PETER G. WARR*

BENEFIT-COST ANALYSIS WITH MARKET DISTORTIONS: AN INDONESIAN CASE STUDY†

A critical aspect of the economic evaluation of public projects is the valuation of the commodities they use and produce. This valuation becomes difficult when the existence of market distortions and/or market failures suggests that observable market prices are potentially misleading indicators of social valuations. In such cases, market prices are potentially inappropriate guides for public investment decisions, and benefit-cost analysis requires an alternative method of valuation. This is the role of shadow pricing. The purpose of this paper is to explore the implications of shadow pricing for the evaluation of four investment alternatives recently faced by the government of Indonesia. The shadow pricing exercise performed leads to the estimation of the social benefits and costs of these public investments in the presence of market distortions.[1] In particular, the market distortions of interest are: (a) a divergence between the social rate of return on capital and the social rate of discount; (b) a divergence between the wage paid in the advanced sector of the economy and the social opportunity cost of labor; and (c) a divergence between the official exchange rate and the social value of a unit of foreign exchange. Income distributional considerations are ignored.

First, the physical and economic characteristics of the investment alternatives are set out, and the literature that has recently appeared on their relative merits is briefly reviewed. Next, the decision criteria that are appropriate for evaluating public investments of this kind are considered, and the shadow prices to be used in the evaluation are derived and estimated. Finally, the results of the economic evaluation under varying sets of assumptions are presented and summarized.

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[1] Of the various studies propounding this approach, the analysis in this paper is most compatible with that found in Dasgupta, Marglin and Sen (2). There are some notable differences, however.

THE INVESTMENT ALTERNATIVES

The four investment alternatives to be analyzed are rice milling facilities of varying capital/labor intensities. The physical characteristics of these facilities were recently described in some detail in an engineering consultant firm's report to the government of Indonesia (*12*). Some physical and economic characteristics of these facilities, together with those of the traditional technique, hand-pounding, are summarized in Table 1.[2] In the table, the various inputs required and outputs produced are expressed per thousand metric tons of rough rice input per year.

The consulting firm's report gave little attention to the economic merits of these alternatives, concerning itself mainly with their engineering efficiency in the extraction of milled rice from the rough rice input. This focus led to the recommendation of an investment package that concentrated 75 percent of its milling capacity in the two most capital-intensive of the four alternatives (C and D above). The wisdom of this recommendation was challenged in later work by Timmer. (See *7*, *8*, *9*, and *10*.) Timmer pointed out that the recommendation was based at best on narrow engineering efficiency criteria and at worst on the simple presumption that the more capital-intensive techniques must be desirable since they are more "modern."

To analyze the economic merits of these four milling techniques relative to the traditional technique, hand-pounding, Timmer constructed a unit isoquant in value added from the data given in Table 1 and the assumption that the rough rice input cost *rupiahs* (Rp.) 18 per kilogram. This isoquant gave the various combinations of capital cost and workers employed per year required to produce a unit of value added in domestic prices (value of milled rice output minus value of rough rice input) for each of the five techniques. The cost-minimizing point on this isoquant was then found graphically by drawing a series of lines the slope of which reflected the present value of the wage bill for employing a worker for a period of 50 years, and obtaining a corner solution. After considering three alternative wage rates and three rates of discount, Timmer concluded that the small rice mill (A) was the optimal technique except under highly unrealistic assumptions.

In this study the four alternative milling facilities are considered explicitly as alternative government investments. Because public sector investment in milling facilities is unlikely to increase the total amount of rough rice produced it is assumed that any rice milled in the public sector is diverted in full from some other milling activity. Recent experience suggests that this activity would be hand-pounding with hired female labor, since that activity is rapidly vanishing as privately and publicly owned mechanical milling facilities expand.[3] To analyze the welfare effects of diverting rice from hand-pounding to a publicly-owned rice

[2] In the Weitz-Hettelsater report and Timmer (*9*), these facilities are identified by the symbols C, G, H-1, K-1, and Z, respectively, rather than A, B, C, D, and H, as above. See these sources for further details on the characteristics of these facilities. The two different unit labor requirements for hand-pounding are derived from Timmer (*9*, p. 27) and Collier *et al.* (*1*, p. 112), respectively. No data are available on maintenance costs for the various facilities, so these costs are ignored here.

