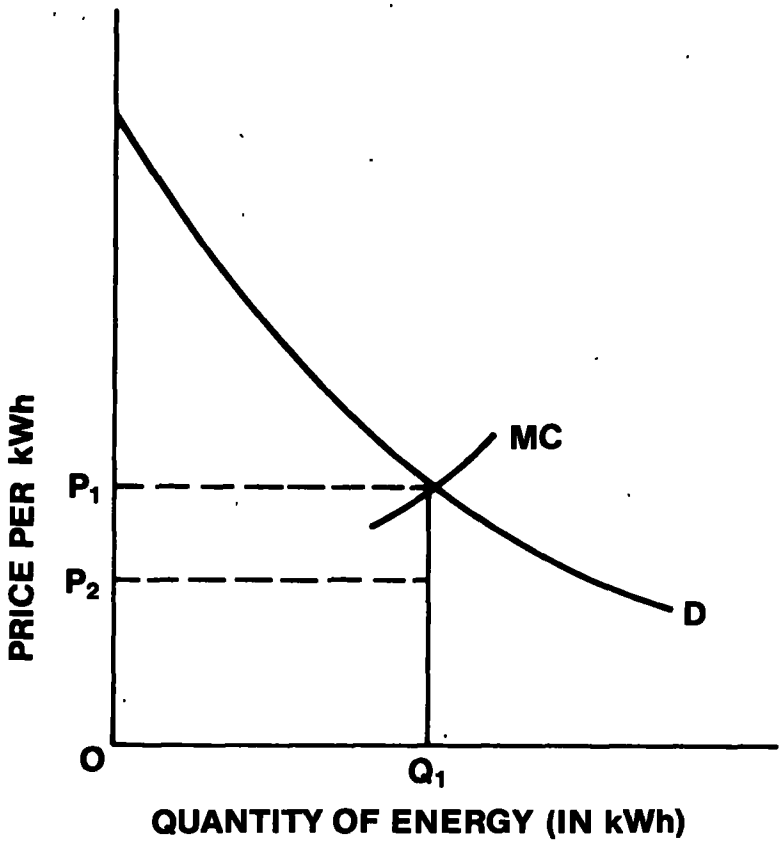

FIGURE 7-1: DEMAND OF USERS FOR ENERGY AND PRICING POLICY

to pay are represented in the demand curve to the right of Q_1. At the price of P_1 they will not enter the market. Thus the market clearing price insures that those who value the energy most will obtain it; that is, the energy will be allocated to its best uses, where "best" is defined as contributing most to the NED objective.

Suppose that there is another objective relevant to the disposition of the energy Q_1, say to increase the incomes of persons in the region of the project (perhaps because the region is a particularly poor region). This can be done by charging less than the market clearing price for the Q_1 units of energy, for example, the price P_2. At this price, the revenue from Q_1 units of energy will be P_2Q_1, rather than P_1Q_1, the revenue when the market clearing price is used. Income is thus shifted from the taxpayers in general, who supported the construction of the project, to the users of energy in the region where the project is located. In principle, it is possible to maintain the maximum NED benefits from the production of Q_1 units of energy by applying a rationing scheme to distribute the energy to the same demanders who would have purchased it at a price of P_1, that is, the demanders with the highest willingness to pay. (Rationing is required at a price of P_2 because the total amount demanded at this price is greater than the Q_1 supplied). However, it may be difficult in practice to develop rationing schemes that insure that only the customers with the highest willingness to pay will receive a given amount of a product. Therefore, the use of a pricing rule that helps to attain a second objective--increasing regional income--may lead to some loss of benefits toward the first objective--NED. This conflict of objectives is expected in project planning. And, of course, the objectives for the distribution of Q_1 units of energy might include the objective of making energy available to a wide range of purchasers, not just those represented in the demand curve to the left of Q_1. In this case, the loss in NED benefits comes about deliberately rather than through the failure to devise an adequate rationing scheme. In any event, this simple example shows that the use of P_1 as a pricing policy is not a sufficient guide to policy

except in the limited instances where the only objective of public policy is the NED objective.

The price equals marginal cost (P = MC) rule appears in the example just given when costs are considered. In Figure 7-1, the curve MC is the marginal cost curve for the project under consideration. Here, Q_1 is not simply an arbitrary amount of energy that is to be disposed of in the most efficient way, but rather represents the amount of energy produced at the optimal NED design of the project. Q_1 is the output at the optimal point because it is at this output that the marginal condition of maximization is fulfilled, namely that marginal benefits equal marginal costs. The market clearing price, P_1, which insures efficient production and allocation, is equal to marginal cost, and hence the rule. This rule says that, all other conditions required for the welfare model being fulfilled, if energy is priced at marginal cost, maximum NED benefits will be obtained. There is an elaborate literature on the efficient pricing rule (for example Williamson, 1966; Turvey, 1971). It is, however, difficult to implement in practice. An instructive article on the practical difficulties is Turvey (1967). On the other hand, the theory of pricing for other objectives is not so well developed, although the principle that pricing policies should differ according to objectives is clear. A good brief discussion is in Marglin (1967, pp. 88-92); see also Masss _et al_. (1962, ch. 2).

An additional objective relating to pricing policy is covering total costs out of revenues. An example is shown in Figure 7-2. In the figure, average costs of energy are shown as AC; these are decreasing for the project shown. Marginal costs are shown as MC; these are below average costs, since when average costs are falling marginal costs must be below average costs. The demand for energy is shown as D. The point of optimal production from the NED standpoint is Q_1, since it is at this point that the marginal condition of maximization (marginal benefits, represented by the demand curve, and marginal costs, are equal) is fulfilled. If pricing is according to the efficient pricing rule, P = MC, price

