PB-224 177

PROJECT SELECTION AND MACROECONOMIC OBJECTIVES: A METHODOLOGY APPLIED TO PERUVIAN IRRIGATION PROJECTS

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Prepared for:

Agency for International Development

1972

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106

BIBLIOGRAPHIC DATA SHEET	1. Report No. PE-338.1-M145	2.	3. Recipient's Accession No. PB-224 177
4. Title and Subtitle "Project Selection and Macroeconomic Objectives: A Methodology Applied to Peruvian Irrigation Projects"			5. Report Date 1972
			6.
7. Author(s) Stephen E. McGaughey, and Erik Thorbecke.			8. Performing Organization Report No.
9. Performing Organization Name and Address Iowa State Univ.			10. Project/Task/Work Unit No. 931-11-140-124
			11. Contract/Grant No. AID/csd-2824 [redacted]
12. Sponsoring Organization Name and Address Department of State Agency for International Development Washington, D.C. 20523			13. Type of Report & Period Covered
			14.

15. Supplementary Notes

16. Abstracts

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17. Key Words and Document Analysis. 17a. Descriptors

17b. Identifiers/Open-Ended Terms

17c. COSATI Field/Group 338

18. Availability Statement	19. Security Class (This Report) UNCLASSIFIED	21. No. of Pages 12
	20. Security Class (This Page) UNCLASSIFIED	22. Price $3.00

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Reprinted from
AMERICAN JOURNAL OF AGRICULTURAL ECONOMICS
Vol. 54, No. 1, February, 1972

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Project Selection and Macroeconomic Objectives: A Methodology Applied to Peruvian Irrigation Projects*

STEPHEN E. MCGAUGHEY AND ERIK THORBECKE

A method of obtaining investment priorities is formulated and applied to 11 Peruvian irrigation projects. The principal feature of the analysis is a ranking function which incorporates national economic objectives with appropriate weights. Project priorities are derived from each economic objective using the applicable investment criteria. The ranking function is used to combine the priorities into a ranking by explicitly accounting for numerical weights on the objectives. The function appears to be a general device which can include as many objectives as there are suitable investment criteria.

DEVELOPMENT planning requires explicit specification of the major macroeconomic targets, e.g., output, income distribution, employment, and balance of payments equilibrium, and their relative importance. The preference function of the policy maker is thus expressed in macroeconomic terms.

A major instrument available to the policy maker in helping him achieve the major objectives is in the allocation of public funds for investment projects and selection of projects. However, the selection process is typically based on investment criteria, which, by their very use in pre-investment studies, tend to emphasize certain objectives, e.g., output, at the expense of others, e.g., balance of payments, employment. It is, therefore, often very difficult to judge whether any given public investment program contributes more or less than another to the preference function of the government.

The present paper is a modest attempt to bridge the gap between the macroeconomic objectives on the one hand and the investment criteria on the other. A methodology is formulated which makes it possible to relate the project selection to the macroeconomic goals.

The paper is divided into a number of sections, beginning with a brief description of a set of Peruvian irrigation projects. Second, a number of investment criteria are defined and reviewed. Third, these investment criteria are applied to the whole set of projects to obtain rankings and priorities corresponding to each criterion. Fourth, a sensitivity analysis of the ranking of projects to a range of shadow wage and foreign exchange rates is undertaken. Then a methodology for relating project selection to macroeconomic goals is presented and applied to the present set of projects. Some general conclusions are drawn from the analysis.

* The authors benefited from helpful comments from the *AJAE* referees and editor.

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The Projects

Eleven public irrigation projects were selected from a set of completed feasibility studies. Each project in the sample could be implemented without further extensive pre-investment studies. Care was taken to select projects sufficiently specific to identify the labor and foreign exchange components of the costs and outputs in addition to containing estimates of direct costs and benefits.

The chosen projects cover four diverse categories of irrigation investment differentiated by project size, location, and purpose. These categories include (1) three small sierra land improvement projects, (2) three small coastal virgin land projects, (3) one very large coastal virgin land project, and (4) four medium-sized combined virgin land and land improvement projects on the coast. A wide spectrum of project types is included, ranging in size from a few hundred hectares to nearly 90,000 hectares and from $670 to a maximum of $2,780 per hectare in investment costs. There are substantial differences in estimated output per hectare, investment gestation periods, and time lags to reach full capacity operation among the projects. Project data are summarized in Table 1.

