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DISCOUNT RATE AND THE BENEFITS-COSTS JUSTIFICATION  
OF FEDERAL IRRIGATION INVESTMENT

BY  
JULIUS MARGOLIS

TECHNICAL REPORT NO. 23

PREPARED UNDER CONTRACT N6onr-25133  
(NR-047-004)  
FOR  
OFFICE OF NAVAL RESEARCH

DEPARTMENT OF ECONOMICS  
STANFORD UNIVERSITY  
STANFORD, CALIFORNIA

NOVEMBER 10, 1955

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THE DISCOUNT RATE AND THE BENEFITS-COSTS JUSTIFICATION  
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By

Julius Margolis

I

1.1 Irrigation projects involve large capital expenditures in the present, lower operating and maintenance costs in the future and the benefits they bring are to extend long in the future. Any attempt to justify these projects involves the question of comparing costs and benefits over different time periods.

How are these heterogeneous incomes and costs to be aggregated and compared? In addition to the problem of justification, the determination of the surplus of benefits over costs, there is the question of the degree of capital intensity of the project. The dam can be made bigger, the canals can be lined, and so on. These larger structures mean a higher cost today for presumably more net benefits in the future. The level of present sacrifice that one is willing to accept is related to the weight that is given to future years relative to the present.

1.2 The usual solution of the problem is to convert the incomes and costs of future years to the present by an appropriate discount.

\* Interest rates may be considered as an expression of the exchange relationships between present and future goods. This premium of interest rate is the added value of having resources presently available in comparison with future values. For comparison with present costs, the determination of present worth of goods available in the future involves scaling down or discounting their future values.

With limited amounts of resources available for capital investment, the cost of investing such resources in a particular project is measured by the rates applicable to other uses that are foregone. This cost is over and above allowances for risk and arises regardless of whether a private or public viewpoint is involved. The interest rate on investments such as long term government bonds would appear to be a reasonably satisfactory measure of the interest return with minimum risk opportunities available for capital investment. Although such a rate may not fully reflect the justifiable preference of society for present goods, it still provides a measure of the yield of other

opportunities for capital investment that are foregone by society if resources are invested in given projects." <sup>1/</sup>

The Federal Inter-Agency River Basin Committee then goes on to specify the following discount rates:  $2\frac{1}{2}$  per cent, the current government rate, should be used to calculate the annual Federal costs; at least 4 per cent should be used to calculate the annual benefits - the increase in income to the farmers. The procedure is then to convert the discounted benefits and costs to an average annual estimate. The ratio of the two forms the index by which priorities are to be established in the selection of the project.

1.3 The argument of this paper is that rather than a ratio of annual benefits and costs it would be preferable to use a ratio of the sum of discounted net benefits to current investment costs. A second conclusion is that, on the assumptions of capital rationing, the appropriate discount rate is the internal rate of return of farmers.

## II

2.1 Since discounting is a procedure to make comparable events in different years in order to facilitate choice of projects, let us state the problem motivating the search for criteria of choice before dealing specifically with the issues of the discount rate. Every act of Congress implies the diversion of resources from private to public use. On the most general level we could state that the problem of an index of choice is one of determining the borders between public and private activity. Under what conditions should the government directly

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<sup>1/</sup> Federal Inter-Agency River Basin Committee, Proposed Practices for Economic Analysis of River Basin Projects, (Washington, D.C., 1950) p. 22.

undertake production, or extend capital to facilitate a line of production or initiate legislation directing or inhibiting a pattern of production, and what quantitative criteria should it develop to guide its decisions? With our current information the attempt to establish these criteria are premature. Instead we can only ask the far more narrow question: In a limited sphere of public policy, natural resources development, can criteria be established which will facilitate a more rational allocation of the government budget? These two questions imply quite different criteria and images of the nature of the government.

2.2 The first question requires the evocation of a criterion for an optimum which social science or social philosophy cannot deliver. The latter question requires a criterion which will unequivocally lead to a better allocation. It accepts an unknown degree of irrationality in the allocative mechanism but the possibility of some areas of rationality. The acceptance of the latter approach enables us to increase the number of variables which are beyond our control in the short-run and therefore can be considered as given.