FIGURE 7-2 HERE

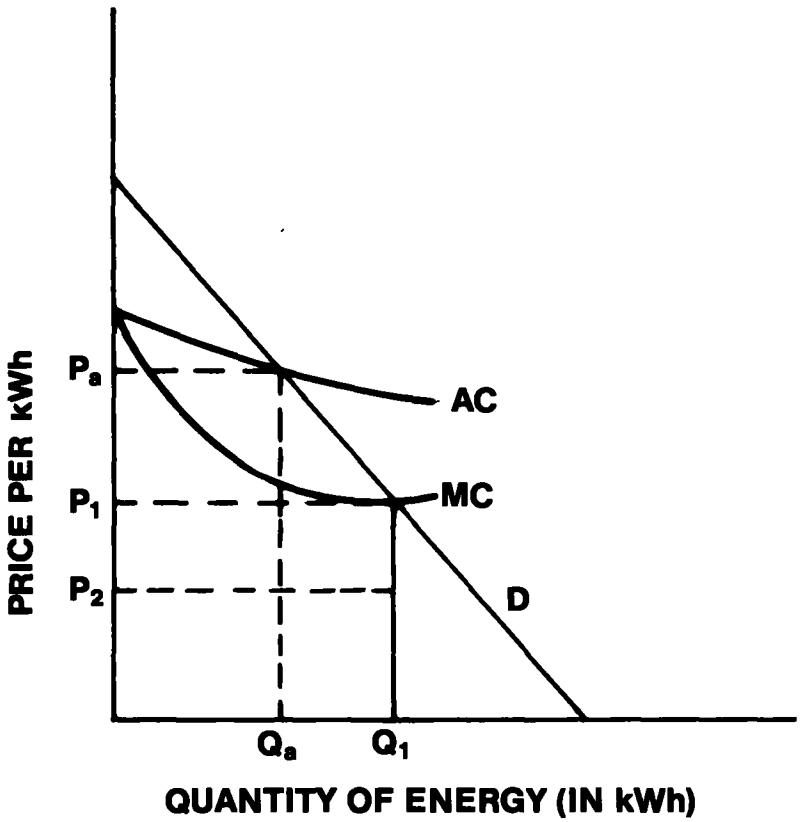

FIGURE 7-2: PRICING AND COST RECOVERY

will be set at P_1, the market clearing price, and the Q_1 units will be allocated without rationing. Pricing at this point will, however, result in revenues (P_1Q_1) that are insufficient to cover total costs, which are equal to the average cost of producing Q_1 units times Q_1. In order to observe the efficient pricing rule, the energy project shown in the figure would have to be subsidized. Pricing for a regional income objective, say at P_2, would increase the shortfall of revenue. If the project is to cover its costs out of its own revenues, either a discriminatory pricing scheme will have to be used (i.e. each demander will be charged his maximum willingness to pay), which is difficult to do in practice, or a smaller non-optimal amount of power will have to be produced and priced at average cost. The second solution, which appears to be one often adopted by regulated industries, is represented in Figure 7-2 by the output Q_a, which can be sold at the market clearing price of P_a. The revenue P_aQ_a will exactly cover total costs, including normal returns to capital. Here again, objectives will conflict: the practical solution to covering costs does not permit the achievement of the output that is optimal from the NED standpoint. This conflict between the marginal cost rule for efficient pricing and other objectives can also occur when the marginal costs of new capacity are rising. In such a case, regulatory authorities might prohibit pricing at marginal cost in order to prevent a windfall gain for utilities with existing, lower-cost generating capacity.

The Current Situation

The current situation of pricing policy for hydropower is complex. Hydropower projects are designed and constructed by one set of agencies according to the objectives specified in the Principles and Standards (United States Water Resources Council, 1973, 1980); pricing policy is set by other agencies according to objectives that are specified by law (Kirkpatrick, 1980) and that are different than the design objectives. The construction agencies are primarily the Corps of Engineers and the Water and Power Resources Service. The marketing of power from projects developed

by these agencies is the responsibility of the Secretary of Energy (formerly, the responsibility of the Secretary of the Interior), and it is exercised through five regional Power Marketing Administrations: Alaska, Bonneville, Southeastern, Southwestern, and Western. (An exception to the distinction between construction and marketing is TVA, which markets the power from its own projects). (For a review of the legislation, see Kirkpatrick, 1980).

The objectives followed by the design and construction agencies for hydropower are the NED and environmental quality (EQ) objectives. The display of effects on regional development (RD) and the other social effects (OSE) account is permitted, but design according to these objectives is not normally permitted. See ch. 11. (The OSE account substitutes for the social well-being account of the 1973 Principles and Standards). The objectives of pricing for the energy outputs of hydropower projects are different, in general, from NED and EQ. They are specified in a variety of laws. The objectives in the power laws include, first, the objective of insuring that preference is given in the sale of public power to public bodies and cooperatives, and thus that the benefits of public power will be distributed on a widespread basis and monopoly will be prevented. Second, the power laws mandate a financial objective for hydropower, that the revenues from the sales of power should be sufficient to cover the allocated costs. At the same time, pricing is to be as low as possible consistent with this and other objectives. Finally, revenues from power are to be used to repay costs of irrigation that are judged to be beyond the capacity of irrigation water users to pay. These objectives relate in part to the RD and OSE accounts in the Principles and Standards, but since design according to these is not normally permitted, there is no adequate way in the current guidance for project design and project pricing policy to be considered together in order to maximize net multiobjective benefits from hydropower. The situation is rather like that depicted in Figure 7-1, where design is for the objective of NED, and pricing (supposing P_2 to be the chosen price) is for a distributional objective. A better approach would be to vary both

design and pricing policy together in order best to achieve the several public objectives relating to hydropower. Developing the institutional mechanisms and working guidelines to accomplish this appears to be a long-term rather than a short-term task.

Recommendations

For near term planning efforts there is probably no alternative but to accept the current distinction between design objectives and pricing policy, and to do screening and initial program recommendation on the basis of the current design objectives. However, there may be opportunities to point out instances where the design and selection of projects according to current rules is inappropriate in terms of the objectives of pricing policy. For the long term, it is appropriate to develop recommendations for pricing policies that permit the integration of pricing and project design, and recommendations for institutional changes that would facilitate this integration.

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Chapter 8: Interest Rates for Hydropower Evaluation

This chapter deals with interest rates for hydropower evaluation. The topics covered include the role of the interest rate in project evaluation; inflation and the interest rate; the principal theories of the interest rate that have been advanced for public project evaluation; the current status of the interest rate in Federal evaluation criteria, and recommendations.

The Interest Rate in Project Evaluation

The necessity for an interest rate in project evaluation arises because the benefits and costs of alternative projects occur in different patterns over time. One project might have low early benefits and high benefits later in its life, and another project might have the reverse pattern. In order to compare the merit of the two projects, it is necessary to have a method of reducing or comparing a unit of benefit or cost that occurs in one time period to a unit of benefit or cost that occurs in another. The usual formula for project evaluation incorporates the interest rate as follows:

$$\max. \sum_{t=0}^{n} \frac{B_t - C_t}{(1+i)^t}.$$

for a project that begins in the present (t=0) and ends in year n, where B_t and C_t are benefits and costs received in year t and i is the interest rate. The factor for reducing a benefit or cost occurring in year t to its equivalent present value is thus:

$$\frac{1}{(1+i)^t}$$

The interest rate acts as an intertemporal price (expressed as a percentage), analogous to a price in current markets, that equates units of benefits and costs occurring in different time periods. A price as normally conceived relates a unit of one commodity to a unit or units of another, with both commodities being available during the same time period. The interest rate for NED acts as a price to equate a generalized unit of economic value, a dollar,

occurring in one time period, to a dollar occurring in another. If the interest rate is taken to be positive, as is usually the case, the intertemporal price attached to a generalized unit of economic value declines as a function of time. This reflects the normal preference of individuals and society for benefits earlier rather than later, and also reflects the possibility of transforming a given set of resources today, through investment, into a larger set of resources in a later time period.

Inflation

The relationship of the rate of inflation and the interest rate in project evaluation is a straightforward one; the relevant principles are given here (see also Howe, 1971).

The usual approach to benefit-cost analysis is that all parameters and estimates should be in "real" terms, that is, constant dollars. Thus, a benefit that is calculated to be available 10 years hence is to be estimated in terms of today's dollars, prior to discounting. Since this "real" benefit is to be compared with "real" costs in today's dollars, evidently the intertemporal price used to compare them should be the real rate of interest, that is, the interest rate free of any inflationary component. Project design will thus take place entirely in terms of real parameter values and estimates. (The benefit 10 years hence, if in fact it is received, will, of course, be in then-current dollars, a circumstance that will be relevant for financial analyses but will not be relevant for the economic benefit-cost analysis of the project.)

An equally acceptable method computationally is to use future benefits and costs in then-current dollars (unadjusted for inflation, that is, unadjusted to "real" dollars) and discount these with an interest rate that includes an inflation factor. If this is properly done the resulting project design will be the same as the design formulated using all "real" values. The rule in dealing with inflation and the interest rate, then, is that the interest rate

should be free of an inflationary component if the analysis is done in "real" terms; and should include an inflationary component if the analysis is done in terms of "current" costs and benefits. (In either case, estimating the inflationary components of interest rates observed in the complex markets for trading between present and future that are characteristic of real economies is a formidable task.) The general principle is that internal consistency among the criteria used to evaluate a project should be maintained.

Alternative Theories of the Interest Rate

The principal alternative theories of the interest rate proposed for the NED evaluation of public projects are: the interest rate in a purely competitive economy; the weighted interest rate at which those from whom funds are taxed to pay for public projects actually operate; the marginal rate of return in the private sector; the government borrowing rate; and the social rate of discount. These are described here.

