E4973

1 MF

Distr.
LIMITED

ID/WG.150/6
23 February 1973

ORIGINAL: ENGLISH

United Nations Industrial Development Organization

Expert Group Meeting on Uses of
National Investment Criteria for
Industrial Project Analysis
Washington, D.C., 28-30 March 1973

Economic Appraisal of an Investment Project in a Developing Nation [1/]

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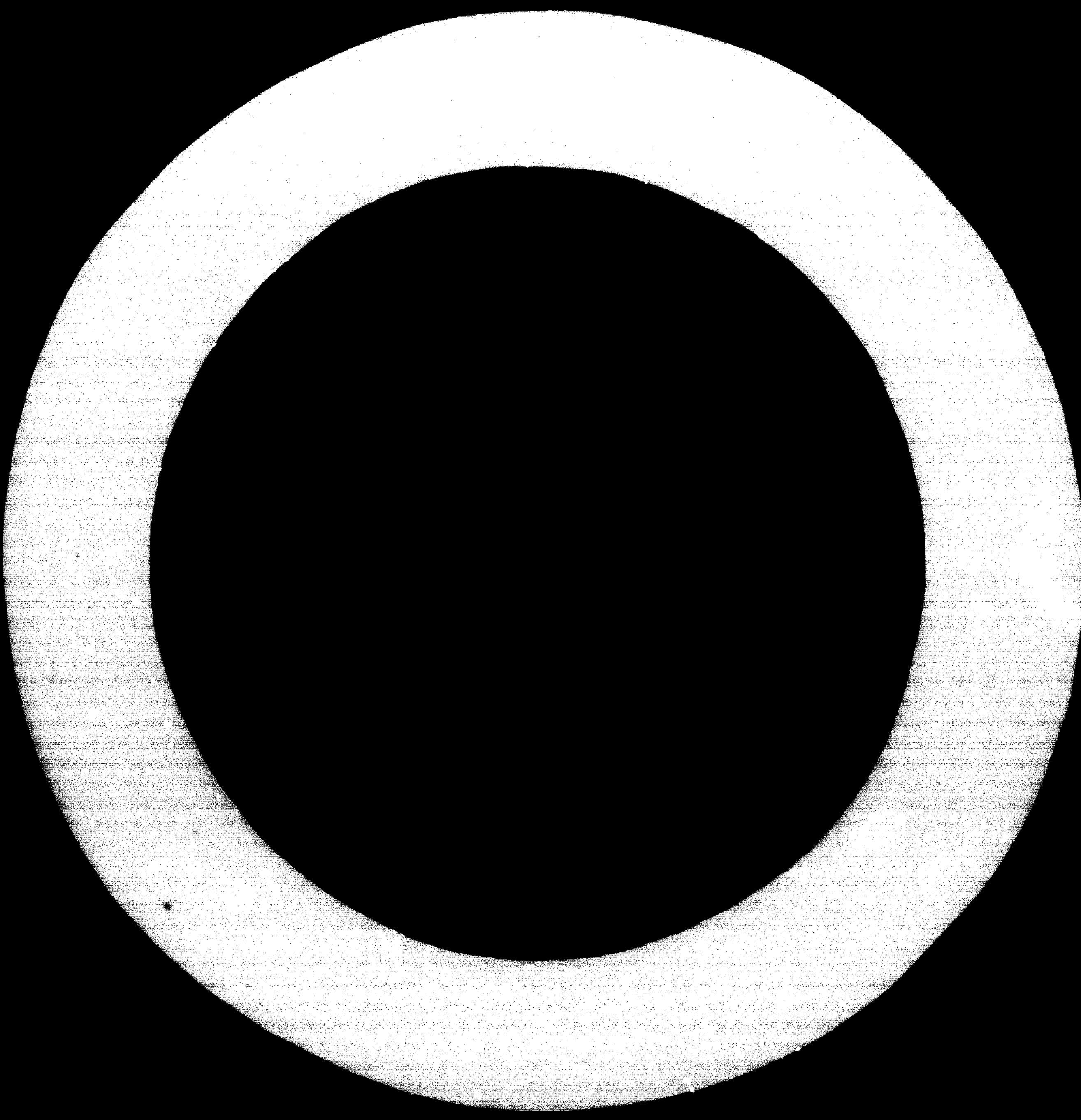
id. 73-1188