[3] There is disagreement, however, on the amount of hand-pounding with hired labor that remains. See Timmer (*8* and *10*) and Collier *et al.* (*1*).

TABLE 1.—CHARACTERISTICS OF RICE MILLING TECHNIQUES
(thousand metric tons of rough rice input per year)

	Small rice mill (A)	Large rice mill (B)	Small bulk facility (C)	Large bulk facility (D)	Hand-pounding (H)
Milled rice produced *(metric tons)*	590	630	650	670	570
Number of operative workers employed per year	12	6.4	3.75	1.81	{22 / 107}
Construction cost *(million Rp.)*	3.059	11.151	19.390	37.159	0
Percentage of construction cost requiring foreign exchange	38.3	63.7	69.5	73.0	—
Price received for milled rice *(Rp. per kg.)*	45	48	49.5	50	40

*Data from C. P. Timmer, "Choice of Technique in Indonesia," *Occasional Papers*, Center for International Affairs, Harvard University, 1974; Weitz-Hettelsater Engineers, *Rice Marketing and Storage: Republic of Indonesia*, Kansas City, Mo., 1972; and W. L. Collier *et al.*, "Choice of Technique in Rice Milling on Java: A Note," *Bull. Indonesian Econ. Studies*, Canberra, March 1974.

mill, it is necessary to value: the milled rice produced, the hand-pounded rice foregone, the resources used by the mill, and the resources released from hand-pounding.

No free trade in rice occurs across Indonesia's boundaries, since all trade is arranged by intergovernmental agreements. It is assumed in this study that marginal changes in the quantity of milled rice produced in the public sector would not affect these agreements. Hence, for the purposes of benefit-cost analysis, rice is considered to be a nontraded good, even though its domestic price is often affected by changes in the international price.[4] The only traded goods involved in the evaluation of these rice-milling projects are the imported

[4] The relevant issue here is whether public production would, or would not, affect trade at the margin. Either assumption could reasonably be made, but fortunately this makes little difference. In 1975 prices, once adjustment is made for transport costs from Bangkok and quality differences, the two prices are fairly close, with the import price slightly exceeding the domestic price. We perform a sensitivity analysis on the price of rice in a later section.

capital goods required in the initial construction. The shadow price of foreign exchange is relevant only with respect to the valuation of these commodities. All construction costs are assumed to be incurred in year zero, and the streams of labor input, rough rice input, and milled rice output shown in Table 1 are assumed to be constant over a 20-year project life, after which project capital has zero scrap value. It is assumed that the only usable resource released from hand-pounding is hired female labor.

DECISION CRITERION FOR CHOICE OF TECHNIQUE

Let the government's welfare function be given by

$$W(C_0, C_1, \ldots, C_\tau),$$

where C_τ is aggregate consumption in year τ, $\tau = 0$ is the present, and $\tau = T$ is a finite but distant horizon. A small change in welfare is given by

$$dW = \sum_{\tau=0}^{T} \frac{\partial W}{\partial C_\tau} dC_\tau.$$

Now, writing W_τ for $\partial W/\partial C_\tau$, the social rate of discount may be defined as

$$i = \frac{W_{\tau-1}}{W_\tau} - 1,$$

which we will assume to be constant over time. By rearranging we have

$$\frac{W_\tau}{W_{\tau-1}} = \frac{1}{1+i}.$$

Normalizing by setting $W_0 = 1$ and noting that

$$W_\tau = \frac{W_\tau}{W_{\tau-1}} \cdot \frac{W_{\tau-1}}{W_{\tau-2}} \cdots \frac{W_2}{W_1} \cdot \frac{W_1}{W_0} \cdot W_0,$$

it is easily verified that

$$dW = \sum_{\tau=0}^{T} \frac{dC_\tau}{(1+i)^\tau}.$$

We now define the shadow price of commodity m at time t, S_t^m, to be the total effect of a change in its public production at time t, x_t^m, on social welfare, discounted to the present. Thus

$$S_t^m = \frac{dW}{dx_t^m} = \sum_{\tau=t}^{T} \frac{\partial W}{\partial C_\tau}\frac{dC_\tau}{dx_t^m} = \sum_{\tau=t}^{T} \frac{1}{(1+i)^\tau}\frac{dC_\tau}{dx_t^m}.$$