Investment Criteria

Four classes of investment criteria are employed in ranking the 11 irrigation projects: (1) the benefit-cost ratio, (2) the social marginal productivity of investment, (3) the internal rate of return[1] and (4) three simple partial in-

[1] The relationship between the internal rate of return and the benefit-cost ratio is fully discussed by Eckstein [2]

Table 1. Basic project data, selected Peruvian irrigation projects (1965 prices) [3, 4, 6, 7, 11]

Irrigation projects by class	Hectares			Investment cost per hectare $[a]	Gross output hectare[b] $[a]	Income per hectare[b] $[a]	Time required (years)	
	New	Improved	Total				For construction	To reach full output
Small sierra		3,625	3,625	670	310	170		
1. Antaura		1,175	1,175	560	250	190	2	7
2. Huanscolla		925	925	610	400	190	2	5
3. Chococo		1,525	1,525	800	290	150	2	7
Small coastal	7,255		7,255	1,570	850	370		
1. El Cural	3,065		3,006	1,440	910	390	1	8
2. La Cano	2,120		2,120	1,730	760	350	1	8
3. El Huevo	2,070		2,070	1,600	850	360	1	8
Large coastal	86,751		86,751	2,780	820	470		
1. Olmos	86,751		86,751	2,780	820	470	19	20
Medium coastal	31,366	66,929	98,295	1,530	430	230		
1. Choclacocha	8,500	28,000	36,500	1,440	490	270	3	7
2. Chira	7,471	28,471	35,585	1,640	300	180	4	12
3. Moquequa	3,080	3,670	6,750	1,750	660	290	3	12
4. Tumbes	12,315	7,145	19,460	1,390	470	210	7	12
Total or average	125,372	70,554	195,926	2,060	620	340		

[a] The dollar amounts were obtained by converting the soles figures at the prevailing exchange rate of soles 26.80=$1.
[b] Average annual at full capacity output.

vestment criteria, namely, the output-investment ratio, the labor-investment ratio and the foreign exchange earnings-investment ratio. Each criterion is computed from the present discounted values of the projects. In addition, approximations of the shadow prices of unskilled labor and foreign exchange are introduced.[2]

and Little and Mirrlees [9]. Estimates of the internal rate of return are not enumerated in later sections because the priorities obtained coincide closely with those of the BCR.

[2] Throughout the exposition the terms shadow wage rate and shadow foreign exchange rate are used. They are defined as the opportunity costs of employing additional quantities of each resource in the new investment projects. With respect to labor, Thorbecke and Stoutjesdijk [13] have shown that there is substantial underemployment of labor in the Peruvian agricultural sector. Thus, the prevailing market wage rates likely overestimate the output which is sacrificed by withdrawing labor from agriculture even during months of peak labor demand. No direct estimates of the shadow wage rate are available, but for project evaluation it is far better to account for an overvaluation of labor than not. The shadow exchange rate is defined as the equilibrium rate that would prevail without major exchange controls. Since the market rate used for the initial project evaluation was that which prevailed in 1965, the shadow rate adjustment employed merely reflects closely the approximate 40 percent devaluation of 1967. Furthermore, this new rate prevails under a regime of continued exchange controls.

The benefit-cost ratio (BCR) measures the ratio of the present discounted value of direct project benefits to the present discounted value of direct project costs. That is,

$$(1) \quad BCR = \sum_{t=0}^{N} B_t(1+i)^{-t} \Big/ \sum_{t=0}^{N} C_t(1+i)^{-t}, \qquad t = 0, 1, \cdots, N$$

where

$$(1.1) \quad B_t = X_t - C_{xt} - I_{at} - O_{at}, \quad \text{and}$$

$$(1.2) \quad C_t = I_t + O_t.$$

The project benefits in time t, B_t, are composed of gross output, X_t, less operating costs, C_{xt}, on-farm investment costs, I_{at}, and the operating, maintenance, and replacement costs, O_{at}, of the on-farm investment. The project costs in year t, C_t, are the sum of public infrastructure investment, I_t, and their corresponding operating, maintenance, and replacemen costs, O_t. Thus, the private farm investment (I_{at}) is included as a negative benefit, and public (infrastructure) investment (I_t) is treated as a positive cost. Furthermore, because of data

limitations, secondary and indirect benefits are ignored.[3]