The Competitive Market Interest Rate

The purely competitive model of economic allocation that is the basis for traditional benefit-cost analysis includes the competitive market interest rate. (This rate is sometimes called the "Pareto" rate, after the social scientist who formulated an early version of the competitive model (see Boulding, 1952, p. 2); or the "Fisher" rate, after the Yale economist Irving Fisher, who wrote a classic work on the interest rate (Fisher, 1930). This rate is determined in free competitive markets for lending and borrowing in which numerous small lenders and borrowers compete; it is a rate that exactly balances, in equilibrium, the preferences of individuals for income now and in the future versus the technological capacity of the economy to convert, through investment, consumption foregone now into greater consumption in the future. This rate balances, in other words, individual preferences and technical possibilities at the margin. From the standpoint of values, this rate reflects the

decentralized preferences of individuals as expressed through a perfect market. It is the intertemporal price that is analogous to the free market commodity prices in the competitive model. While, since no real economies are purely competitive, the value of the Pareto rate is unknown, nonetheless this rate is of great importance in discussions of the appropriate rate for discounting government projects because it provides the theoretical notions behind recommendations for a market rate of interest.

The Weighted Interest Rate Of Those Taxed

Because the theoretical Pareto interest rate that represents decentralized private values for trading between present and future in the purely competitive system is unknown, various attempts have been made to estimate market interest rates that, while not the Pareto rate, relate to its theoretical foundations. One attempt in the field of water resources is that of Krutilla and Eckstein (1958, ch. 4). They reasoned that, while it would not be possible to estimate the pure Pareto rate of interest, nonetheless it would be possible to investigate the rates of interest at which the businesses and individuals who would be taxed to finance government projects were operating. These rates would reflect the actual preferences and possibilities involved in trading between present and future (the basic theoretical foundations of the Pareto rate) and therefore, it was reasoned, would constitute an appropriate estimate of the social value of the funds taxed to pay for public projects. By estimating the incidence of the tax change required to finance the marginal government project, the weighted market rate of interest (the rates of interest at which individuals and businesses were operating weighted by the proportional tax burden of each) could be found. This, the authors argued, estimated the social cost of capital raised to finance government projects and thus was the appropriate interest rate for use in NED discounting in the public sector. They made estimates of this weighted market rate of interest for two assumed tax changes: one relating primarily to consumption, and the other to investment. Using data from the mid-

1950's, a period of relative price stability, they estimated the relevant weighted rates at 5.7% and 5.44%, respectively, for the consumption and investment tax changes.

The Rate of Return in the Private Sector

Another rate of interest that has been recommended for use in discounting the NED benefits and costs of public projects is the real rate of return in the private sector. The real rate of return on investment in the private sector is defined as the true NED return, rather than the actual money interest rate earned. The actual money interest rate must be corrected for various market imperfections (such as externalities) and transfers to yield the true NED return. The real rate of return will therefore only coincidentally be a rate at which any individual or business operates. It is the rate at which real resources are converted, through investment, into future real resources, rather than a rate that reflects the expressed preferences of persons in the market. The real rate of return is to be estimated at the margin, since it is marginal investment that will be foregone in the private sector if resources are diverted to the public sector. (A practical difficulty is that most data available on private sector investment relate to average rates of return, rather than marginal rates.) According to this approach the real rate of return is to be used for the NED evaluation of public projects such as hydropower projects. The argument is that, since the real rate of return can be obtained in the private sector, government projects should be evaluated with this rate; this will insure that no government projects are undertaken that do not yield at least the same return as the private investment projects that would be (it is implicitly assumed) foregone in order to provide resources for the public projects. An estimate of rates of return in the private sector is that of Stockfisch (1968), who gave the value of 12% or, on an inflation - adjusted basis, 10.4%. Using the real rate of return as the discount rate for public projects has the defect of confronting a question of values--preferences for present versus future

consumption--with a technical criterion--the rate at which resources can be converted, through investment, into future resources. (See Marglin, 1968, for a discussion of this problem). The social rate of discount approach to public sector discounting, described below, also takes into account the real rate of return in the private sector but in a different way: not as an interest rate, but rather as an adjustment factor on costs to prevent the misallocation of resources between the private and public sectors.

The Government Borrowing Rate

A market rate that is sometimes recommended for use in the NED evaluation of public projects is the rate at which the Federal government borrows funds. The argument is based on a simple financial criterion: that government projects should return at least the cost of borrowing to the government. A day-to-day government borrowing rate is available in the financial pages; or some average rate based on previous borrowings can be used, as is done in water resources planning now, as a surrogate for the government borrowing rate that might hold at the particular moment funds are borrowed. There are two thorny problems with using the government borrowing rate as the discount rate for NED evaluation of public projects. First, the government does not borrow most of its funds, but rather taxes them; so that if opportunity cost is to be the measure of the interest rate used for evaluation, a rate such as that calculated by Krutilla and Eckstein (1958) would be more appropriate, because it is based on the assumption that funds are taxed rather than borrowed. Secondly, even if the government did borrow funds for projects, the rates at which the government borrows do not reflect any market estimate of the worthwhileness of particular projects. Repayment of the borrowing is guaranteed by the stability of the government as a whole and its taxing powers, rather than by any merit or lack thereof pertaining to a particular project.

The Social Rate of Discount

This approach suggests that the choice of an interest rate, a choice of values over time, should be treated as a question of social choice. This is particularly so, it is argued, since the rate of interest determines the rate of investment and therefore affects the growth of the economy as a whole, an important social question. From this point of view, the choice of an interest rate for discounting public investment returns is a decision that is different in kind from decisions made in decentralized markets, where preferences reflect only the welfare of the individuals active in the markets. This approach thus says that the interest rate used for discounting the economic benefits and costs of public projects should be based explicitly on social preferences for benefits and costs in future time periods as compared to benefits and costs occurring in the present (Marglin, 1963a, 1967). The interest rate so chosen is termed the social rate of discount. (This theory applies to multiobjectives also; see ch. 11). The social rate of discount is to be estimated, not from market rates of interest, with which it would only accidentally coincide, but rather from information on social time preferences derived from studies of legislative decisions and legislative history; from information developed in interchanges between project designers and decision-makers (United Nations Industrial Development Organization, 1972, ch. 18); by studies of previous projects (Major and Major, 1978); and by surveys.

Utilizing a social rate of discount that is different (say lower) than the real rate of return in the private sector raises the possibility of a misallocation of resources if better opportunities are lost in the private sector through taxation or borrowing to finance public projects. This problem is dealt with in the social rate of discount approach by examining the sources of funds which are taken from the private sector; estimating their present NED value; and taking this information into account in the design and selection of public projects. To do this, the division of funds taken from the private sector as between current consumption and

private investment is estimated. Current private consumption brings no future returns, of course, and so need not be discounted. Private investment brings returns at the NED rate of return in the private sector, and these returns must be discounted to the present. This discounting is done using the social rate of discount in order to establish their current value on a basis consistent with the value of discounted benefits from public projects. The current value of consumption foregone and investment returns foregone is summed and applied to the dollar costs of the public project as an adjustment factor (termed a shadow price). When properly calculated, this adjustment factor allows the project designer to evaluate public projects in the usual way, maximizing net NED benefits (taking into account adjusted costs); projects with positive net NED benefits are worthwhile. At the same time this procedure insures that funds will not be diverted from the private sector that, if they remained in that sector, would have had higher NED values than the public projects under consideration. This procedure is explained in detail in Marglin (1963b) and United Nations Industrial Development Organization (1972).