It is now clear that the effect on social welfare of public production using technique k is expressed by the net present value of the stream of aggregate consumption that it generates. Denoting this by N_k,

$$N_k = \sum_{t=0}^{T} \sum_{m} S_t^m x_{kt}^m.$$

If the public sector was not constrained in its investment behavior, it clearly should continue to invest in every available rice-milling technique for which $N_k > 0$. Suppose that it faces two kinds of constraints, one on the total supply of rough rice that may be diverted from hand-pounding in year t, $\bar{G}_t$,

$$\bar{G}_t - \sum_k x_{kt}^G \geq 0, \qquad t = 1, \ldots, 20,$$

and another on the total volume of investment that may be financed, $\bar{K}$,

$$\bar{K} - \sum_k x_k^K \geq 0.$$

To obtain the necessary conditions for optimal public production in rice milling we maximize $\sum_k N_k$ subject to the above two constraints and the non-negativity of x_{kt}^e, x_{kt}^G and x_k^K for all k and t. We thus formulate the Lagrangian

$$L = \sum_k \sum_{t=1}^{20} \{S_t^k x_{kt}^k - S_t^e x_{kt}^e - S_t^G x_{kt}^G\}$$

$$- \sum_k S^K x_k^K + \sum_{t=1}^{20} \lambda_t^G \left(\bar{G}_t - \sum_k x_{kt}^G\right) + \lambda^K \left(\bar{K} - \sum_k x_k^K\right),$$

where S_t^k, S_t^e, S_t^G and S^K are the shadow prices of milled rice of type k, labor employed, rough rice, and capital, respectively.

From the Kuhn-Tucker conditions for a stationary point we have

$$x_{kt}^e \left(S_t^k \frac{\partial x_{kt}^k}{\partial x_{kt}^e} - S_t^e \right) = 0, \qquad \text{all } k;\ t = 1, \ldots, 20;$$

$$x_{kt}^G \left(S_t^k \frac{\partial x_{kt}^k}{\partial x_{kt}^G} - \lambda_t^G - S_t^G \right) = 0, \qquad \text{all } k;\ t = 1, \ldots, 20;$$

$$x_k^K \left(\sum_{t=1}^{20} S_t^k \frac{\partial x_{kt}^k}{\partial x_k^K} - \lambda^K - S^K \right) = 0, \qquad \text{all } k.$$

For each of these expressions, either the term inside the parentheses must be zero or the input level outside the parentheses must be zero. In the latter case the technique is not used at all since we assume that a zero level of any input ensures zero output. When only one of the two constraints considered is binding (as we would normally expect), only one technique will be used. Equating the term in parentheses in each of the above equations to zero we find that at the optimum

$$\frac{\partial x_{kt}^k}{\partial x_{kt}^e} = \frac{S_t^e}{S_t^k}, \qquad t = 1, \ldots, 20;$$

$$\frac{\partial x_{kt}^k}{\partial x_{kt}^G} = \frac{S_t^G + \lambda_t^G}{S_t^k}, \qquad t = 1, \ldots, 20;$$

and

$$\sum_{t=1}^{20} S_t^k \frac{\partial x_{kt}^k}{\partial x_k^K} = S^K + \lambda^K.$$

Thus the relative shadow prices of the various commodities should reflect their direct welfare costs or benefits plus, in the case of inputs subject to supply constraints, a premium which reflects the welfare costs of those supply constraints. It is easily verified that

$$\lambda^K = \frac{\partial W}{\partial \bar{K}} \qquad \text{and} \qquad \lambda_t^G = \frac{\partial W}{\partial \bar{G}_t}.$$

The appropriate decision criterion is thus

$$\max_k \sum_{t=1}^{20} \{S_t^k x_{kt}^k - S_t^e x_{kt}^e - (S_t^G + \lambda_t^G) x_{kt}^G\} - (S^K + \lambda^K) x_k^K$$

or

$$\max_k N_k - \sum_{t=1}^{20} \lambda_t^G x_{kt}^G - \lambda^K x_k^K,$$

where N_k is defined as before.