The social marginal productivity of investment (SMP) as elaborated by Chenery [1] consists of two components: the social profitability ratio[4] and the balance of payments effects of project operation and investment. Therefore,

$$(2) \qquad SMP = \frac{V - C}{K} + r\frac{B}{K}$$

where V is the present value of the domestic value added composed of gross output less imported material costs and C is the present value of operating costs made up of labor and domestic material costs. The present value of project investment costs are denoted by K, while r is the proportion by which the shadow exchange rate exceeds the official rate, i.e., the extent of overvaluation of the exchange rate.[5] The term B is the present value of the total balance of payments effects computed to include the direct and indirect effects of the project investment (B_1), the direct operating effects (B_2), and the indirect operating effects (B_3). In functional terms,[6]

$$(3) \qquad B = B_1(K) + B_2(X) + B_3(X).$$

In addition to the above criteria, three partial ratios can be used in project selection, utilizing limited project information to measure the contribution of investment to specific development targets. These criteria are the output-investment ratio, the employment-investment ratio, and the foreign exchange earnings-investment ratio.

The output-investment ratio is defined as the present discounted value of a measure of output (gross output, value-added or income) divided by the present discounted value of investment. That is,

$$(4) \quad X/K = \sum_{t=0}^{N} X_t(1+i)^{-t} \Big/ \sum_{t=0}^{N} K_t(1+i)^{-t}, \qquad t = 0, 1, \cdots, N.$$

The employment-investment ratio is similarly measured as the present discounted value of unskilled labor costs per unit of the present discounted value of project investment. Hence,

$$(5) \quad L/K = \sum_{t=0}^{N} L_t(1+i)^{-t} \Big/ \sum_{t=0}^{N} K_t(i+i)^{-t}.$$

The net direct foreign exchange earnings per unit of project investment, expressed in present values, is given by the ratio

$$(6) \quad F/K = \sum_{t=0}^{N} F_t(1+i)^{-t} \Big/ \sum_{t=0}^{N} K_t(1+i)^{-t}.$$

Project Priorities

Each of the previously defined investment criteria is applied to the irrigation projects, permitting specification of independent priorities according to each criterion.

The BCR was computed for the set of projects using a 10 percent discount rate and two sets of prices corresponding, respectively, to market and selected shadow prices of labor and foreign exchange. The results (Table 2) are representative of the effects of shadow rate adjustments. Inclusion of these rates causes the BCR of each project to rise regardless of the discount rate chosen. The higher the discount rate, the more crucial the choice of shadow prices in determining the feasibility, i.e., $BCR \geq 1$, of projects. Thus, for example, among the projects being considered only two are feasible at market prices using a 15 percent discount rate, whereas eight would be feasible at the chosen shadow prices.

Failure to include shadow prices, common in Peruvian feasibility studies, understates benefit-cost ratios over the whole range of discount rates. Indeed, this omission can alter the composition of the final project selection by overestimating the contribution of capital intensive

[3] The benefits of the one large project (Olmos) were estimated in the feasibility study to account for projected reductions in product prices arising from the project's contribution to national output. The remaining studies implicitly assumed an infinitely elastic demand for each project's output.

[4] See Little and Mirrlees [9] for an analysis of the social profitability ratio from the viewpoint of the firm and society.

[5] As defined here, r corresponds to the ratio of the shadow exchange rate minus the official exchange rate to the latter, i.e., $r = (F - O/O)$ where F = shadow exchange rate expressed as number of soles per U.S. \$, and O = the official exchange rate, i.e., 26.8 soles = \$1 in 1967; thus, $r = (F/O) - 1$. $F/O = f$ and $r = f - 1$ can be expressed where f becomes the shadow exchange rate as a proportion of the official rate. Thus, for example, $f = 1.5$ implies a shadow rate of 50 percent above the official rate, i.e., 40.2 soles = \$1. (See footnote 9 for more detail.) In the sensitivity analysis which is conducted in a later part of this paper the shadow foreign exchange rate is expressed as f. In any case, r is always equal to $f - 1$ as shown above.

[6] The balance of payments effect is described in detail by Chenery [1] and in the U. N. project manual [14].