Comparisons

Of the rates described, the social rate of discount approach is the only one that both permits the public to decide on its preferences for present versus future NED benefits, and at the same time takes into account the NED consequences in the private sector of public investment. The Pareto rate (and attempts to approximate it such as the weighted rate of those taxed) is relevant only if it is decided that the decision on present versus future for public projects is to be made in the same way as decisions in the market place; the real rate of return criterion leaves preferences out altogether by attempting to substitute a technical rate of transformation for them. As for the government borrowing rate, its main apparent advantage is the simple one of financial repayment, although this holds only if the rate at the time of borrowing is used as the discount rate. A more subtle advantage of the

government borrowing rate is that, because the choice of the actual numerical value used is in reality a compromise (nearly any value can be found by appropriate choice of weighting factors for outstanding government bonds) it to some extent partakes of the merit of a social choice rate.

The Current Situation

The current situation with respect to the interest rate for the NED evaluation of Federal water projects is that the agencies are directed by law (Section 80 of the Water Resources Development Act of 1974, PL 93-251) to use a weighted Federal borrowing rate based on the average yield of outstanding United States marketable securities that, at the time of computation, have terms of 15 or more years remaining to maturity. This rate, although it has the surface appeal of all government borrowing rates of requiring projects to return to the government at least the government cost of borrowing (albeit largely past rather than current borrowing), has the theoretical defects described earlier. On the other hand the rate chosen by the Congress does have the advantage of partaking to some degree of the merit of a social choice rate; however, the choice was made at a time when inflationary expectations were quite different than at present; so that even if regarded as a sort of social choice rate, the rate would have to be adjusted for this factor. As it is, the rate currently calculated is probably rather high as a real rate. (The rate is treated by the agencies as a real rate, in effect, since it is used to discount real costs and benefits). Since it is not clear that the current NED rate is correct on any theoretical ground, this throws uncertainty also on the comparability test (that is, the calculation of true alternative cost; see ch. 4).

The current situation with respect to rates of interest for accounts other than NED is that no separate rates are specified for use in discounting EQ, RD, and OSE benefits and costs. Such effects are in general simply to be displayed together with the times of

their occurence. Thus, when Congress begins to choose among alternative project designs based on multiobjective standards, it will be implicitly assigning social rates of discount to these accounts. (U.S. Water Resources Council, 1980, p. 64391, sec. 711.19, provides that the section 80 rate to be used to convert "future monetary values to present values." While some values in the regional development account, for example, are monetary, there is no reason in principle why an NED rate should be applied to them. See Marglin, 1967, p. 67.)

Recommendations

The current status of the interest rate for hydropower evaluation cannot be regarded as satisfactory. The current NED rate, even if some element of social choice be ascribed to it, is incorrectly used as a real rate in current practice; and there are no separate non-NED rates at all. The ideal remedy would be to move toward the use of social rates of discount for the NED and other accounts, with appropriate adjustments on the cost side (Marglin, 1967, p. 67). A practical approach recommended for the near term is to design projects for several NED interest rates (the rates chosen should be the same for each Federal design agency), and to present the results to the President and Congress for final decision. (In addition to such parametric variation, the interest rates used might include the offical Federal rate adjusted for inflationary expectations at the time it was defined). The rates could be chosen at least initially using a simple switching value approach. The official rate would be used, together with a higher and a lower rate. The last two would be chosen so that programs designed on the basis of them would differ significantly in size from the program designed on the basis of the official rate. A more sophisticated variant of this approach is recommended as a further step: sensitivity analysis with several assumed NED social rates of discount, accompanied by the adjustments on the cost side appropriate to each. It is also recommended, of course, that the agencies continue to use private rates of interest to calculate the viability of private alternatives to public projects (ch. 3).

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Chapter 9: Relative Price Shifts and Scheduling

In this chapter, relative price shifts and the scheduling criterion are discussed. The sections include discussions of relative price shifts in general and in relation to the alternative cost criterion; the current status of relative price shift analysis; recommendations with respect to it; the nature and significance of the scheduling criterion and its relation to relative price shift analysis; its current status; and recommendations with respect to the scheduling criterion. (Relative price shifts affect both the costs and the benefits of projects, and thus the term "relative price shift analysis," used in this study, is more general than "life-cycle costing," which has been used in the past to describe this analysis).

Relative Price Shifts

The usual assumption in water resources planning has been that relative prices will remain constant. Inflation, if any, is assumed to be symmetrical, and is taken into account by using real prices and a real interest rate (see ch. 8). Project evaluation is then carried out on the basis of these assumptions. However, the assumption of relative price stability has been made largely out of ignorance. In a real economy, the normal situation is one of relative price shifts over time rather than one of relative price stability. These relative price shifts, sometimes abrupt, reflect changes in preferences, resource availabilities, and institutional arrangements.

The analysis of relative price shifts has taken on particular importance for hydropower evaluation because of recent changes in the relative prices of fossil fuels and the impacts of these changes on the alternative cost measure of benefit for evaluating public hydropower projects. Since the private alternative has, at least

until recently, usually been assumed to be a thermal plant, a rise in relative prices of fossil fuels will result in a substantial increase in the costs of the private thermal plant as compared to the public hydropower project, and will thus tend to favor hydropower. Because this factor will tend to change the number and sizes of hydropower projects that are recommended, as compared to an analysis based on constant relative prices, it needs to be incorporated in agency evaluation procedures.

The relative price shift principle is a general one, so that in principle all relative price changes that can be expected to influence substantially the outcome of project evaluation should be incorporated into the analysis. For example, if fossil fuel prices are expected to increase relatively, the prices of other goods and services that are heavily dependent upon fossil fuels as inputs are also likely to increase. If these increases are expected to be substantial, they should be forecast and incorporated in project evaluation along with the initial shift in fuel prices. (Note that, while the initial increase in fossil fuel prices will tend to favor hydropower through the alternative cost measure of benefits, increases in construction costs might tend to favor non-hydro alternatives, which are relatively less capital intensive).

As is the case with all forecasting, predicting the "right" relative price shifts for hydropower analysis is a difficult matter; and, in fact, when single forecasts are made, the only near certainty is that they will be wrong. (This is also true when the single forecast is one of constant relative prices.) This suggests that planning should take place in the context of a range of forecasts for relative price changes. Fortunately, this problem is one in which the use of "switching value" analysis will be helpful. In comparing a hydropower project to a private thermal alternative, which can be assumed for the sake of illustration to be cheaper than the public project, it can be asked what the level of

increase in fossil fuels would have to be to make the two plants exactly equal in cost. This value of fossil fuel price increase is called the "switching value". If it is exceeded, the public plant will be chosen, and if it is not exceeded, the private plant will be chosen. Once this has been calculated, an exact forecast of the relative price increase in fossil fuels is not required to make a decision as between the two plants; it is only necessary to say whether the increase in fossil fuel prices will exceed the switching value or not. This is an easier question although, as with all forecasting questions, still a difficult one. (Where a range of forecasts is made, this range can be compared to the switching value. As a practical matter, if the switching value falls toward the lower end of the range, the project could be recommended for implementation.)

An additional consideration in relative price shift analysis for hydropower evaluation is that an increase in relative prices of fossil fuels, if it is substantial, will require a case-by-case analysis of the suitability of the way in which the alternative cost measure of benefits is used. If fossil fuel prices increase sufficiently, it can no longer be assumed that a thermal plant will be the viable alternative to a public power project. There may be a different alternative (including non-conventional alternatives), or there may be only a partial alternative, in which case at least some direct benefit measurement is required for the public plant; or there may be no viable alternative.

Current Status

Under the Principles and Standards (U.S. Water Resources Council, 1973, 24783-4) relative price shift analysis has been permitted, although, given the wording of the relevant provision, not encouraged. On the other hand, the hydropower section of the 1979 NED Manual (U.S. Water Resources Council, 1979, 72940-41),

while it retains the general wording of the Principles and Standards relating to relative price shifts, mentions explicitly the possibility of taking into account the real escalation of fuel costs (as well as several other possible relative price shifts). Thus, it can be expected that the agencies will be encouraged to undertake this analysis. A study of various available relative price forecasts for fossil fuels sponsored by the U.S. Army Corps of Engineers Institute for Water Resources (Bushnell, Pearsall and Trozzo, 1980) evaluates the available alternative forecasts and discusses the use of a modified Federal Energy Regulatory Commission computer program to deal with relative price shifts of fossil fuels in Corps project analysis.