If the constraint on the supply of rough rice at time t is binding, then $\lambda_t^G > 0$, and x_{kt}^G will be the same no matter which technique is chosen. Likewise, if the investment constraint is binding, $\lambda^K > 0$ and x_k^K will be the same no matter which technique is chosen. Suppose the investment constraint is binding, but the rough rice constraint is not. Since x_k^K must then be the same no matter which technique is chosen, the ranking of techniques according to the above criterion cannot be changed by dividing through by x_k^K. This leaves us with the criterion

$$\max_k \frac{N_k}{x_k^K},$$

since λ^K is the same for all techniques and can be ignored. If the constraint on rough rice input is binding and x_{kt}^G is constant over time at x_k^G for each technique (which is so for the facilities considered here, given the initial investment), but the investment constraint is not binding, we are left with the criterion

$$\max_k \frac{N_k}{x_k^G}.$$

It is now clear that if the investment behavior of the government is constrained by the supply of a single input, alternative investments may be ranked by considering their returns to that input. This is done by comparing the amount of net present value generated per unit of that input, where the dual variable corresponding to that constraint has not been considered in the calculation of net present value. This comparison can produce only a ranking, however. To determine which of the investments should be undertaken, if any, it is necessary to compute the value of the dual variable concerned. Furthermore, when more than one constraint is binding, not even a ranking can be achieved without knowledge of the relative values of the dual variables corresponding to the various constraints.

This result provides some insight on the implications of the way a project is normally defined in benefit-cost analysis. When there is some unique natural resource such as a dam site on a river, it seems natural to compare alternative dams by choosing the one which returns the highest net present value to that dam site. This procedure is correct provided that the only binding constraint on the supply of inputs for dam construction is the uniqueness of the dam site. Otherwise, in order to rank the alternatives it is necessary to know either the value of the dual variable corresponding to the dam site relative to those corresponding to the other constraints or the absolute values of each of the dual variables but one.

DERIVATION OF SHADOW PRICES

In this section we derive the shadow prices to be used in the choice of technique exercise. The inputs used by the four milling techniques are capital, labor, foreign exchange, and rough rice. Rough rice is valued at the value of the hand-pounded rice foregone when it is diverted from hand-pounding to mechanical milling minus the value of the hired labor released. The final consumption goods to be valued are milled and hand-pounded rice. Except in the cases of capital and foreign exchange, we derive below the various shadow prices in terms of aggregate consumption in year t, $S_{(t)}^m$. This shadow price can be expressed in terms of the numeraire, aggregate consumption in the initial period (year zero), by writing

$$S_t^m = (1+i)^{-t} S_{(t)}^m.$$

Shadow price of capital

Recalling from the previous section that the shadow price of a commodity is, given the assumptions listed, the present value of the stream of aggregate consumption it generates, the shadow price of capital used in a public investment is the present value of the stream of aggregate consumption foregone by its use, or

$$S^K = \sum_{t=0}^{T} \frac{1}{(1+i)^t} \frac{dC_t}{dx_k^K}.$$

Consider first the shadow price of a unit of investment, S^I, made in that part of the economy where the funds used for public investment are obtained. We will suppose, for simplicity, that this alternative investment yields an annuity of value q. That is, Rp. 1 invested in year zero yields Rp. q each year indefinitely. q is sometimes referred to as the marginal productivity of capital. Suppose that a proportion c^2 of these annual returns is consumed, and the remainder is reinvested. These reinvested funds are themselves valued at S^I and hence

$$\frac{dC_t}{dx_k^K} = c^2q + (1-c^2)qS^I, \qquad 0 < c^2 \leq 1$$

and

$$S^I = \sum_{t=0}^{T} \frac{c^2q + (1-c^2)qS^I}{(1+i)^t}.$$

We now use the fact that, for $i > 0$,

$$\lim_{T \to \infty} S^I = \frac{c^2q + (1-c^2)qS^I}{i},$$

and solve for S^I, giving, for $i > (1-c^2)q$,

$$S^I = \frac{c^2q}{i-(1-c^2)q}.$$

If capital employed in the investment considered comes entirely out of investment elsewhere, then $S^K = S^I$; but if a proportion c^3 of this capital comes out of alternative consumption with $1-c^3$ coming out of investment, then