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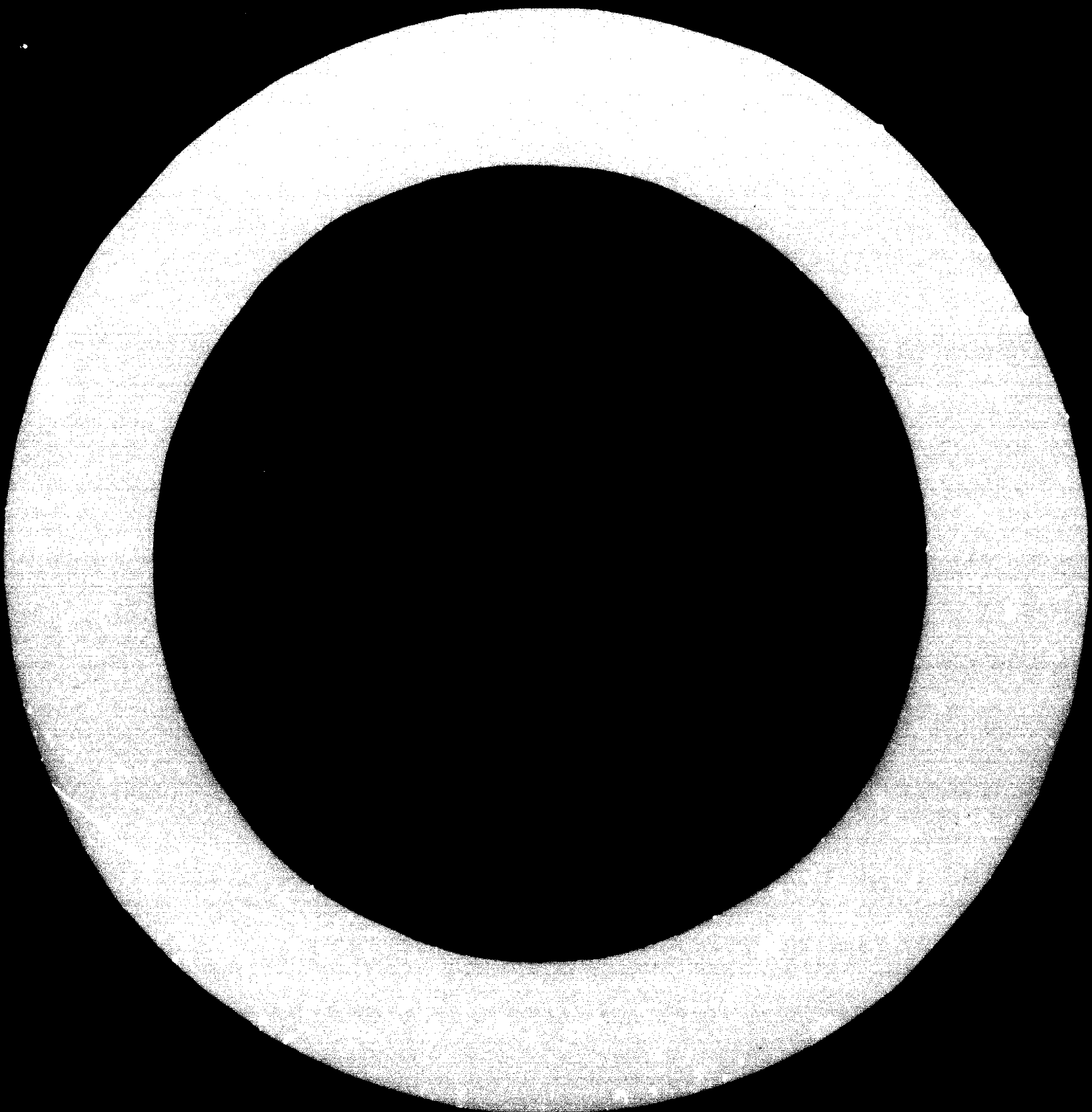

Economic Appraisal of an Investment Project in a Developing Nation

1. Introduction

Governments of developing nations have often received technical help in making economic appraisals of complex systems from economists and engineers of developed countries. In most cases, however, these experts have not properly adjusted their planning and economic evaluation techniques to the special economic and social characteristics of developing countries. For example, the traditional concept of benefit-cost analysis, which is developed for evaluation of public projects such as transportation and water resources development in the United States, is often used for appraisal of public projects in developing nations of Asia, Africa and Latin America. It is only within the last few years that the need for new techniques of engineering-economic analysis, within the context of developing nations, has been realized. The UNIDO Guidelines for Project Evaluation, I believe, is a significant contribution in the field of project formulation and appraisal.[1/]

The framework of the synthesized criterion in the Guidelines is the concept of benefit-cost analysis. However, modifications are carried out so that national goals and important economic characteristics of developing countries are reflected in the decision-making criterion, for example, there exists various types of structural disequilibrium such as a high rate of unemployment and underemployment at the going market wage, shortage of hard foreign currency at

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1/ UNIDO, Guidelines for Project Evaluation, United Nations, New York, 1972.

established exchange rates, and scarcity of investment capital at market interest rate. These are taken into account in the appraisal of a project by introducing concepts such as social rate of discount, the social opportunity cost of capital and the shadow prices for production factors and products.

In developing nations, the most important national goal is the achievement of a high rate of economic growth. The rate of capital accumulation directly influences the rate of economic growth. Project appraisal, therefore, should take into account the dynamic aspects of economic growth by reflecting the effect of a public investment project upon the rate of future saving and investment by private sectors of the economy and by public agencies. The Guidelines indirectly treats this problem by introducing the possibility of the reinvestment of some portion of net benefits.

2. A Modified Criterion

I formulated an economic appraisal criterion while at the University of California, Berkeley during 1965-1967.2/ I had the benefit of attending lectures by Professor A.K. Sen while he was teaching a course on economic development at UC Berkeley. At the same time I was introduced to the writings of Professor Stephen Marglin on the opportunity cost of public investment, the social rate of discount and optimal rates of investment.3/4/ The criterion formulated is, therefore, very similar to the one in the Guidelines.

2/ Mobasheri, Fereidoun, Economic Evaluation of a Water Resources Development Project in a Developing Nation, University of California, Berkeley, Water Resource Center, Contribution No. 126, July 1968.

3/ Marglin, S., "The Opportunity Cost of Public Investment", Quarterly Journal of Economics, May 1963, pp. 274-289.

4/ Marglin, S., "The Social Rate of Discount and Optimal Rates of Investment", Quarterly Journal of Economics, February 1963, pp. 95-111.