Recommendations with Respect to Relative Price Shift Analysis

Because of its potentially significant impact on hydroelectric power program recommendations, relative price shift analysis should be incorporated on a regular basis into the evaluation procedures for hydroelectric power projects. Planning resources should be devoted first to an analysis of the most important price shifts, which are, in this case, rises in prices of alternative fuels. However, at an early time, the impacts of other relative price shifts should be included in project evaluation; for example, relative shifts in construction prices. Where relative price shifts for alternative fuels are thought to be substantial, the viability of alternatives must be reexamined to insure that the alternative cost measure of benefits is correctly applied. The use of switching value techniques will help to make the incorporation of relative price shift analysis into hydropower evaluation procedures manageable.

Scheduling

The increasing importance of relative price shift analysis will inevitably bring with it concern for a related investment criterion, the scheduling criterion. The scheduling criterion deals with the optimal date of implementation of a project. It is a more complete version of benefit-cost analysis than traditional procedures. Traditionally, projects have been evaluated as if they were to be implemented in the present time period. Benefits and costs are discounted to the present, (or to the date of project completion, with construction beginning the present) and, if net benefits are positive, the project is, other things being equal, recommended. This approach is appropriate if benefits and costs are solely a function of project life. In such a case, a benefit occurring in, for example, the 10th year of a project's life will always occur in the 10th year from the date of implementation, and the value of the objective function for the project will be the same, seen from the starting date of the project, no matter what that starting date is. Assuming no time-related budget or other constraints, there is no reason to consider the postponement of such a project if it has positive net benefits, because postponement would subject those net benefits to discounting and thus diminish their value as seen from the present.

However, if benefits and costs are not functions of project life (that is, of "project time") alone, but rather are also functions of calendar time, then this traditional approach will no longer in general give the right answer to the questions of whether and when a project should be implemented. When benefits and costs are functions of calendar time, it is necessary to examine the

effects on the objective function of a project of moving its date of implementation in calendar time. In other words, project analysis has to be expanded from its usual focus on questions of size to include questions of date.

The case of rising relative prices for fossil fuels brings this question to the fore in hydropower analysis because of the role of fossil fuels in the alternative cost measure of benefits. It can be expected that prices of fossil fuels will change relatively whether or not a particular hydroproject or program is undertaken. Thus, from the standpoint of the analyst of hydropower these price changes are changes in calendar time; and since the price of fuel is an important component of alternative cost, project benefits are functions of calendar time. As a result the scheduling criterion should be applied in hydropower analysis.

The importance of the scheduling criterion can be illustrated as follows. (The next few paragraphs follow Major, 1977, pp. 42-43). Assume that the benefits that can be reaped by a project of a given size increase over calendar time regardless of whether the project is constructed. This will be the case for rising relative fuel prices in the context of the alternative cost criterion. For simplicity, it can also be assumed that the real costs of the project will remain constant whatever the date of implementation.

Consider now what a graph of net benefits for this project for different years of implementation might look like. If the project were implemented immediately, the result would be to gain relatively low benefits in the early years of the project and to incur costs early. If the project were postponed, the relatively low early benefits would not be reaped. On the other hand, the costs of the project would not be incurred immediately. This would postpone (and thus subject to discounting) costs; and would permit the capital that would have been invested in the project to be used productively

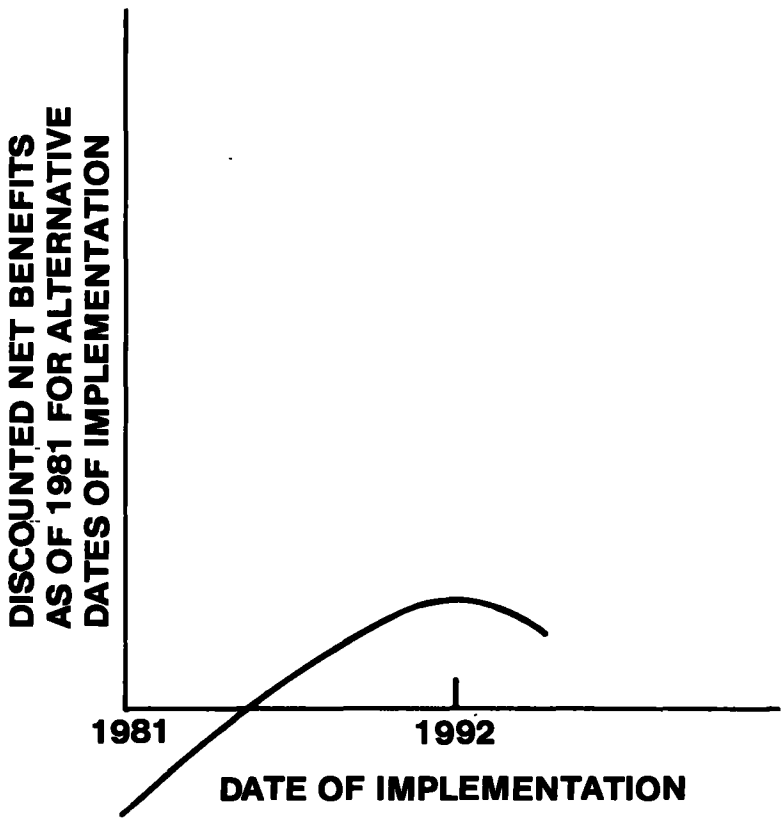
elsewhere. The scheduling question thus turns on whether the early losses from postponing a project (the benefits foregone) exceed the gains from postponing the project (the deferring of costs).

A net benefit function drawn on the assumption that some postponement of the project is worthwhile is shown in Figure 9-1. In this example, the optimal time of implementation of the project is 1992. The net benefit curve, which shows discounted net benefits as of the present of implementing the project at different times, declines after 1992. Postponement after that date would require foregoing project years during which the benefits of the project exceeded the gains of further postponement. (For complete system optimization alternative project sizes and their scheduling must also be studied). In this illustration a fascinating aspect of the scheduling criterion is brought out. If ordinary project evaluation procedures had been used, the worthwhile project for which net benefits are illustrated in Figure 9-1 would have been discarded entirely, since the present value of net benefits for immediate construction is shown as being less than zero (the benefit-cost ratio is less than 1). Using the scheduling criterion, on the other hand, the project would be included correctly in the recommended hydropower program. The introduction of scheduling considerations adds to the number of variables that must be examined in multi-objective planning. Fortunately, there are some situations in which simplified scheduling rules can reduce the complexity of scheduling problems; these are described by Marglin (1967, pp. 77-79).

The Current Status of the Scheduling Criterion

Scheduling is called for explicitly in the 1973 Principles and Standards (U.S. Water Resources Council, 1973, p. 24784) but to date this criterion has not been utilized in Federal water resources planning in the theoretically correct form. This may be because the description of scheduling in the Principles and Standards could also

FIGURE 9-1 HERE



NOTE: THE OPTIMAL DATE OF IMPLEMENTATION FOR THE PROJECT REPRESENTED IN FIGURE 9-1 IS 1992.

FIGURE 9-1: OPTIMAL SCHEDULING

be interpreted (incorrectly) to refer to the traditional procedure of "staging" projects to meet forecast output requirements (rather than to maximize net benefits).