Table 2. Project values for the benefit-cost ratio (BCR) and the social marginal productivity of investment (SMP) [3, 4, 6, 7, 11][a]

Project	BCR at market prices	BCR at accounting prices[b]	Project	SMP[b]	$(V-C)/K$	$0.5(B/K)$
Huanscolla	2.4	4.7	Huanscolla	3.6	2.8	0.83
Antaura	2.4	3.7	Antaura	2.8	2.4	0.38
Choclacocha	1.5	3.2	El Cural	1.7	1.5	0.21
Chococo	1.5	2.7	El Huevo	1.7	1.5	0.19
Olmos	1.4	2.1	La Cano	1.5	1.2	0.26
El Cural	1.4	2.2	Chococo	1.4	1.2	0.23
La Cano	1.4	2.2	Choclacocha	1.3	1.3	0.01
El Huevo	1.4	2.5	Olmos	1.1	0.8	0.26
Moquequa	1.0	1.4	Tumbes	0.5	0.4	0.08
Tumbes	0.8	1.5	Moquequa	0.3	0.4	0.15
Chira	0.5	0.6	Chira	−0.6	−0.3	−0.27

[a] Discounted at a 10 percent rate of interest.
[b] Computed at a foreign exchange rate of 150 percent of the official rate and a wage rate of 50 percent of the market rate.

projects requiring large initial foreign exchange outlays and relatively fewer unskilled workers during the construction phase.[7]

The SMP is a useful adjunct to benefit-cost analysis because the balance of payments effects are separated from the total effects of the project investment and operation. The magnitude of the SMP and its two components are given in Table 2 for the set of projects, assuming as before a shadow foreign exchange rate of 150 percent of the official rate and a shadow wage rate of 50 percent of the market rate.

Incorporation of the indirect balance of payments effects in the SMP is responsible for a substantial change in the ranking of the projects as compared to that resulting on the basis of the BCR criterion. More specifically, the large projects (Choclacocha and Olmos) which have a substantial foreign exchange component have a relatively lower ranking on the basis of the SMP than the BCR criterion. This demonstrates the limitations of relying on a single direct measure of project performance, even for a set of relatively homogeneous projects.

Three categories of partial criteria are computed in Table 3. First, one measure of the output-investment ratio is shown.[8] The variation

[7] The project employment effects are quantified in Table 3.

[8] Many other forms of the output-investment ratio were computed including the use of value added and investment

Table 3. Output-investment, labor-investment, and foreign exchange-investment ratios [3, 4, 6, 7, 11][a]

Gross output-investment ratio: Project	X/K	Labor-investment ratios: Project	Total $(L_0+L_c)/K$	Operation phase L_0/K	Construction phase L_c/K	Foreign exchange-investment ratio: Project	F/K
Huanscolla	5.4	Huanscolla	0.89	0.66	0.23	Huanscolla	2.7
Antaura	3.7	El Cural	0.79	0.60	0.19	Antaura	1.6
El Cural	3.6	El Huevo	0.76	0.51	0.25	Olmos	1.3
El Huevo	3.6	Choclacocha	0.63	0.43	0.20	Chococo	1.2
Choclacocha	3.6	La Cano	0.58	0.39	0.19	La Cano	1.2
La Cano	3.3	Chococo	0.57	0.33	0.24	El Cural	1.1
Chococo	3.2	Olmos	0.52	0.36	0.16	El Huevo	1.0
Olmos	2.8	Tumbes	0.52	0.36	0.16	Tumbes	0.6
Moquequa	2.5	Moquequa	0.47	0.34	0.13	Choclacocha	0.5
Tumbes	2.2	Antaura	0.46	0.24	0.23	Moquequa	0.4
Chira	1.5	Chira	0.27	0.16	0.11	Chira	−0.1

Source: Same as Table 1.
[a] All ratios were computed on the basis of a 10 percent annual discount rate.

in priorities between it and the BCR are not great but the use of gross output overestimates benefits and, therefore, is not appropriate for determining feasibility. Thus, it should be used only for project comparison when no other measures are available.

Second, the employment-investment ratio is broken down over two project employment periods, namely, the construction and operating phases. It can be seen that employment effects during the operation phase are significantly larger than during the construction phase. It is evident that small projects require more labor per dollar of investment in the operating and construction phases.

The final partial investment criterion which is computed in Table 3 is the ratio measuring the direct foreign exchange contribution of each project. There is a striking uniformity in project rankings between this ratio and the balance of payments component of the SMP given in Table 2.