2.3 What is the world within which the Budget Bureau, the Congressional appropriations committees and the interested administrative agencies operate? The Budget Bureau must present the administration's budget. It is the agency most directly concerned with "rationality" in budgetary procedures. Its planning procedures go in two directions. It establishes an overall budgetary limit, limits for programs, agencies and at the same time approves the lines of the appropriations. All three items are determined by the Bureau in consultation with legislators and bureaucrats with the legislative influence changing as it moves from the overall to the specific appropriations.

2.4 Of most consequence for our analysis is that the Budget Bureau, when it considers the resources development agencies appropriations and goes into conference with them, has already arrived at a preliminary overall estimate, an estimate which is a function of the pressures of Congressional attitudes and competing agencies. In the traditional terms of private economic analysis the Bureau of Reclamation is confronted with capital rationing. In the case of commercial firms capital rationing has implications for the planning process and it is necessary to ask whether the same is true in the case of public agencies.

2.5 The Federal Inter-Agency River Basin Committee accepts a framework similar to that outlined above. They ignore all other government programs, even those which might accomplish the objectives of increased agricultural production through non-resources development programs as increased foreign trade. They implicitly accept capital rationing by setting up a priority of programs rather than recommending that all "profitable" operations be undertaken. A priority system implies that a project may be postponed even though the computations show that it is justifiable. Though the computations of the benefits and costs of a project may have demonstrated the project will result in an increase in welfare, it may find itself being postponed in favor of another project. Since every "economically justified" project is not immediately initiated, either the relevant benefits and costs have not been included or there exists another discount rate. If the latter is true, and probably both are true, we are faced with the situation common in business of using an external rate of interest which diverges from the internal rate used in business planning. But before we get involved in specific arguments let us state some further points about irrigation policy.

2.6 The goals of public policy in irrigation are manifold. Some would stress the establishment of family-sized farms. Others urge the necessity of an expansion of agricultural production in light of the expanding world population, growing Western population and possibilities of war. Still others are mainly concerned about the boost that irrigated agriculture in the Western states would give to the economic development of that region. Probably all of these goals are operative in decision-making. But all of them have one feature in common. Federal irrigation works are an advance of capital to the agricultural sector. A large part of it is a direct subsidy - the interest free component and the amount repaid by power users. Less directly the very generous terms, fifty years and frequently longer, are another form of capital subsidy. The benefits primarily accrue to the farmers on the project, though there are external economies, consumers' surpluses and profit inhibitions, because of acreage limitations. The program is mainly an advance of capital to specific farmers. The opportunity costs are a function of the budgetary freedom of the government. In our narrow frame of reference, the opportunity costs are the benefits which might have accrued to another set of farmers with the same capital subsidy.

2.7 One other item of general background is needed. In any given year the federal government does not exhaust its list of "worthwhile" activities. This, as mentioned earlier, is implicit in the establishment of a priority system rather than the exhaustive initiation of all acceptable projects. It also follows from the assumption of a dynamic growing economy. Rather than a static environment where we achieve an equilibrium at the margin after completing all inframarginal projects, we assume that population growth and technological progress

will be offering new investment opportunities.<sup>2/</sup> The future is unknown but it is reasonable to assume that the average rates of return in the present will hold - that the government or the public will be able to invest in the future at the same profit expectations which they hold today.

### III

3.1 Ignoring social policy aspects the economic goal of irrigation policy is the maximization of a possible stock of capital at some point in the future. This goal is identical with the maximization of an income stream to the future point, since the maximum income will allow the maximum investment while maintaining a steady flow of consumption. The usual theorem is that the entrepreneur allocates his capital funds so as to set up a net income stream which when discounted by the current market rate and then summed will realize the greatest present net worth. Though the benefits-costs measurers never estimate the present capitalized value of the investment, they attempt an approximation by estimating and comparing the discounted annual benefits and costs. Under certain conditions the allocation of investment funds, so as to maximize the current net worth equal to the sum of future incomes discounted at the market rate, will also maximize the future income stream. These conditions do not hold in the case of federal irrigation programming and therefore the use of annual benefits and costs discounted by the market rate of interest leads to an inefficient allocation.