Recommendations

The importance of rising alternative prices of energy over time, which have to be dealt with through relative price shift analysis, indicates that the implementation of the scheduling criterion will have a potentially important impact on the total size, design, and dates of implementation of hydropower projects in the United States over the next several decades. This impact will include in particular the retention in the choice set of worthwhile projects that under traditional procedures would show negative net benefits for immediate implementation, and which would be (incorrectly) removed from further consideration. The scheduling criterion should therefore be made a regular part of evaluation procedures for hydroelectric energy projects.

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Chapter 10: Evaluation of Non-Structural Measures

In this chapter the NED evaluation of non-structural measures is discussed. The sections of the chapter include: the definition of non-structural measures; the with and without principle applied to them; some aspects of evaluation; current guidance; and recommendations.

Definition of Non-Structural Measures

Perhaps surprisingly, there is no analytically precise, generally accepted definition of non-structural measures. The term has come into use as a kind of opposite to traditional large scale construction measures. (See, for example, U.S. Water Resources Council, 1980, p. 64393). In this usage the term indicates not measures that are strictly non-structural, but rather the range of measures for water resources that are other than certain large-scale, traditional construction options. Thus, the term might be taken to mean all measures other than, say, large dams and levees. Such measures would include various types of restrictions and pricing schemes, but would also include some measures that are in fact structural, such as insulation of houses.

Looked at from this point of view, non-structural measures relating to hydroelectric energy production include:

- insulation
- increased education
- pricing
- legal prohibitions
- load management
- changes in power plant operating schemes
- process and management efficiencies in the industrial, commercial, and household sectors
- system interties

There has been some empirical work done on non-structural measures relating to hydropower planning; see, for example, the study on water heater load management in U.S. Army Corps of Engineers (1980) and the references therein. (Some work has also been done on non-structural measures relating to flood control; see Johnson, 1978.)

The lack of analytic clarity in the common definition of non-structural, referring simply to measures other than traditional large-scale construction works, brings with it the possibility of misallocating planning resources, because it gives the incorrect impression that all such measures have something in common in terms of the details of evaluation. It would be better to replace the terms structural and non-structural simply with the injunction that in water resources planning the entire spectrum of measures should be considered (Major, 1980.)

In current usage, non-structural appears to relate not only to the measures described above but also to objectives. It appears that the emphasis on non-structural measures has related, in particular, to a preference by some participants in the water resources decision-making process for environmental quality. Non-structural measures might at first sight seem closely linked to environmental quality, at least as compared to structural measures. However, some structural measures might be very good for environmental quality, such as the installation of new turbines at a dam that would not degrade water quality but would avoid the necessity for thermal power elsewhere in the system. On the other hand, some non-structural measures might be considered to be quite bad for environmental quality; an example is the traditional non-structural measure of dredging, which has serious ecosystem impacts. From this point of view also the term is not analytically precise. Where objectives are important, they should be taken into account through standard multiobjective methods rather than through a presumed linkage between some objectives and certain measures for water resources development and management.

NED Evaluation of Non-structural Measures: The With and Without Principle

An essential factor in considering non-structural alternatives is the with and without principle. The non-structural alternatives that might be included in a given hydropower program, the with alternatives, are those that would not occur in the absence of the government program. Some non-structural measures (which ones will depend on the planning situation) will be undertaken whether or not the measures considered in hydropower programs are undertaken. Thus, the demand for energy has to be forecast taking into account the reasonably expected "without" measures. The alternatives to structural measures that are to be considered within the hydropower program are only those that would not be included in the "without" situation.

The idea is that larger forces, including energy prices and other matters, are likely to bring about non-structural measures independently of measures taken within the hydropower sector; and these measures have to be taken into account in forecasting demand for hydropower. Thus, the "without" situation is a forecast situation. In the past in electric energy analysis, it could be assumed that demands would grow fairly regularly, and the forecasting problem, although not straightforward, was easier because if demands did not grow on schedule they would grow later. In the present situation, demand forecasting is more complex because of the necessity to include forecasts about non-structural measures that previously could have been neglected. This can be expressed by saying that demands for energy appear to be more uncertain than in the past; this in turn requires a greater concern for hydropower programs that are likely to be good investments over a range of alternative futures.

NED Evaluation

The evaluation of each non-structural measure in terms of NED benefits and costs will depend on its particular characteristics. As an indication of the range of evaluation problems, several types of non-structural measures are given here, together with a description of the appropriate evaluation approach for each. These range from relatively straightforward alternative cost measures to more complex problems of direct benefit estimation; the same range, in fact, as for structural measures.

1. Energy saving proposals (industry)

Here it can be supposed that a proposal is made such that, in lieu of a certain portion of the energy required to maintain an industrial process at a given level, process or other changes (which may be structural) are substituted such that the given portion of energy is not consumed and the level of production is maintained.

Now if this proposal is privately profitable, it might be assumed that corporations would have implemented it whether or not a hydropower program is undertaken; and thus the energy saved must be deducted from demand forecasts. This will be an appropriate assumption in many cases. However, there will also be cases in which the proposal, although in fact privately profitable, had not previously been made known or made known sufficiently widely. In this case it might not be part of the without situation, and it can possibly be included in a government hydropower program. Another case is that in which a proposal is economically profitable, according to the government's NED criteria, but is not privately profitable according to financial criteria. In this case the program would only be implemented through subsidies or other incentives adopted as part of the government's general hydropower and energy program.

In the cases that are included in the "with" situation, evaluation from the NED standpoint is straightforward, given the assumptions. It is simply necessary to compare the costs of the non-structural measure with the costs of supplying the energy that would be required absent the proposed measure. This simplicity is possible because it is assumed that the level of output is maintained. If, contrary to the assumption, the output level is changed, the NED effects of this must be examined.

2. Energy saving proposals (consumers)

This case has the same characteristics as energy saving proposals for industry, and is also evaluated on a simple cost basis, provided that, first, target levels of consumption are maintained and, second, that consumers' satisfaction is a function only of those target levels. This latter assumption might well not hold in some cases of consumer behavior. Consider, as an example, the maintenance of a target temperature in a home of 68°. It can be assumed that this temperature can be maintained either with energy consumption or with a combination of energy consumption and additional insulation. However, it may well be that the level of 68° achieved with additional insulation may be stuffier than the level of 68° achieved without insulation, and that hence consumers' utilities will not be the same under both alternatives. In such a case the simple cost comparison will not suffice as a measure of NED benefits; some attention will have to be paid to direct willingness to pay measures.

3. Restrictions on demand (industry)

Here it can be supposed that coercive restrictions are placed on demand, e.g. at certain times of day, or on certain amounts of energy. The NED benefits of such measures are the resource savings of reduced energy generation. The costs are estimated in two parts. First, there is the net productivity loss that is engendered by the restrictions, which can be estimated by industry budget

studies (similar to farm budget studies). Second, there are the administrative and other costs associated with the development, implementation, and maintenance of the restrictions.

4. Restrictions on demand (consumers)

Here again coercive restrictions on energy demand are supposed, such as time-of-day or quantity restrictions. The imposition of these restrictions prevents consumers from maximizing given their preferences and budgets. The gains from such measures are the resource savings from reduced energy production. The NED losses from these restrictions include, in addition to the administrative, implementation, and maintenance costs, the losses in real income suffered by the consumers as a result of the restrictions. This case may therefore be one of the most difficult in practice, since estimating these losses requires the examination of consumers' demand functions.

5. Pricing policies

Many pricing policies are available. Consider the case in which a scheme for differential time-of-day pricing is compared to, say, a current system in which energy prices per unit are the same at all times of day. The evaluation of this pricing scheme requires the estimation of the changes in benefits from energy supplied, which will require both industry budget studies and consumer demand curve analysis; the estimation of energy production cost changes and the estimation of the costs of devising, implementing, and maintaining the scheme. (Pricing schemes will as a rule have distributive consequences among groups of users, the taxpayers at large, and the stockholders of utility companies, but these distributive consequences are outside of the realm of strict NED analysis; they have to be studied, if at all, in a multiobjective context).