Sensitivity Analysis

Shadow prices of resources, e.g., capital, foreign exchange, and unskilled labor, can be estimated only within the context of an economy-wide, sectoral, or microeconomic model. For planning purposes such estimates should be derived from an economy-wide multisectoral model. In the absence of such a model and corresponding estimates, an alternative procedure is to conduct a sensitivity analysis of the investment criteria to systematic variations in the prices of the principal limiting resources over a realistic range. The BCR is subjected to this sensitivity analysis over the following range of shadow prices for foreign exchange: between the official rate and twice that rate; for the wage rate: between zero and the market rate; and for the interest (discount) rate: between 6 and 15 percent per annum. Thus,

$$BCR = g(f, w, i), \quad \text{for} \quad 1.0 \leq f \leq 2.0, \quad 0 \leq w \leq 1.0, \quad \text{and} \quad 0.06 \leq i \leq 0.15 \tag{7}$$

where:

f = the shadow foreign exchange rate as a proportion of the official rate,[9]

w = the shadow wage as a proportion of the market wage, and

i = the interest (discount) rate.

The sensitivity of the BCR to parametric variations in the foreign exchange, wage, and interest rates is illustrated in Figure 1. It can be seen that the BCR is highly sensitive to changes in the interest rate, holding f and w constant; an increase in i reduces the BCR uniformly for all projects. Similarly, a reduction in the price of unskilled labor (w) increases all BCR's as does a

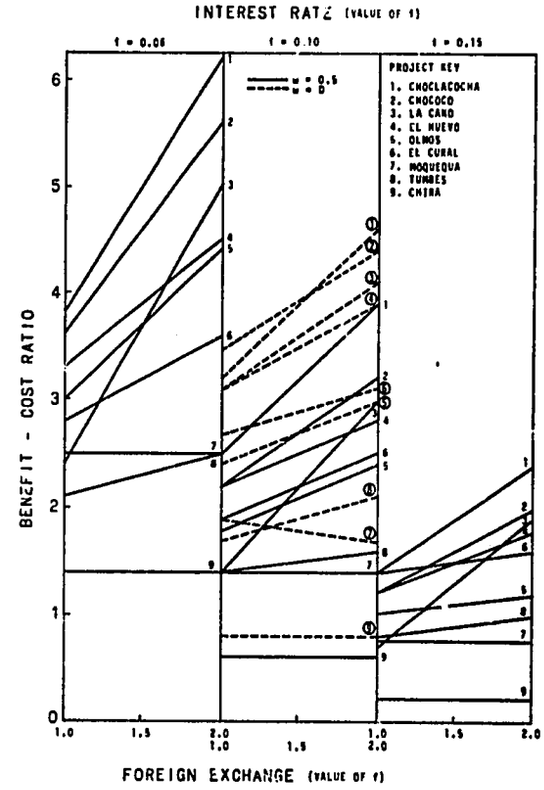

Figure 1. Sensitivity of the Benefit-Cost Ratio (BCR) to variations in foreign exchange, wage and discount rates. (See text)[a]

[a] Two projects (Antaura and Huanscolla) are not shown here because their relative ranking is invariant over the whole range of chosen shadow prices and discount rates. These two projects would occupy the first two ranks for any values of the shadow prices and discount rates selected here if they had been included in the sample.

Source: Computed on the basis of data in [3, 4, 6, 7, 11].

with and without operating and maintenance costs, but the variation in priorities was sufficiently small to exclude them from Table 3.

[9] Expressed in soles per dollar. Thus, since the official (market) exchange rate was equal to 26.8 soles=$1 in 1965; f=1.0 means the market rate; f=1.5 implies a shadow rate of 40.2 soles=$1; and f=2.0 implies a shadow rate of 53.6 soles=$1. The sol was devalued in 1967 and the present (1970) rate of exchange is 38.7 soles=$1.

change in the foreign exchange rate (f is increased).

Although changes in i, f, and w affect the absolute values of the BCR's substantially, the priorities are not greatly altered. For example, a reduction in unskilled labor costs from 50 percent of market costs to a price of zero (with $i=0.10$) increases the BCR's, but the priorities do not change over the selected exchange rate range.

The sensitivity analysis reveals an important result in the evaluation of Peruvian irrigation projects. By reducing the wage to at least 50 percent of the market price and by increasing the domestic currency cost of foreign exchange to at least 150 percent of the official rate, the choice of the interest rate between 6 and 15 percent has little effect on the project ranking. Thus, the use of shadow wage and exchange rates, especially with the range employed, effectively eliminates for Peruvian irrigation planners the difficult task of selecting an appropriate interest rate for discounting purposes.

An Irrigation Investment Program Related to Macroeconomic Objectives

The Peruvian National Planning Institute [5] specified without inferring priorities four major national objectives: (1) increased per capita income, (2) reduced dependence on international markets, i.e., balance of payments equilibrium, (3) reduced underemployment and unemployment, and (4) a more equitable distribution of income.