Appendix A shows the detail formulation of this modified criterion. The social rate of discount, the social opportunity cost of capital, the effects of the operation of a public project upon capital accumulation, and finally shadow prices of unskilled labour and foreign exchange are introduced to the appraisal of the project.

The social rate of discount is used to discount the future benefits. The question is, what should be the value of the social rate of discount. Dobb states that:

> clearly, for planning purposes we are interested in tomorrow's satisfaction as such, not in today's assessment of tomorrow's satisfaction. To discount later enjoyment in comparison with earlier ones is a practice which is ethically indefensible and arises merely from the weakness of imagination.5/

Sen presents the same idea by writing that:

> a distant object looks smaller, we tend to value a unit of consumption in the future less than we value the same now. However, if the difference is only due to the distance in time, then the position is symmetrical. A future object looks less important now, and similarily, a present object will look less important in the future. While it is true that the decision has to be taken now, there is no necessary reason why today's discount of tomorrow should be used and not tomorrow's discount of today.6/

In fact, if there was no economic growth and stagnation were prevailing, then there are good reasons to set the social rate of discount equal to zero. Further, if the rate of the population growth were larger than the rate of the growth of national product, a situation where income per capita is decreasing over time, then a negative social rate of discount will be permissible. However, in most cases because of economic development, the income per capita in the future is likely to be greater than it is at the present time. It is reasonable, therefore, to have a positive social rate of discount. The recommended

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5/ Dobb, Maurice, <u>An Essay of Economic Growth and Planning</u>, Monthly Review Press, New York, 1960.

6/ Sen, A.K., "On Optimizing the Rate of Saving", <u>Economic Journal</u>, Vol. LXXI, September 1961, pp. 433-448.

equation by the Guidelines is:

i = (Elasticity of marginal utility) x (Rate of growth of per capita consumption)

or, using the symbols E and G for the elasticity and the rate of growth,

$$i = -EG$$

The elasticity of marginal utility is said to reflect normative judgements with respect to the rate at which the marginal utility of consumption declines as the level of consumption increases. In my opinion, however, the value for E should be set at minus one. This means the social significance of extra consumption should decline one per cent with each one per cent increase in average consumption. This would mean there is no systematic preference for present over future and social time preference is perfectly symmetrical between present and future. The equation for the social rate of discount will be simply:

$$i = G.$$

Discount rate has perhaps the most important influence on the economic feasibility of a project. For example, for the projects authorized in 1962 for the Corps of Engineers in the United States, an interest rate of 2 5/8 was generally applied. However, if rates of 4, 6 and 8 per cent had been used, the following percentages of the initial gross investment by the corps would have had negative present values 9, 64 and 80 per cent, respectively.[7] In my opinion, to base the determination of the elasticity of marginal utility on the value judgement of the planners means to set an arbitrary value for the social rate of discount. I am not sure that the international lending agencies will accept a discount rate determined by the value judgement of the planners of the developing countries.

7/ Fox, Irving and Orris Herfindahl, "Attainment of Efficiency in Satisfying Demands for Water Resources", American Economic Review, Vol. LIV, No. 3, May 1964, pp. 198-206.

Both the social rate of discount and the social opportunity cost
of capital must be specified for the economic evaluation of public
projects. The social opportunity cost of capital should reflect the
opportunity and benefits which will not be realized because of
investing the capital in the project under consideration. In other
words, investment by the government involves the allocation of
current resources which have alternative uses. These resources are
collected from the private sector of the economy. Government
investment, therefore, will lead to a reduction of the present
level of consumption, to a decline in private investment, or both.
To calculate the social opportunity cost of public investment, it
becomes necessary, therefore, to find the actual structure of
capital flow in the economy and to estimate what value is attached
to capital by various segments of the private sector. In fact,
an empirical investigation must be carried out to determine the
source of tax money which provides capital for public investment
and to discover the value of the money in the use to which it would
be put in the absence of public investment projects. Such a study
has been carried out by Krutilla and Eckstein to estimate the social
opportunity cost of capital used by the Federal Government of the
United States in development of water resources projects.8/ Two
alternative models were studied. In the first model, the rate of
personal income tax, in the second model the rate of personal
income tax of upper-income brackets and the rate of corporation
income tax were reduced.

In Chapter 14 of the *Guidelines* several models are discussed
for the measurement of the *social opportunity cost of capital*. A
realistic model, in my opinion, should take into consideration that
the rate of return on capital is different for the various economic
sectors. Therefore, to calculate the social opportunity cost of
capital a general economic model with several economic sectors may
be necessary. A simple multi-sector model is presented in Appendix B

8/ Krutilla, John and Otto Eckstein, *Multiple Purpose River Developments*, The John Hopkins Press, Baltimore, 1958, pp. 7[illegible]-1[illegible]0.

that may be useful in calculation of the social opportunity cost of capital.

In a traditional benefit-cost analysis a project is economical if benefits to whomsoever they may occur are in excess of the estimated costs. The behavior of the benefit recipients with respect to saving and consumption are not taken into consideration. The amount of subsequent savings and investments by the recipients of the benefits from the operation of a public project does not enter into the economic evaluation of a project. However, an investment criterion should take explicit cognizance of the influence of a public investment project on the rate of capital accumulation. Furthermore, pricing policy and therefore revenue received from the operation of a public project usually is considered in the financial analysis and does not enter the economic feasibility analysis of a project. However, if reinvestment of a portion of returns to the government from the operation of the project is a possibility, then pricing policy for the project products should influence the economic analysis. Therefore, the subsequent allocation of the income generated by the development of a public project are introduced in Appendix A for the formulation of the modified criterion.