3.2 The major assumption underlying the practise of maximizing the sum of the discounted net income stream is that there does not exist any capital

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<sup>2/</sup> I am indebted to John Power for this point.

rationing. In addition, if the current market rate is used and the capitalised net worth is to be judged as socially desirable, it is assumed that there are no imperfections in the capital market, that is, the interest rate accurately balances at the margin the functions of productivity of capital and the time preferences of consumers. The latter assumption is admitted by all to be invalid. The interest rate is subject to control by Federal authorities and is determined by the exigencies of monetary counter-cyclical policy rather than any "real" long-run forces. The first assumption needs further elaboration.

3.3 In theory the entrepreneur is assumed to scan the horizon of opportunities surrounding him. For each alternative he estimates the costs and revenues and if the rate of return is greater than the costs of the capital funds he requires, he initiates that activity. Further, he or his fellow entrepreneurs, initiate all activities where the rate of return - the discount rate necessary to make the stream of net revenues equal to the cost of construction - is greater than the interest rate. The market rate of interest is used because he always has the alternative of lending his money and allowing it to grow at that rate. But this assumes a perfectly elastic supply of equity financing - wherever there are profitable possibilities there exists a supply of capital funds to exploit these opportunities. In reality the supply of equity financing is limited by considerations other than profit expectations.<sup>3/</sup> In the field relevant to our

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<sup>3/</sup> T. Scitovsky classifies the limitations on capital use for a firm according to the willingness to borrow and willingness to lend. The willingness to borrow is limited by the "entrepreneur's fear of bankruptcy, his unwillingness to fix in advance too high a proportion of his total cost expenditures, and his fear of losing control over his firm's policy and the distribution of its gains. The willingness to lend is limited by the investor's desire for security which is related to the assets already held by the firm. Welfare and Competition, (Irwin, Chicago, 1951) pp. 194-200. These two "willingnesses" are usually referred to as risk aversion and capital rationing.

topic, the financing available to the farmer is limited to a proportion of his equity, not to a proportion of his profit expectations. A farmer therefore may not use fertiliser or machinery though the net productivity is greater than the interest rate - the price he must pay for the capital funds to procure these services and assets. If this case holds, and most agricultural economists consider it generally true, though in the past decade capital has become more plentiful to the agricultural sector, it would not be advisable for the farmer to discount his future revenues and costs by the market rate of interest. The farmer's internal rate of return is greater than the external market rate of interest. To see why it would be advisable to allocate his capital according to the internal rate of return rather than to maximize the present value of his net income stream discounted at the market rate, let us examine an illustration specific to the choice confronting the government in choosing among irrigation projects. <sup>4/</sup>

3.4 Table 1 gives the benefits, internal rates of return and value of the discounted stream of benefits for two projects of equal cost which will last

Table 1

Project	Cost	Benefits		Internal Rate of Return (percent)	Present Value, Discount Rate		
		in year 1	2		3 per cent	6 per cent	10 per cent
A	100	0	121	10	114	110	100
B	100	115	0	15	112	110	105

for two years and then collapse. Assume that only \$100 is budgeted by the

<sup>4/</sup> For discussions of the two criteria see: T. Scitovsky, *op.cit.*, pp. 203-214; K. Boulding, *Economic Analysis*, 3rd ed., (Harpers, N.Y. 1955) pp. 862-875; E.O. Heady, *Economics of Agricultural Production and Resource Use*, (Prentice-Hall, N.Y., 1952) pp. 573-574; A.G. Hart, *Anticipations, Uncertainty, and Dynamic Planning*, (Kelley, N.Y., 1951) pp. 92-95.

government for projects. If we used the procedures used by the government, discounting benefits and costs by the market rate of, let us say, 3 per cent and then compared them, project A would be chosen, though project B has the higher internal rate of return. Under the assumptions of capital rationing project B should be chosen. What is the opportunity cost of choosing one project? It is the rate of return which is lost by not being able to undertake the second. If we discounted the projects by this rate, then B is preferable. If there were no capital rationing, then both projects and all other projects with an internal rate of return greater than the market rate of interest would have been undertaken and the marginal internal rate of return would have been equal to the market rate of interest. The choice of B may be based on stronger grounds than the above if we go beyond the static argument it relies upon and make assumptions of growth. If population change, technological progress and so on always gave rise to a set of opportunities as great as today, each year we will be confronted by another set of A and B projects. If this were true, B would create a perpetual stream of benefits available for consumption of 15 per year while A would create only 21 every other year. The two necessary assumptions are the existence of capital rationing and an opportunity to reinvest the proceeds at the same high internal rate. The latter assumption can be relaxed somewhat. It is not necessary that a project with the same internal rate of return be available but the sufficient condition is that the marginal internal rate of return be greater than the market rate of interest. If this is the case, then a ranking of projects by the internal rate or by the sum of benefits discounted by the marginal internal rate will be more efficient than a ranking by the sum of benefits discounted at the market rate of interest.<sup>5/</sup>