The process of project selection designed here involved the selection of appropriate investment criteria measuring the contribution of each project to the distinct national targets above. With respect to the income objective, two criteria are available—the BCR and the social marginal productivity of investment, SMP. The main difference between the BCR and the SMP is that the latter includes the indirect effects on the balance of payments. A final judgment as to whether the BCR or the SMP should be used to reflect the income objective would depend on the indirect balance of payments effect and any other secondary effect that might have been included in one criterion or the other.

The effect on the balance of payments of the project investment and operation is measured by the last component of the SMP (B/K) or the foreign exchange-investment ratio (F/K).

The goal of increased employment is represented by the employment-investment ratio. The income redistributional objective is not explicitly treated; nevertheless, the employment criterion might be used as an indirect measure of the increased income of unskilled low income workers in different functional groups and regions stemming from an investment program.[10]

Priorities among projects can be determined on the basis of each project's contributions to the aforementioned objectives. Two such ranking schemes are proposed here, one ordinal and the second cardinal.

In the ordinal ranking scheme, each project is ranked according to the value of the appropriate investment criterion reflecting each corresponding macroeconomic objective. Thus, for the current demonstration a mean ordinal ranking of the set of projects is obtained between the SMP and the BCR criteria and is then treated as the final ordinal ranking reflecting the income objective[11] (column 1, Table 4). Likewise, since there are only minor differences in the ordinal ranking obtained on the basis of the foreign exchange-investment ratio (F/K), given in the last column of Table 3, and the balance of payments component of the SMP (B/K), which can be inferred from Table 2, the mean ordinal ranking on the basis of these two criteria was computed and used to reflect the balance of payments objective (column 3, Table 4). The employment-investment ratio was used to reflect the goal of increased employment and a more equal income distribution (for the ordinal ranking corresponding to the employment objective, see column 6, Table 4).

A second alternative ranking method is formulated to reflect more clearly the cardinal differences of projects according to the investment criteria. Instead of ranking projects ordinally for each criterion, the ratio of the value of each project's performance for any

[10] Marglin [10] and Little and Mirrlees [9] infer that the goal of redistributing income can be indirectly represented by the employment effect of project investment and operation. For a recent study in which there is presented a framework to define and measure the redistributional effects among income classes of the single efficiency (output) objective, see Kalter and Stevens [8].

[11] For the irrigation projects, the mean ranking of the BCR and the SMP does not significantly affect the final ranking, but this result is unlikely for a more heterogeneous group of projects, e.g., a coastal irrigation project versus a jungle colonization project. Indeed, the final choice between the BCR and the SMP would depend upon the project analyst's judgment regarding the accuracy of the indirect balance of payments effects of the SMP and the possibility of including the indirect effects in the BCR.

Table 4. Ordinal project rankings by econonic objectives and cardinal measures of projects' contributions to economic objectives*

Income objective (Y)			Balance of payments objective (B)			Employment objective (E)		
Project	Ranking		Project	Ranking		Project	Ranking	
	Ordinal Y^p	Cardinal $\overline{Y}^p$		Ordinal B^p	Cardinal $\overline{B}^p$		Ordinal E^p	Cardinal $\overline{E}^p$
Huanscolla	1	2.26	Huanscolla	1	3.50	Huanscolla	1	1.52
Antaura	2	1.77	Antaura	2	1.77	El Cural	2	1.35
El Huevo	3	1.12	Olmos	3	1.33	El Huevo	3	1.29
Choclacocha	4	1.13	La Cano	4	1.25	Choclacocha	4	1.07
El Cural	5	1.06	Chococo	5	1.19	La Cano	5	0.99
Chococo	5	1.06	El Cural	6	1.08	Chococo	6	0.97
La Cano	7	0.99	El Huevo	7	0.98	Olmos	7.5	0.89
Olmos	8	0.83	Tumbes	8	0.53	Tumbes	7.5	0.89
Tumbes	9	0.49	Choclacocha	9	0.28	Moquequa	9	0.80
Moquequa	10	0.40	Moquequa	10	−0.08	Antaura	10	0.78
Chira	11	−0.09	Chira	11	−0.78	Chira	11	0.46

* Source: Based on Tables 2 and 3. For explanation of methodology used to compute ordinal and cardinal values see text.