Current Guidance

The 1980 Level C Principles and Standards require the consideration of a primarily nonstructural plan when structural plans are considered (U.S. Water Resources Council, 1980, p. 64387); this injunction applies to hydropower. The hydropower section of the 1979 manual requires, correctly, that the without project condition should include "the effects of implementing all reasonably expected nonstructural and conservation measures, including those required or encouraged by Federal, State, and local policies." With-project nonstructural measures are to be evaluated with the alternative cost measure except for "load-altering measures," (revised rate structures are cited as an example) for which "attempts to measure ... benefits... on the basis of direct willingness to pay are encouraged, although the display of such benefits is not required." (U.S. Water Resources Council, 1979 p. 72938; see also p. 72941) (As indicated by the household temperature example given above, willingness to pay measures can be required for non-load-altering situations also, a case not addressed in the manual). No further guidance on particular cases and situations is given.

Recommendations

The current situation with respect to non-structural measures is thus that they must be considered, but that inadequate guidance is given for this consideration. Guidelines for individual project evaluation should be developed based on NED Principles and the available examples of non-structural evaluation at the field level. Near-term broad planning efforts can deal with non-structural elements in two ways: first, through the use of load forecasts that take into account the "without" elements; and second, for "with" elements, through the use of sensitivity analysis, including switching value methods, to bound the decision problem.

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Chapter 11: Multiobjective Aspects of Hydropower Evaluation

In earlier chapters economic evaluation criteria for hydropower have been examined. In this chapter multiobjective aspects of hydropower evaluation are described. Multiobjective analysis is a generalization of traditional benefit-cost analysis. The latter focusses on the economic aspects of evaluation, whereas multiobjective analysis emphasizes the design of projects and programs in terms of all relevant objectives: environmental, social, regional, and other, including the economic objective. This chapter includes first a description of multiobjective analysis; then a description of the current status of this analysis in Federal regulations; an assessment of needed extensions to permit adequate multiobjective evaluation of hydropower projects; and recommendations.

Multiobjective Analysis

The economic analysis dealt with elsewhere in this report embodies the optimization of a single dimension of social welfare, net economic gains to the nation as a whole (the national income or NED objective). This objective is the traditional objective of benefit-cost analysis. This approach omits the consideration of a range of other objectives that are of social value and which are not, as a general matter, adequately captured by the national income objective. These objectives are many, including regional objectives, income distribution objectives, environmental quality objectives, international objectives, and others. Their importance in project evaluation arises from the fact that, in general, the attainment of one objective does not necessarily result in the attainment of other objectives; as a consequence, trade-offs among objectives are required as part of social decision-making. Thus, for hydropower, as for other purposes, multiobjective analysis is required for correct project and program design. The theoretical basis of multiobjective analysis, and some details of its

application, can be found in Maass et al., (1962); Marglin (1967); United Nations Industrial Development Organization (1972); Major (1977) and Cohon (1979).

The theory of multiobjective planning can be explained in terms of Figure 11-1. It is assumed that a hydropower program is to be formulated that is responsive to two objectives: increasing national income, and reducing imports of oil. Reducing the level of oil imports might be taken as an objective, apart from the national income effects (which are included in the national income account) of changing oil imports, for foreign policy or other reasons. Other objectives could be used to demonstrate the approach, and more than two objectives could be used; the analysis is restricted to two here for convenience in graphical exposition. In Figure 11-1, contributions to the national income objective are measured in dollars along the vertical axis. These are the willingness to pay contributions described in chapter 2. They are measured on a net basis, and they are discounted to reflect the necessity of comparing benefits and costs that occur in different time periods. Contributions to the objective of reducing oil imports are measured along the horizontal axis in an appropriate physical unit such as million barrels per day. These contributions are also net, and they are discounted, reflecting the need to compare import reductions made in different years (see ch. 8 on interest rates).

In principle, every alternative hydropower program will make contributions, positive or negative, to the two objectives, and these contributions can be displayed in the graph. (The graph thus depicts what is called "net benefit space.") For example, a program with positive contributions to both objectives will be represented by a point in the northeast quadrant; and a program with negative contributions to both objectives will be represented by a point in the southwest quadrant. In multiobjective planning planners will examine various alternative possible programs and will estimate and display the contributions of these to different objectives. There will be, in general, very many alternative possible programs, each represented by a point in net benefit space. If it is assumed that

FIGURE 11-1 HERE

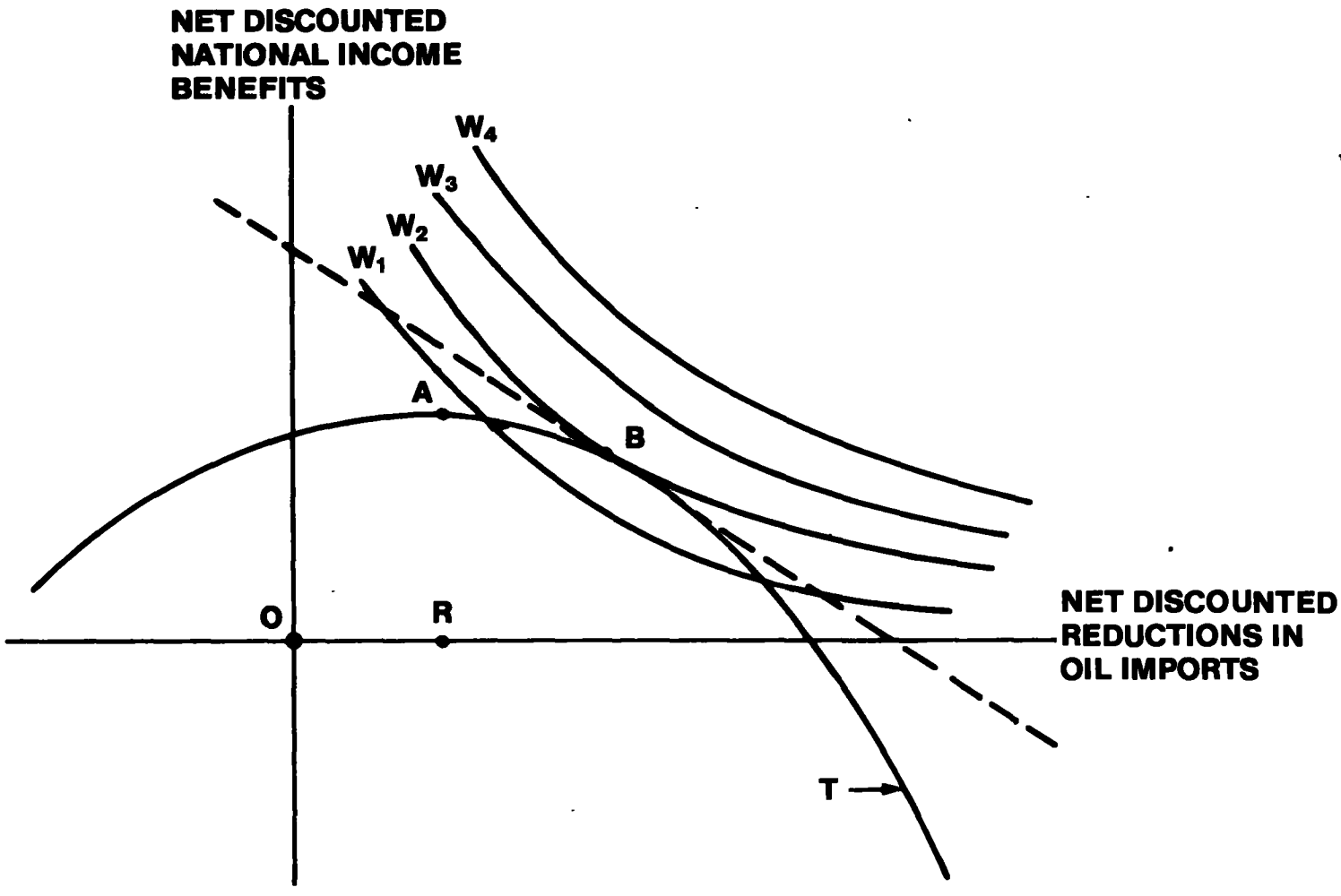

FIGURE 11-1: MULTIOBJECTIVE PLANNING

all such points for a particular problem are estimated, the aggregate of such points in net benefit space is called the "feasible set." Planning with respect to hydropower then consists of choosing the feasible point that contributes most to the overall welfare of society, where welfare is measured by degree of contribution to the two objectives that have been assumed to define the problem. The boundary of the feasible set can also be plotted; this is shown as T in Figure 11-1 and is called the "net benefit transformation curve."