The data requirements for the application of the Guidelines or the modified criterion in Appendix A may seem prohibitive for countries where even the use of the traditional benefit-cost analysis requires a great number of approximations and assumptions. Of course, the use of sophisticated economic appraisal models for keeping up to date with the latest developments of the art and theory, is not justifiable if inadequate data will make the results unreliable. As King, reviewing methods of project appraisal, states that a "healthy skepticism is a cardinal virture",[9] he goes on to say the World Bank considers that:

9/ King, Jr., John A, Economic Development Projects and Their Appraisal, The John Hopkins Press, Baltimore, 1967.

> This scepticism must be applied to the economic, technical, institutional and financial aspects of the project appraisal, beginning with a questioning of the basic statistical data to make sure that a false sense of accuracy has not been reached through the application of sophisticated techniques of analysis to questionable basic data.

To find out the difficulties that may arise because of inadequate data the criterion formulated in Appendix A was applied to study the economic feasibility of a water resource project in Guatemala.10/ The Government of Guatemala is considering the development of land and water resources in an area of about 1400 square kilometers located in the northern part of the country. Preliminary studies show possibilities for multipurpose water resources development projects to generate hydro-power and to obtain water for municipal and agricultural purposes. One of the sites available is El Jocote on the Chixoy River. Some 50 kilometers to the north of El Jocote there are approximately 42,800 hectares of land with moderate suitability for irrigation. Physical conditions would allow the building of a dam with a maximum height of 240 meters. An additional 180 meters of fixed head could be obtained by a tunnel of 9.75 kilometers.

The data requirements of the criterion in Appendix A appear more formidable than they really are. When applied to the El Jocote project, for example, the only real difficulty encountered was in the evaluation of the social opportunity cost of the capital. Although it was considered that data to evaluate this parameter was included in several economic reports, it was concluded that the computation and measurements of parameters and data used in the modified criterion are possible with a moderate effort by the economic planners at the national level and the engineers at the project level.

10/ Garcia-Martinez, Luis Ernesto, The Effect of Data Limitations on the Application of Systems Analysis to Water Resources Planning in Developing Countries, Water Management Technical Report No. 7, Engineering Research Center, Colorado State University, May 1971.

3. Limitations of the New Criteria

As Professor Marglin has stated correctly, the major limitation of the *Guidelines* is that it deals with the tactics of development, not basic strategy.11/ This limitation also applies to the criterion formulated in Appendix A. This means that these criteria should be used for the economic evaluation of projects and comparisons of alternatives that fall within a single economic sector. Furthermore, as far as project feasibility analysis goes, these new criteria have three types of limitations that may be important. They are:

3.1 Secondary Benefits

Secondary or indirect benefits are defined as the increase in net income as a result of activities stemming from or induced by the project. These benefits are not included in the new criteria. There is a great deal of controversy with regard to their inclusion in the project appraisal. It has been argued that the available methods to measure secondary benefits are such that they offer ample opportunities for abuse. However, in developing countries the importance of the secondary benefits can not be neglected. Explicit recognition should be given to the fact that all activities in an economy are interrelated so that effect of a large project will eventually affect other projects, at least to some degree. Input-output analysis can be useful to trace secondary benefits of large projects.

3.2 Project Timing

The question of optimal timing of investment does not receive enough attention in the *Guidelines*. For a regional and national planning to be effective, the one-at-a-time project analysis should

11/ Marglin, Stephen A., "The Essentials of the UNIDO Approach to Benefit-Cost Analysis: An Introduction to the *Guidelines for Project Evaluation*", August 1972, unpublished paper.

be replaced by the analysis of a long-range plan of sequential development. When alternate sources of supply are considered, all too often they are treated as mutually exclusive and competitive alternatives. Each project is assessed independently and the relative merits are usually compared on an average unit-cost basis.[12] Therefore, reinforcing characteristics are often ignored. For example, a ten-year life desalinization plant with high average unit cost combined with a ten-year deferral of a large dam with lower average unit cost can be a more economical way to meet an increasing demand. Capacity expansion models developed by Manne[13] and Kendrick[14] are useful in answering the question of when, where and how much to invest for the expansion of an industry.

3.3 Environmental Impact

In developing countries planning objectives usually are:

- to increase national income;
- to improve employment situation;
- to achieve and to maintain balance of payments equilibrium;
- to achieve and maintain price stability;
- to obtain a more equal distribution of income among individuals;
- to obtain a balance regional economic development.

The Guidelines introduces most of these objectives into the economic evaluation criterion.

A new objective which may become significant in the very near future is the preservation of the environmental aspects of the nation. It may become necessary to study in detail the beneficial and adverse effects of a proposed project on the environmental characteristics of an area.

12/ Hall, Warren A. and John A. Dracup, Water Resrouces Systems Engineering, MacGraw-Hill, 1970, Chapter on Water Resource Investment Timing.

13/ Manne, A.S., Investment for Capacity Expansion, George Allen and Unwin Ltd., London, 1967.

14/ Kendrik, D., Programming Investment in the Process Industry, Massachusetts Institute of Technology Press, Cambridge, Massachusetts, 1967.

In the United States environmental impact studies are becoming mandatory in the economic evaluation of water resources projects. Techniques are being formulated to include environmental objectives in multiple-objective planning of water resources development.[15] Review of these proposed principles and standards for possible future use may be valuable.