given investment criterion to the mean value of all projects for the same criterion was computed. The advantage of using the latter measure as a decision rule in the project selection process is that, in contrast to the ordinal method, it avoids discriminating against projects which are clearly superior in terms of the magnitude of given investment criteria but only slightly inferior in terms of other criteria.[12]

Thus, for project p, the cardinal magnitude for each criterion is determined

$$\overline{BCR}^p = \frac{BCR^p}{\sum_{p=1}^{n} \frac{BCR^p}{n}} \tag{8}$$

where $p=1, 2, \ldots, n$ projects (in the specific example $n=11$); and BCR^p is the value of the BCR for project p and,

$$\overline{SMP}^p = \frac{SMP^p}{\sum_{p=1}^{n} \frac{SMP^p}{n}} \tag{9}$$

and similarly for the remaining criteria ($\overline{B/K}$), ($\overline{F/K}$), and ($\overline{L/K}$).

[12] For example, assume (1) two projects, A and B; (2) two investment criteria (reflecting two macroeconomic objectives) α and β, which are equally weighted. If project A has a magnitude of α which is twice as large as that of project B, while B's performance according to criterion β is only 1 percent higher than that of A, an ordinal comparison of these two projects would fail to distinguish between them since their mean ranking would be the same. On the other hand, a decision rule based on cardinal values of the investment criteria would clearly select A over B.

The cardinal measures of each project's relative contribution to the macroeconomic objectives are obtained in a similar way as in the case of the ordinal rankings by taking the arithmetic average between $\overline{BCR}^p$ and $\overline{SMP}^p$ to reflect the income objective and between $\overline{B/K}$ and $\overline{F/K}$ to reflect the balance of payments objective.

Table 4 gives the resulting ordinal project rankings according to the three economic objectives and the cardinal measures of each project's contributions to the latter.

Investment criteria (usually limited to the BCR in pre-investment studies) are typically unidimensional and partial in nature. They tend to be applied simply to individual projects in the process of selection. On the other hand, national developmental policy objectives are macroeconomic and multidimensional by their very nature. Hence, an attempt is made below to formulate a methodology permitting a quantitative evaluation and selection of projects, given the major policy objectives of the government. A national preference function including the major policy targets can be postulated. The authors have chosen to express the preference function as a linear function of the three major policy objectives mentioned above.[13] It is clear that the relative weights attached to these macroeconomic targets can change depending on the initial conditions and the preferences of the decision makers.

[13] A number of macroeconomic policy models have been constructed which specified preference functions. For an example of such a model, using a linear preference function, see Van Eijk and Sandee [15]; for a policy model using a quadratic preference function, see Theil [12].

$Y^p(\overline{Y}^p)$ are the ordinal ranks (cardinal measure) of each project according to the income objective, while $B^p(\overline{B}^p)$ and $E^p(\overline{E}^p)$ stand for the corresponding ordinal ranks (cardinal measures) of the projects in terms of the balance of payments and employment objectives. The ordinal range for each of the above variables is from 1 to 11 since there are 11 projects in the sample. The cardinal range depends upon the relative magnitudes of the criteria shown in Table 4. A weighted linear function of these objectives could then be used as a decision rule in the selection of projects according to their weighted contributions (ordinal and then cardinal) to the major national economic goals, as follows:

$$R^p = yY^p + bB^p + eE^p \tag{10}$$

or for the cardinal rule

$$\overline{R}^p = y\overline{Y}^p + b\overline{B}^p + e\overline{E}^p \tag{10.1}$$

where $p = 1, 2, \cdots, 11$

and y, b, and e stand for the relative weights attached to the corresponding objectives so that

$$y + b + e = 1. \tag{11}$$

A final weighted ranking can be defined for each set of weights, with index j as

$$R_j = R_j(y, b, e) \tag{11.1}$$

or

$$\overline{R}_j = \overline{R}_j(y, b, e) \qquad j = 1, 2, 3, 4. \tag{11.2}$$

Four sets of weights are considered (Table 5). In the ranking alternative R_1, each goal receives an equal weighting in the policy maker's preference function, and for the remaining alternatives (R_2, R_3, and R_4) each objective in turn is weighted twice as heavily as the remaining objectives. It is, of course, clear that a parametric test of the sensitivity of the final ranking (R_j) to variations in the welfare weights i.e., in j, can be undertaken.