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<sup>5/</sup> There are problems in ranking by the internal rate of return but they do not effect our later conclusions. See R. McKean, Cost-Benefit Analysis and Efficiency in Government, Rand Research Memorandum (mimeographed, March, 1955) pp. 79-82.

3.5 The above argument included a hidden institutional assumption. A Reclamation Fund was implicitly assumed. As benefits were generated the Fund claimed them and could either declare dividends or undertake new projects. There exists a Reclamation Fund but the Bureau of Reclamation cannot freely initiate projects on the basis of its size. Each project must be authorized by Congress and Congress must appropriate funds for it. The rates of return on existing projects influence the addition of new projects only indirectly. A high rate of return is a potent argument for the extension of the project and as such the Bureau is interested in this criterion. Secondly the Bureau does not capture all of the benefits. Ignoring the vexing question of secondary benefits, the benefits of the project are the enhanced productivity of the farms supplied with water. The Federal government rather than sharing in any "profits" extends a handsome subsidy to these groups. Previously we had justified the use of ranking via the internal rate of return by assuming that the opportunity cost of investment in a project were the federal benefits of an alternative investment which the government could not undertake because of a politically rationed budget. The political rationing extends to the real situation but the opportunity costs are the incomes of the farmers who are themselves subjected to capital rationing by the private capital market.

3.6 Since the government enhances private productivity, the internal rate of return to the farmers would be the opportunity cost of selecting one project over another. The costs incurred by the nation in the construction of one irrigation project is not the private goods sacrificed (the level of government expenditures is assumed to be determined by level of employment considerations) nor other unrelated government projects (political rationing among programs is assumed) but the enhanced income and investment potential of other farmers who are

denied capital because of the project. Therefore the internal rate of return of farmers is the appropriate discount rate. On the previously stated assumptions of growth the average rather than marginal rate should be used. The implications of using an average internal rate of return of farmers as a discount rate is sensible on other though related grounds. This discount factor will probably be higher than the current market rate. A higher discount factor will give a larger present value to those projects which mature more rapidly. This is of importance since one of the major problems confronting irrigation farmers is the lack of capital to support them in the early years. Farm predevelopment will probably be judged more beneficial because of its consequences for early income achievement.<sup>6/</sup> The obverse effect, the writing down of the benefits of later years is sensible since any forecasting for such periods is highly questionable and therefore the higher discount rate reflects the uncertainties surrounding the lengthy planning period.

3.7 A foreseeable consequence of the use of a higher discount factor is that many projects may cease to be "economically feasible." If this is so, it should not be cloaked but made explicit. If other forms of capital subsidy to farmers are more productive, this should be considered in the decision to initiate irrigation projects. But though a project may be judged a nonoptimal form of capital subsidy to farmers, a budgetary allocation may be defensible on other grounds of social policy: regional development and "democratic" land settlement.

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<sup>6/</sup> For analyses of the capital access problems of irrigators and the role of early net income growth see, C.E. Stewart and D.C. Myrick, Control and Use of Resources in the Development of Irrigated Farms, Montana State College Agricultural Experiment Station, Bull. 476, Oct., 1951; and J.R. Tompkin, G. Brock, Jr., and P. Petzoldt, Riverton/Shoshone Settlers - An Economic Study, Wyoming Agricultural Experiment Station Bull. 323, April, 1953.

IV

4.1 Another aspect of the treatment of time in the benefits-costs ratios creates inefficiencies. In the preceding argument we have assumed that the factor which had to be optimally allocated was capital. Though the arguments in defence of benefits-costs measurements can be interpreted to have the same objective in practise, they do not consistently follow this goal.