15/ Water Resources Council, Proposed Principles and Standards for Planning Water and Related Land Resources, 1971.

APPENDIX A

A Modified Criterion[16]

In a traditional benefit-cost analysis, the criterion function is usually written as

$$\max Z = \sum_{t=1}^{T} \frac{b_{ty} - O_{ty}}{(1+i)^t} - C_y \qquad (1)$$

where Z is the present net value of benefit, y is the scale of development, b_{ty} is benefit at period t for scale y, C_y is the initial investment for scale y, O_{ty} is the operation and maintenance cost at period t for scale y, i is the interest rate and T is the economic life of the project. The objective is to find the optimum feasible scale which is a scale that maximizes the present value of net return.

If $\sum_{t=1}^{T} \frac{b_{ty} - O_{ty}}{(1+i)^t}$ is denoted by B_y, then to maximize Z the following condition must be satisfied:

$$\frac{dB_y}{dy} - \frac{dC_y}{dy} = 0 \quad \text{or} \quad \frac{\frac{dB_y}{dy}}{\frac{dC_y}{dy}} = 1.0 \qquad (2)$$

which means the marginal benefit-cost ratio must be equal to unity.

Introducing social rate of discount and the social opportunity cost of capital into economic evaluation of a project, equation (1)

16/ This appendix is based on "A Criterion for Appraisal of Economic Development Projects", Fereidoun Mobasheri, The Engineering Economist, Vol. 15, No. 1, pp. 9-27, 1969.

becomes

$$\max Z = \sum_{t=1}^{T} \frac{b_{ty} - c_{ty}}{(1+r)^t} - \theta_g C_y \qquad . \qquad (3)$$

where r is social rate of discount and θ_g the social opportunity cost of capital per dollar of investment. The condition for maximization of present value of net benefit becomes

$$\frac{dB_y}{dy} - \theta_g \frac{dC_y}{dy} = 0 \text{ or } \frac{\frac{dB_y}{dy}}{\frac{dC_y}{dy}} = \theta_g \qquad (4)$$

Assume that the total benefit from a project is distributed among n sectors of the economy, where b_{ity} is the benefit, before payment to the government for products or services received from the project, to sector i at period t when the project under consideration is developed at scale y. Assume, further, that P_i is the per cent of b_{ity} paid to the government by sector i for products and services from the project where P_i does not change over time and is independent of the scale of development. With these assumptions, sector i receives a net additional income of $(1-P_i)b_{ity}$ at period t when the public project is developed at scale y. The portion of this additional income that will be saved and reinvested is

$$[1 - (1 - \mu_i)n_i] \qquad (5)$$

where:

n_i = income elasticity of demand for consumption goods, in sector i;

μ_i = average propensity to save, in sector i;

$1 - \mu$ = average propensity to consume, in sector.

Therefore, $[(1 - \mu_i)n_i](1 - P_i)b_{ity}$ and $[1 - (1 - \mu_i)n_i](1 - P_i)b_{ity}$ are, respectively, additions to consumption and to investment in sector i at period t when the public project is developed at scale y. If the yield from investment in sector i is in perpetuity with a continuous throw-off at annual rate of p_i per cent of the amount invested then the social value of the net additional income received by sector i at period t at scale of development y is

$$V_{ity} = [(1 - \mu_i)n_i](1 - P_i)b_{ity} + \frac{p_i}{r}[1 - (1 - \mu_i)n_i](1 - P_i)b_{ity} \quad (6)$$

where r is the social rate of discount and the assumption is made that all throw-off from investment is consumed.

The first term on the right side of this equation shows the value of additional consumption to sector i, while the second term reflects the social value of investment made by sector i because of the operation of the public project. The sum of net benefits received by n sectors is then

$$\sum_{i=1}^{n} V_{ity} = \sum_{i=1}^{n} (1 - \mu_i)n_i(1 - P_i)b_{ity}$$

$$+ \sum_{i=1}^{n} \frac{p_i}{r}[1 - (1 - \mu_i)n_i](1 - P_i)b_{ity} \quad (7)$$

In most economic studies pricing policy and therefore revenue received from the operation of a public project is not considered in the economic evaluation of projects. This would be correct if the productivity of capital in various sectors, social rate of discount, and the social rate of opportunity cost of capital in the government sector were all equal. However, it has been shown that these rates differ. Therefore, financial returns from public projects should enter the economic evaluation of the project, especially if reinvestment of a portion of returns from the project is a possibility. As states previously, government receives a payment of $P_i b_{ity}$ from sector i at time t when scale of development is y. The government revenue from the project is then

$$\sum_{i=1}^{n} P_i b_{ity} \qquad (8)$$

If O_{ty} is the operation, maintenance and replacement cost of the project at time period t and scale of development y, then the net government revenue at time t scale y is

$$\sum_{i=1}^{n} P_i b_{ity} - O_{ty} \qquad (9)$$

where each dollar of this net revenue has a social value of θ_g, the social opportunity cost of capital. Using equations (3), (7) and (9), the criterion function becomes

$$\max Z = \sum_{t=1}^{T} \left[\sum_{i=1}^{n} [(1 - \mu_i) r_i](1 - P_i) b_{ity} \right.$$

$$\left. + \sum_{i=1}^{n} \frac{\rho_i}{r} [1 - (1 - \mu_i) r_i](1 - P_i) b_{ity} \right] \left(\frac{1}{1+r}\right)^t$$

$$+ \sum_{t=1}^{T} \theta_g \left[\sum_{i=1}^{n} P_i b_{ity} - O_{ty} \right] \left(\frac{1}{1+r}\right)^t - \theta_g C_y \qquad (10)$$

This equation not only takes into account the time flow of benefits and costs at a different scale of development, but it also reflects the influence of the development of a project upon national capital accumulation during the initial construction and the operational phase of the project. This is done by introducing social opportunity cost of capital and reinvestment of some portion of benefits into the economic evaluation criterion.