$$S^K = c^3 + (1-c^3)S^I, \qquad 0 \leq c^3 \leq 1.$$

The parameters c^2, c^3, and q can potentially be estimated empirically. But, as earlier analysis implies, the social rate of discount, i, involves a value judgment. In this study we treat the social rate of discount as an unknown exogenous parameter and attempt to show the implications of different discount rates for choice of technique.

It is possible to argue, however, that in economies where the rate of investment is determined primarily by private decision makers acting independently, $i \leq q$. Suppose that the capital market functions efficiently and that the private rate of discount, i^p, as expressed in market behavior, and the private rate of return, q^p, are equated. We can then argue that $i \leq i^p$, since i reflects society's concern for the welfare of future generations, whereas i^p does not.[5] Furthermore, we can argue that normally $q \geq q^p$ in a dual economy, since market wages in the advanced sector exceed the social opportunity cost of labor, and hence the social rate of return to investment exceeds the private rate of return.[6] It follows that

$$i \leq q.$$

Clearly, $i < q$ implies $S^I > 1$.

Shadow price of labor employed

We have shown that the shadow price of a worker employed in a public investment project in year t, in terms of aggregate consumption in year zero, is given by

$$S_t^e = \sum_{\tau=t}^{T} \frac{1}{(1+i)^\tau} \frac{dC_\tau}{dx_{kt}^e}.$$

Writing w_k for the wage paid in technique k, w_h for the wage paid in hand-pounding, which we assume to be equal to the worker's marginal product there, and c^1 for workers' propensity to consume, we then obtain, using aggregate consumption in year t as numeraire,

$$S_{(t)}^e = w_k\{c^2 + (1-c^2)S^I\} - c^1(w_k - w_h) - (1-c^1)(w_k - w_h)S^I.$$

The first term in this expression is the cost in terms of aggregate consumption in year t of paying the worker a wage of w_k out of government revenue.[7] The second term is the social valuation in terms of aggregate present consumption if that part of the worker's increased income that he consumes, and the third term is the social valuation of his additional savings.[8] Rearranging, we have

$$S_{(t)}^e = w_k(c^1 - c^2)(S^I - 1) + w_h\{c^1 + (1-c^1)S^I\}.$$

[5] For a fuller elaboration of this argument, see Sen (4).

[6] See Sen (6, pp. 493-4) and the references cited therein.

[7] It is important to recall that income distributional judgments are being ignored here. Only aggregate consumption is being considered.

[8] The author has analyzed the relationship between suboptimal savings and the shadow price of labor in more detail in Warr (11).

Shadow price of labor displaced

Given the framework adopted here, the shadow price of a worker displaced from hand-pounding in year t, in terms of aggregate consumption in year t, $S^d_{(t)}$, is the value of his contribution to production in his alternative employment. Writing w_a for the wage paid in the alternative employment, which we will assume to be equal to his marginal product there, we have

$$S^d_{(t)} = w_a\{c^1 + (1 - c^1)S^I\}.$$

Shadow price of foreign exchange

Suppose a rupiah's worth of foreign exchange is spent on importing the traded commodity z. The number of units of commodity z this foreign exchange will purchase is given by $1/p^z_c$, where p^z_c is the c.i.f. import price of commodity z at the official exchange rate. The contribution each unit makes to our numeraire, aggregate consumption, is given by its domestic price, p^z, as faced by consumers. This rupiah's worth of foreign exchange spent on commodity z thus contributes p^z/p^z_c to aggregate consumption. If, instead, a rupiah's worth of foreign exchange is spread over Z commodities, where α^z is the proportion spent on good z, then the shadow price of foreign exchange is given by