If it can be assumed that from society's point of view more net benefits toward each objective are better than fewer net benefits, it is not necessary to consider all points in the feasible set. Rather, the search for the best net benefit combination will be restricted to points on the net benefit transformation curve where this slopes from northwest to southeast. This is because, if more is better than less (and absent budget constraints: see Major, 1977, pp. 43-47), every interior point of the feasible set will be dominated by at least one point on the boundary which will provide both more net national income and more net reductions in oil imports. Similarly, every point on the net benefit transformation curve where it does not slope from northwest to southeast will be dominated in terms of contributions to both objectives by at least one point on that part of the curve. The choice of the optimal point in the feasible set thus comes down to the choice of the point on the boundary where it slopes from northwest to southeast that yields the combination of contributions to the objectives most preferred by society.

The most general way of considering this choice theoretically is to assume that society, through a political process, has been able to rank in order of merit the different points in net benefit space. These rankings, which are together called the social welfare function, are represented in Figure 11-1 by the curves W_1, W_2... etc. Each of these curves is the locus of all net benefit combinations that yield a certain level of social welfare. Thus,

for example, on curve W_1, movement from northwest to southeast involves sacrificing some national income benefits in order to obtain greater reductions in oil imports, thus maintaining social welfare at a constant level. On the principle that more is better than less, curves to the northeast represent successively higher levels of social welfare. The problem of choosing the optimal hydropower program is thus to find that point on the net benefit transformation curve that is tangent to the highest attainable social welfare curve. In Figure 11-1, this is point B, which represents a program that provides a mix of contributions both to national income and to reducing oil imports. While to be sure the point shown is determined by the way the curves in the example were chosen, it is clear that as a general matter the result of multiobjective analysis will seldom be to choose a point that represents the maximization of a single objective. Such a point is A in Figure 11-1, which maximizes contributions to the national income objective and is the point that would be chosen if traditional economic benefit-cost analysis had been applied to the problem shown.

(The dotted line tangent to the net benefit curve at B is of interest both theoretically and in applied multiobjective planning. The negative of its slope is the value that society places on the marginal reduction of oil imports as compared to the marginal dollar of net national income obtained. It is the "price" that society places on the attainment, at the margin, of a unit of one type of benefit in terms of a unit of another type.)

Current Status of Multiobjective Analysis for Hydropower

Multiobjective analysis is the theoretical basis for the current Principles and Standards of the United States Water Resources Council (U.S. Water Resources Council, 1973, 1980) for all project purposes, including hydropower. Four objectives are considered: national income (national economic development or NED);

environmental quality (EQ); regional development (RD); and social well-being (SWB). (In United States Water Resources Council, 1980, the last two accounts are the regional economic development (RED) and other social effects (OSE) accounts.) A distinction is made between the first two objectives, for which projects may be designed, and the second two objectives, the impacts on which of projects designed for the first two objectives may be displayed. However, projects may not be normally designed in terms of the second two objectives.

This current use of multiobjectives has two important limitations relevant to hydropower analysis. First, the restriction of the principles to four objectives omits some objectives that are relevant to hydropower and that therefore should be taken into account in hydropower planning. The effect of omitting objectives that are relevant can be seen by referring to Figure 11-1. The objective of reducing oil imports is not currently a permitted objective. Thus, if planners design hydropower projects and programs on the basis of the current standards, the information on the horizontal axis, which is evidently of importance to project and program design, cannot be either developed or considered in planning. In the example given, benefits toward the oil import reduction objective from hydropower programs, to the extent that they existed, would be coincidental rather than planned; and in any case planners would not be permitted to estimate their magnitude.

The second limitation is the distinction between design and display objectives. The effect of this can also be seen by referring to Figure 11-1. If, in the example given there, only the NED objective were permitted as a design objective, and the oil import objective were permitted only as a display objective, then the hydropower program would have to be developed only with respect to the NED objective, and the recommended program would have to be the program at point A that maximizes NED benefits. The information about the impact of this program on oil imports, i.e., that these

would be reduced by the discounted amount represented by the distance OR on the horizontal axis, could be displayed and possibly taken into account in decision-making; but planners would normally be prohibited from formulating the optimal program at B. The distinction between design and display objectives is thus, like the omission of objectives, inimical to the proper formulation of hydropower projects and programs.

Needed Extensions for Hydropower Evaluation

It follows from the above that two principal ways in which the current Principles and Standards should be extended in order to make them fully suitable for the multiobjective analysis of hydropower projects are with respect to the range of permitted objectives, and with respect to the design/display distinction.

With respect to the range of permitted objectives, the current set of objectives does not include certain new objectives that are likely to be important for the multiobjective analysis of hydropower projects. These objectives include, but are not limited to, freedom from dependence on foreign energy sources, balance of trade objectives, and the local control and management of energy sources, an objective likely to be of importance particularly with respect to small hydro projects. Provision should be made for the inclusion of these objectives, and other new objectives as they arise, in project analysis.

The second extension of the current standards needed to insure that new objectives are fully taken into account in hydropower evaluation is to make all objectives design rather than display objectives. While, as suggested above, the distinction between design and display objectives is not a suitable distinction in any case, it is particularly inappropriate where the new objectives might have very substantial impacts on design, as an objective such as freedom from dependence on foreign energy sources might have.

In addition to the two extensions just described the current Principles and Standards ought to be expanded for the multiobjective analysis of hydropower (as well as all other purposes) with respect to interest rates. Full multiobjective analysis requires interest rates for each objective; the current standards incorporate only the interest rate for the NED account (see ch. 8) based on government borrowing rates. Effects on other objectives, including the EQ objective, are simply displayed with their times of occurrence; thus, the interest rates (intertemporal prices) for these objectives are determined implicitly in the process of project selection. Multiobjective analysis can be done more efficiently and effectively by using multiobjective interest rates explicitly, perhaps on a trial or sensitivity basis. (Interest rates for objectives other than national income (NED) are discussed in Marglin, 1967, pp. 67-69; see also Major, 1977, p. 37.)

Finally, with respect to benefit-cost criteria generally, it should be said that these all require adaptation from their traditional economic form for full use in multiobjective evaluation for hydropower and for other purposes. A simple example of such an extension is the extension of the alternative cost rule, for a particular range of assumptions, to multiobjectives (Major, 1977, pp. 35-36).

Recommendations

Current Federal standards restrict the application of multiobjective analysis in ways that adversely affect the proper formulation of hydropower projects and programs. Two principal changes are required to correct this situation. First, the range of evaluation objectives should be expanded to encompass all national objectives relevant to the evaluation of hydropower projects, including energy independence objectives. Second, the current distinction between design and display objectives should be abandoned, and all legitimate objectives should be design objectives.

References to Chapter 11

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