It is clear that if the productivity of capital in all economic sectors were the same and equal to the social rate of discount (i.e., if the economy were operating at its equilibrium state under pure competition), then equation (10) would become simply equation (1), which represents the present value of benefits in a traditional benefit-cost analysis.

In recent years, surplus underemployed and also seasonal unemployed labourers have been mobilized in various countries for the construction of public works such as irrigation networks and transportation systems. The social cost of employing these labourers will be less than the actual wage payments. If the total wage payments for unskilled labourers employed in the construction is g per cent of the total cost of the project, then the social cost of the project would be

$$\theta_g(1 - t_y)C_y + \frac{SL}{ML}(t_y C_y)$$

where SL/ML is the ratio of the shadow wage of an unskilled labourer (11) to the market wage rate for an unskilled construction worker.

The effects of an investment project upon balance of payments may be divided into effects during two separate periods: construction and operation. In the construction period the investment will have, in all cases, a direct negative effect on balance of payments since most underdeveloped countries have to import most of their capital goods, machinery and equipment. In the operational period there will be negative and positive effects. To analyze operation effects of the project on the balance of payments it is important to know the types of commodities produced by the project. These commodities may be grouped into two categories:

1) Products that increase exports, or are a substitute for imports;

2) Products that go to increased domestic use, or to replace goods previously produced and consumed domestically.

The first group has a direct positive effect upon balance of payments while the second does not influence foreign trade. If project products are intermediate producer goods, then there will be associated costs to recipients of these intermediate goods before final products are made. For example, in a water resource project, farmers who are going to receive irrigation water have to purchase additional equipment, chemicals, seeds, etc. Therefore, to find the effect of the project upon balance of payments it becomes necessary to estimate the portion of operation costs of the project itself and to portion of the associated costs of benefit recipients that are in foreign exchanges. It would seem that the algebraic total of these effects during project construction and operation will represent the project's effect on the balance of payments. However, in some cases other secondary effects should also be included in the analysis. For example, investment in a project increases the income of construction workers and benefit recipients. Their marginal propensities to import will have additional effects on the balance of payments. But these secondary effects may be omitted in order to enhance the practical possibilities of estimating the project's balance-of-payment effect without greatly restricting the scope of evaluation.

$$\Delta BP_y = -f_{cy}C_y - \sum_{t=1}^{T} f_{oty}O_{ty}\left(\frac{1}{1+r}\right)^t \sum_{t=1}^{T}\left[\sum_{i=1}^{n} f_{ity}b_{ity}\right]\left(\frac{1}{1+r}\right)^t$$

$$- \sum_{t=1}^{T}\left[\sum_{i=1}^{n} e_{ity}O_{ity}\right]\left(\frac{1}{1+r}\right)^t \qquad (12)$$

where ΔBP_y = the present value of net effect on balance of payment when the scale of development is y; f_{cy} = per cent of construction cost which requires foreign exchange; f_{oty} = per cent of operation cost which requires foreign exchange; f_{ity} = per cent of benefit to sector i at year t which goes to export or to reduction of imports; O_{ity} = associated operation cost incurred by sector i to produce benefit b_{ity} at period t scale y; e_{ity} = per cent of O_{ity} which requires foreign exchange, and other terms are as defined previously.

If SF = shadow foreign exchange rate and GF = government established exchange rate, then the net effect of project development on balance of payments will be [illegible]

$$(\frac{SF}{GF} - 1)\Delta BP_y \qquad (13)$$

The term ΔBP_y is multiplied by $(SF/GF - 1)$ rather than SF/GF simply to prevent double counting of the effect of the project on balance of payments.

When the divergence between the social opportunity cost and market wage rate for unskilled surplus agricultural workers [Equation (11)] and the effect of project development upon the balance of payments equilibrium [Equations (12, 13)] are taken into consideration in the economic evaluation of an investment project, equation (10), the criterion function, must be modified to an equation such as:

$$\max Z = \sum_{t=1}^{T} \left[\sum_{i=1}^{n} [(1 - \mu_i)n_i](1 - p_i)b_{ity} + \sum_{i=1}^{n} \frac{p_i}{r}[1 - (1 - \mu_i)n_i](1 - p_i)b_{ity} \right] (\frac{1}{1+r})^t + \sum_{t=1}^{T} \theta_g \left[\sum_{i=1}^{n} p_i b_{ity} - O_{ty} \right] (\frac{1}{1+r})^t - \theta_g(1 - \ell_y)C_y - (\frac{SL}{ML})(\ell_y C_y) + (\frac{SF}{GF} - 1)\Delta BP_y \qquad (14)$$

where all terms are as defined previously.