$$S^F = \sum_{z=1}^{Z} \alpha^z \frac{p^z}{p^z_c}.$$

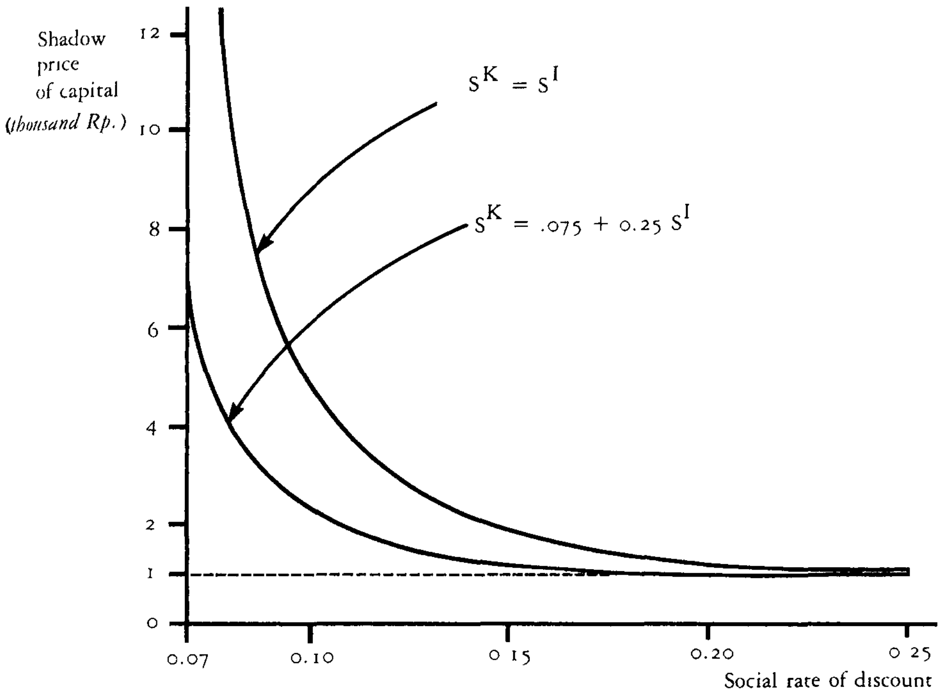
Shadow prices of milled and hand-pounded rice

Since the market price of a nontraded final consumption good measures its contribution to aggregate consumption, the shadow prices of the consumption goods, milled and hand-pounded rice, used in this study are their market prices.

ESTIMATION OF SHADOW PRICES

The main parametric assumptions to be used in this paper are summarized in Table 2. Capital used in construction of rice-milling projects is assumed to be derived from aid funds from a foreign government. These aid funds could be made available in three different ways: (a) they could be given for use by the Indonesian government for whatever purpose it desired, (b) they could be restricted to use for general investment, or (c) they could be tied to specific investment projects. In case (a) these funds are indistinguishable from general government revenue. We assume that 75 percent of these funds come out of government consumption and 25 percent out of government investment (i.e., $c^3 = 0.75$) which yields an annual return of 25 percent. Of these returns 75 percent are consumed and 25 percent reinvested, etc.Thus, $S^K = 0.75 + 0.25\, S^I$. In case (b) funds used for investment in rice milling come entirely out of alternative government investment (i.e., $c^3 = 0$), and then $S^K = S^I$. In case (c) the terms under which the aid funds are given become relevant and this case is explored in the following section.