Table 5. Alternative preference weights

R_j (or $\overline{R}_j$)	y	b	e	$y+b+e=1$
R_1	0.33	0.33	0.33	1.00
R_2	0.50	0.25	0.25	1.00
R_3	0.25	0.50	0.25	1.00
R_4	0.25	0.25	0.50	1.00

Table 6 provides the resulting project ordering under the four weighting schemes specified previously to test the sensitivity of these rankings to changes in welfare weights. It can be seen that the irrigation project priorities derived by the four weighting schemes are remarkably similar. The smaller sierra and coastal projects are ranked consistently high and, with the exception of Choclacocha, the medium-sized projects do not perform well. The small projects perform uniformly well given the major national objectives irrespective of the choice of weights. The one large project (Olmos) maintains a uniform ranking as well. Hence, in this case Peruvian policy makers can look to small sierra and coastal projects to satisfy best the prevailing objectives over a wide range of different welfare weights.

A comparison of the rankings in Table 6 shows that they are only very marginally affected by applying the cardinal rather than the ordinal decision rule to the present set of projects. However, important additional information is provided regarding the relative quantitative extent to which any given project compares with others under various alternative

Table 6. Relative project priorities according to four alternative weighting schemes of macroeconomic objectives, cardinal and ordinal methods[a]

R_1	$\overline{R}_1$	R_2	$\overline{R}_2$	R_3	$\overline{R}_3$	R_4	$\overline{R}_4$
Huanscolla	2.43	Huanscolla	2.39	Huanscolla	2.70	Huanscolla	2.20
El Huevo	1.13	El Huevo	1.13	Antaura	1.52	El Cural	1.21
El Cural	1.15	Antaura	1.52	El Cural	1.14	El Huevo	1.17
Antaura	1.44	El Cural	1.14	La Cano	1.12	La Cano	1.06
Chococo	1.07	Chococo	1.07	El Huevo	1.09	Choclacocha	0.89
La Cano	1.07	La Cano	1.06	Chococo	1.10	Chococo	1.05
Choclacocha	0.82	Choclacocha	0.90	Olmos	1.10	Antaura	1.28
Olmos	1.01	Olmos	0.97	Choclacocha	0.69	Olmos	0.99
Tumbes	0.62	Tumbes	0.59	Tumbes	0.60	Tumbes	0.69
Moquequa	0.37	Moquequa	0.38	Moquequa	0.26	Moquequa	0.48
Chira	−0.14	Chira	−0.13	Chira	−0.30	Chira	0.01

[a] Projects are listed by name in their ordinal ranking and in each case the numerical value gives the cardinal measure. Based on Table 4.

macroeconomic preference schemes. Thus, for example, the test reveals that Huanscolla is far superior in terms of its contribution to the macroeconomic objectives per unit of investment than any other project. In the same vein, it can be seen that five projects are very closely clustered in the third weighting alternatives ($\overline{R}_3$) between a weighted index of 1.09 (El Huevo) and 1.14 (El Cural). Given the marginal difference separating these projects, no clear-cut choice presents itself within this subset if the relevant weights are those of alternative R_3.

Summary and Conclusions

A method of selecting investment project priorities has been presented and applied to 11 Peruvian irrigation projects. Central to this analysis is a function that explicitly incorporates the national economic targets with appropriate weights. Initially, a specific investment criterion is paired with each development objective, be it income generation, employment creation, or balance of payments equilibrium. A ranking function which combines these various objectives is then defined and expressed in ordinal and cardinal terms. This ranking function appears to be a very general and applicable device which can be extended easily to incorporate as many goals as necessary or desired as long as the corresponding investment criteria can be specified and computed.

Each investment criterion yields a set of priorities. Approximations of the shadow prices of labor, capital, and foreign exchange are introduced and the sensitivity of the benefit-cost ratio to variations in these prices is undertaken. This analysis revealed that although the absolute magnitude of the benefit-cost ratios is sensitive to changes in the shadow prices, the priorities to a significant degree are invariant to changes in the rate of interest when combined with shadow wage and exchange rates—at least over a fairly wide range of the latter.

With respect to the specific irrigation project priorities, it is shown that the performance of the small sierra and coastal irrigation projects is consistently higher than that of the other projects in terms of their estimated contributions to the macroeconomic objectives of increased income and employment and foreign exchange generation. The medium and large projects appear to be less desirable investment choices for policy makers. Obviously, the above investment priorities can change to the extent that the weights attached to the national economic objectives also change. In any case, this type of adjustment can be incorporated easily into the ranking function.

Although the methodology developed in this paper was applied only to a set of irrigation projects in Peru, it is generally applicable to a wide variety of macroeconomic situations and projects.

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