APPENDIX B

The Social Opportunity Cost of Capital[17]

The following notations are used in this model:

X = Annual gross national product;

L = Total employment;

N = Total population;

X_i = The value of the annual gross production in sector i;

L_i = The number of labourers in sector i;

K_i = The value of the total capital investment in sector i;

W_i = The labour wage rate in sector i;

δ_i = The capital depreciation rate in sector i;

a_i = The value of intermediate goods used in sector i in terms of proportion of the value of production of sector i;

ρ_i = Average rate of return on capital invested in sector i;

π_i = The excise tax rate on products produced in sector i;

γ_i = The profit tax rate on profit made in sector i;

τ_i = The income tax rate on the wages earned in sector i.

Production in any sector is a function of capital and labour. These are substitutable factors of production. However, the production function is shifting overtime due to technological progress where the rate of technological progress is a constant exponential growth. Therefore,

$$X_i = f(L_i, K_i, e^{r_i t})$$

17/ This appendix is based on Chapter V of Economic Evaluation of a Water Resources Development Project in a Developing Nation by Fereidoun Mobasheri, Water Resources Center, University of California, Contribution No. 12[illegible], July 196[illegible].

where ϵ_i is the rate of technological progress in sector i. Specifying the production function as a Cobb-Douglas function, the equation for production in sector i will be

$$X_i = A_i L_i^{\alpha_i} K_i^{\beta_i} e^{\epsilon_i t} \qquad (1)$$

where A_i is a constant of proportionality,* and α_i and β_i are constant production coefficients. This production function is assumed to have the usual properties of constant returns to scale and isoquants convex to the origin. Therefore, $\alpha_i + \beta_i = 1.0$.

The cost of the production in sector i includes:

Cost of intermediate goods and materials $= M_i = a_i X_i$;

Cost of labour $= W_i = w_i L_i$;

Cost of capital depreciation $= D_i = \delta_i K_i$;

Excise taxes $= m_i X_i$;

Cost of capital invested in the sector $= p_i K_i$.

If Π_i is the profit in sector i after deduction for excise taxes but before deduction of direct taxes on corporation profit, then

$$\Pi_i = X_i - a_i X_i - w_i L_i - \delta_i K_i - m_i X_i - p_i K_i$$

or

$$\Pi_i = (1 - a_i - m_i) X_i - w_i L_i - (\delta_i + p_i) K_i$$

By analogy, viewing the sector as a firm, the partial derivatives of profit with respect to capital and labour should be set equal to zero for the maximization of profit to the sector. That is:

$$\frac{d\Pi_i}{dK_i} = \frac{d}{dK_i}\left[(1 - a_i - m_i)X_i - w_i L_i - (\delta_i + p_i)K_i\right] = 0$$

$$\frac{d\Pi_i}{dL_i} = \frac{d}{dL_i}\left[(1 - a_i - m_i)X_i - w_i L_i - (\delta_i + p_i)K_i\right] = 0$$

When X_i in these two last equations is replaced by $A_i L_i^{\alpha_i} K_i^{\beta_i} e^{\epsilon_i t}$, then these equations become

$$(1 - e_i - m_i)\, \beta_i \frac{X_i}{K_i} - (p_i + \delta_i) = 0$$

and

$$(1 - e_i - m_i)\, \alpha_i \frac{X_i}{L_i} - w_i = 0$$

From these two equations p_i and w_i become:

$$p_i = (1 - e_i - m_i)\, \beta_i \frac{X_i}{K_i} - \delta_i \qquad (2)$$

$$w_i = (1 - e_i - m_i)\, \alpha_i \frac{X_i}{L_i} \qquad (3)$$

where p_i and w_i are the rate of return on capital and the wage rate for labour, respectively.

The government tax rate on corporation profit in sector i is γ_i; therefore, $(1 - \gamma_i) p_i K_i$ is the net return to capital in sector i after corporation taxes. If this net return is denoted by F_i and the value of p_i from equation (2) is used, then

$$F_i = (1 - \gamma_i)\left[(1 - e_i - m_i)\, \beta_i X_i - \delta_i K_i\right] \qquad (4)$$

The government collects three different taxes from sector i:

1) Excise taxes;
2) Income taxes on wage earners;
3) Taxes on profit.

If the total government taxes from sector i be denoted by G_i, then

$$G_i = m_i X_i + \tau_i w_i L_i + \gamma_i p_i K_i \qquad (5)$$

Using equations (2) and (3), the above equation becomes:

$$G_i = m_i X_i + \tau_i (1 - e_i - m_i)\, \alpha_i X_i + \gamma_i K_i \left[(1 - e_i - m_i) \frac{\beta_i X_i}{K_i} - \delta_i\right] \qquad (6)$$

In summary, the total value of the production of sector i is distributed as follows:

$$X_i = M_i + W_i (1 - \tau_i) + D_i + P_i + G_i \qquad (7)$$

where the first term is the cost of goods and materials used in sector i, the second term is the payment to labour employed in sector i after deduction for income tax on wages, the third term is the cost of capital depreciation, the fourth term is the net return to capital invested in sector i, and the fifth term in the equation is government taxes received from sector i in the form of excise taxes, income taxes on wages and taxes on corporation profit.