CHART 1.—SHADOW PRICE OF CAPITAL AND THE RATE OF DISCOUNT



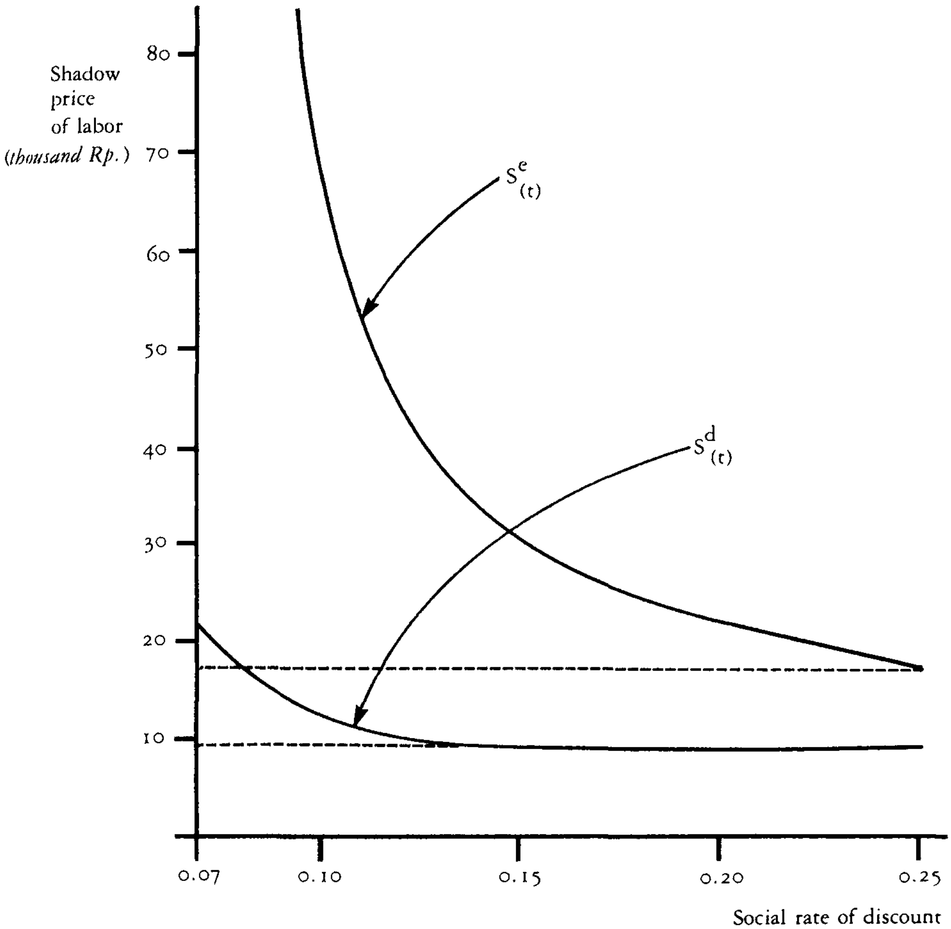
The range of discount rates considered here is 0.07 to 0.25. For $i \leq 0.0625$ the shadow price of investment is no longer defined, and so 0.07 seems a natural lower bound. The upper bound of 0.25 seems appropriate in view of our earlier argument that $i \leq q$. The values of the shadow price of capital in both cases (a) and (b) above are tabulated (though not in that order) in the first two columns of Table 3, and plotted in Chart 1. Table 2 also shows that wages paid in rice milling are substantially above the wages paid in hand-pounding and in the alternative employment, rice harvesting. Table 3 shows, in the third and fourth columns, the shadow prices of labor employed in and displaced by rice milling, respectively. These shadow prices are plotted in Chart 2. The final two columns of Table 3 show the relative shadow prices of labor employed and capital for various rates of discount. When $S^K = S^I$ the shadow price of labor relative to capital falls as the rate of discount falls, but when $S^K = 0.75 + 0.25\ S^I$, the opposite occurs.

It has not been possible to obtain the price information necessary to apply the expression for the shadow price of foreign exchange developed earlier. Indonesia does not seem to have a seriously distorted exchange rate, however, and the only reason for suspecting $S^F > 1$ is the existence of tariffs. Nominal tariff rates have been quite high, until a recent (1973) liberalization, many being at least 100 percent, but smuggling abounds and domestic prices seldom rise more than 20-30 percent above c.i.f. prices at the official exchange rate. We assume, therefore, that $S^F = 1.2$.