4.2 Let  $I$  be project construction costs,  $M$  be project operating and maintenance costs,  $B$  be net benefits. The Federal Inter-Agency River Basin Committee offers three measures that might be used and rejects all but the benefits-costs ratio,  $\frac{B}{I+M}$ . The first measure is the absolute amount of net benefits per project,  $B - (I + M)$ . This is rejected since it "would afford no comparison of the relative costs of realizing such benefits. Two projects with equal surpluses of benefits would appear equally desirable in such a comparison even though the costs of one might be several times that of the other. This method of comparison would be useful only if relative costs were no object."<sup>7/</sup> This objection is perfectly correct so long as there is the possibility of some surpluses arising through the alternative use of the resources. It becomes even more intuitively obvious once we accept the institutional limitation of capital rationing through the budget.

4.3 A second measure which they also reject is the rate of return on investments,  $\frac{B-M}{I}$ . This method is inadequate, they claim, since "under this method comparison of respective operation and maintenance costs is incomplete, since they are deducted before computation of percentages. This method has a limited usefulness, as for example, for determining relative desirability of projects when construction funds are limited and when the relative costs of operation and maintenance is considered of secondary importance."<sup>8/</sup> The

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<sup>7/</sup> Federal Inter-Agency River Basin Committee, op.cit., p.14  
<sup>8/</sup> ibid.

exceptional instances when they consider it of importance are of course the general case. Construction funds are always limited and operation and maintenance expenditures are matched by an inflow of power and agricultural sales.

4.4 The third measure is the ratio of benefits to costs. "The procedures recommended herein are based on the assumption that, in general, the economic resources involved in the project development over and above those accounted for in project benefits and project costs would be used with equal effectiveness with or without the project. Therefore, a ratio of project benefits to project costs constitute the proper measure of the effectiveness of use of the Nation's resources insofar as the use of such resources for project purposes is concerned."<sup>9/</sup> This is a measure which we would rarely meet outside the world of government justifications. In the commercial world it would be akin to a gross receipts-gross expenses ratio in the evaluation of an investment decision.

4.5 The second and third measures would be equally efficient if all we desired was to classify the projects as justifiable or not. If  $B = I + M$ , then both indices would equal 1 and if  $B > I + M$ , both indices would also be greater than 1. But the Federal Inter-Agency River Basin Committee not only wants to flag the "unprofitable" projects, they also seek indices which will reflect the "relative economic desirability (exclusive of considerations of intangibles) of a number of projects which have been properly formulated in accordance with the procedures recommended herein. . . ." <sup>10/</sup> The two measures would assign different rankings to projects based upon the relationships of annual and investment costs. For instance, if we had two projects with the same net benefits,  $B > (I + M)$ , and the same total costs,  $I + M$ , but if in one project

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<sup>9/</sup> ibid.

<sup>10/</sup> op. cit., p; 38.

$I_1 > I_2$  and  $M_1 < M_2$  so that  $I_1 \cdot M_1 = I_2 \cdot M_2$ , their ratios of benefits to costs would be the same, but the second index,  $\frac{B-M}{I}$ , would rank the first project higher. Which sets of results do we want? Are we indifferent between the projects or is one preferable?

4.6 The answers to the questions are simplified by the fact that the water and power users pay charges for the services. Prior to the delivery of water the government agencies must complete contracts with the water users so that the construction costs and operating and maintenance costs would be reimbursed. Clearly there is no shortage of capital for current operating costs, but instead the costs which must be minimized by the budget bureau are the advances by the government of the construction costs. Therefore the projects which afford the highest return on the factor limited in supply, initial capital, should be favored. If a ratio is to be used, instead of the ratio of annual benefits to annual costs, the correct ratio should be the ratio of the discounted sum of net benefits to investment costs.

V

5.1 The argument of this paper was based on the factual assumption that capital rationing exists for the government and for the sector most benefited by irrigation investment, the farmers. The government will not offer a full supply of equity financing to the farm sector. The politically rationed public financing to assist the agricultural sector will be most efficiently allocated if it maximizes the incomes of the farmers. To best approximate this target the future net benefits should be discounted at the average internal rate of return of farmers. The sum of these discounted benefits should be compared to the public investment costs which are the funds to be rationed.

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