If the rate of production growth overtime for sector i is denoted by g_i, then

$$g_i = \frac{\frac{dX_i}{dt}}{X_i} \qquad (8)$$

using equation (1) for X_i

$$g_i = \alpha_i \frac{\frac{dL_i}{dt}}{L_i} + \beta_i \frac{\frac{dK_i}{dt}}{K_i} + \epsilon_i \qquad (9)$$

where

$$l_i = \frac{\frac{dL_i}{dt}}{L_i} = \text{ the rate of labour growth in sector i;}$$

$$k_i = \frac{\frac{dK_i}{dt}}{K_i} = \text{ the rate of capital accumulation in sector i;}$$

$$\epsilon_i = \text{ the rate of technological progress in sector i;}$$

therefore

$$g_i = \alpha_i l_i + \beta_i k_i + \epsilon_i \qquad (10)$$

If the rates of production growth and labour growth are known, and α_i, β_i and ϵ_i are constant, then

$$k_i = \frac{G_i - \alpha_i l_i - \epsilon_i}{\beta_i} \qquad (11)$$

Capital accumulation in sector i to achieve G_i rate of production growth is then

$$I_i = k_i K_i = \frac{G_i - \alpha_i l_i - \epsilon_i}{\beta_i} K_i \qquad (12)$$

It is assumed that this capital accumulation comes from net profit made in sector i. In other words, a portion of F_i, net profit, is retained by the sector for reinvestment. Then the surplus profit which is equal to $(F_i - I_i)$ is distributed as a dividend to investors. With this assumption, then, taxation on profit by the government does not affect investment and production growth of sector i when $F_i - I_i \geq 0$. However, taxation of corporation profit has a direct effect upon F_i. The higher the tax rate on corporation profit the lower is the F_i. If this tax rate is increased to a point where $F_i - I_i = 0$, then further increase in the tax rate on corporation profit will leave a net profit smaller than the required capital investment. This will affect the rate of production growth in the private sector. If the amount of reduction in investment due to high rate of taxes on profit for sector i is denoted by R_i, then

$$\begin{cases} R_i = I_i - F_i & \text{when } F_i - I_i < 0 \\ R_i = 0 & \text{when } F_i - I_i \geq 0 \end{cases} \qquad (13)$$

When $F_i - I_i \geq 0$ all the taxes received by the government from sector i represent a reduction of consumption. Under this condition the social opportunity cost of marginal tax received from sector i is simply equal to the marginal utility of consumption of this tax. However, when $F_i - I_i < 0$, then at the margin social opportunity cost of taxes received from sector i is equal to the social value of returns that have been lost due to the reduction in investment. Since p_i is the productivity of capital and r the social rate of discount, then p_i/r is the social opportunity cost of each dollar of taxes received from sector i when $F_i - I_i < 0$.

In many countries the government owns and operates some of the economic sectors. Therefore, government revenues will include surplus from operation of these public sectors besides revenue from taxation. Government expenditures are assumed to be for general services – such as education, health, defense and so on – and for capital accumulation in government-controlled productive sectors.

The total government revenue from taxation is equal to

$$\sum_{i=1}^{n} G_i \quad ,$$

where G_i is the total taxation from sector i – excise taxes, income taxes and taxes on profit as defined by equation (5) – and n is the number of productive sectors. The total surplus from government-controlled sectors is denoted by F_p, where F_p can be calculated by an equation similar to equation (4).[19] On the expenditure side, the net operation maintenance and replacement costs of normal public service are denoted by C_p and capital accumulation in productive sectors controlled by government is denoted by I_p. To have a balanced budget, therefore,

$$C_p + I_p = F_p + \sum_{i=1}^{n} G_i \qquad (14)$$

The level of C_p depends upon public policy and consideration of the welfare of the present population, while I_p depends upon the rate of capital accumulation and economic growth. F_p depends upon the

18/ Generally, ξ = zero for government-controlled sectors; therefore, $F_p = \pi_p$

type of sectors controlled by government. In most cases the government controls sectors such as resources development and power production, which have a lower rate of return than most privately controlled sectors. The level of total taxation depends not only upon national product but also upon tax rates, as is apparent from equation ([illegible]). Assuming that the levels of C_p and F_p are fixed, then changing the rate of capital accumulation the rate of taxes on corporation profit is changed to balance the government budget while the rate of taxes on wage earners and the rate of excise taxes remain constant. This is very similar to the second model studied by Krutilla-Eckstein noted previously. Theoretically, the optimum solution will be one that balances the government budget while having the minimum effect upon capital accumulation in the private sectors. This means that different rates of taxes on profit should be applied to various sectors. However, in practice such a solution would be most difficult. A uniform tax rate will be assumed, which means $\tau_1 = \tau_2 = \ldots = \tau_n$. As government increases the level of this uniform tax rate on corporation profit to balance its budget in some sectors, $(P_i - I_i)$ will become negative, which means capital accumulation for these sectors is being negatively affected by taxation, while there might be sectors that still show positive $(P_i - I_i)$. With a given rate of τ the social cost of the total government budget will be equal to

$$\sum_{i=1}^{n} R_i \frac{[illegible]}{r} + \left(\text{Total budget} - \sum_{i=1}^{n} R_i\right) U_c \qquad (15)$$

where $R_i = 0$ when $P_i - I_i \geq 0$

$R_i = I_i - P_i$ when $P_i - I_i < 0$

and U_c = social value of present consumption. In this equation the first term measures the opportunity cost of reducing investment due to taxes on profit while the second term measures the opportunity cost of reducing consumption due to various taxes. To calculate the social opportunity cost of taxes at the margin, a_i, is defined as R_i divided by total government budget. Then

$$\theta_g = \sum_{i=1}^{n} a_i \frac{t_i}{r} + \left(1 - \sum_{i=1}^{n} a_i\right) \theta_c \qquad (16)$$

where θ_g is the social opportunity cost of tax money at the margin.

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