TABLE 2.—MAJOR PARAMETRIC ASSUMPTIONS

Parameter	q	i	c^1	c^2	c^3	w_k	w_b	w_a	S^F
Value	0.25	0.07-0.25	0.95	0.75	0 0.75	57,000	17,000	9,500	1.2
Units	—	—	—	—	—	Rp./yr.	Rp./yr.	Rp./yr.	—

CHART 2.—SHADOW PRICE OF LABOR AND THE RATE OF DISCOUNT



CHOICE OF TECHNIQUE RESULTS

In Charts 3, 4, and 5 we plot the relationship between net present value and the social rate of discount for each technique. The data in Table 1 and the shadow prices in Table 3 have been used, but with six different sets of assumptions.[9] In Chart 3, panel (a), it is assumed that the supply of rough rice input is constraining the government's investment behavior, so the results are expressed in net present value (in Rp. millions) per thousand tons of rough rice input. It is further assumed that $S^K = S^l$ and that all facilities operate at full capacity. Panel (b) is based on the same assumptions, except that all facilities operate at only 75 percent

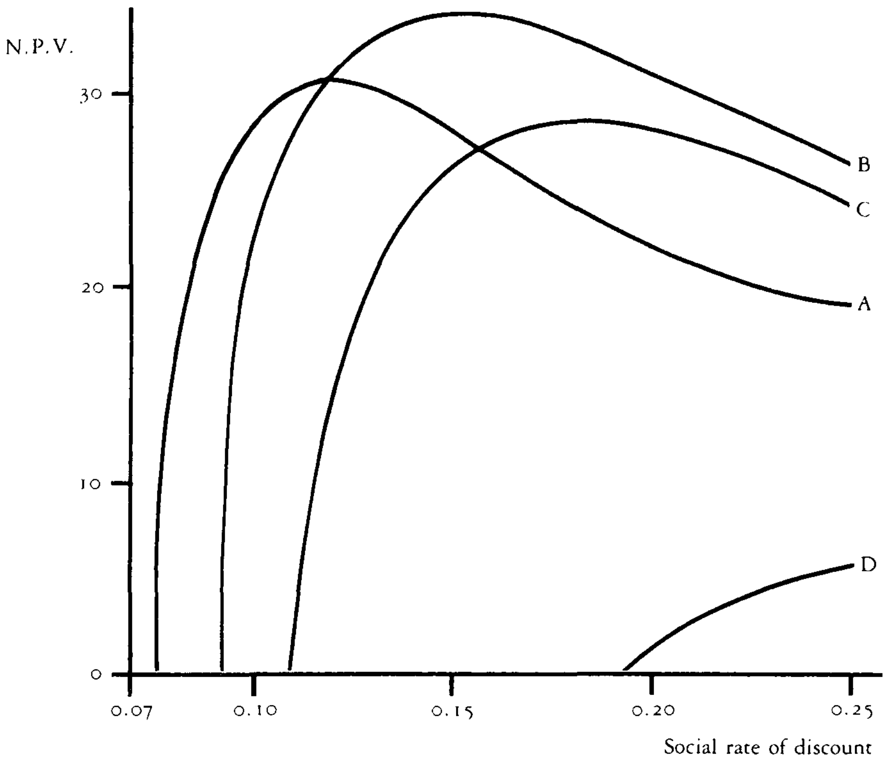
[9] We assume that 107 workers are released from hand-pounding per 1,000 tons of rough rice diverted from that activity.

TABLE 3.—VALUES OF MAIN SHADOW PRICES FOR DIFFERENT RATES OF DISCOUNT

Social rate of discount (i)	S^I	$0.75+0.25S^I$	S^e_t	$S^d_{(t)}$	$S^e_{(t)}/S^I$	$S^e_t/(0.75+0.25S^I)$
0.25	1.000	1.000	17.00	9.50	17.00	17.00
0.24	1.056	1.014	17.69	9.53	16.75	17.45
0.23	1.119	1.030	18.46	9.56	16.50	17.92
0.22	1.190	1.048	19.33	9.59	16.24	18.44
0.21	1.271	1.068	20.32	9.63	15.99	19.03
0.20	1.364	1.091	21.46	9.67	15.73	19.67
0.19	1.471	1.118	22.77	9.72	15.48	20.37
0.18	1.596	1.149	24.30	9.78	15.23	21.15
0.17	1.744	1.186	26.11	9.85	14.97	22.02
0.16	1.923	1.231	28.31	9.94	14.72	23.00
0.15	2.143	1.286	31.00	10.04	14.47	24.11
0.14	2.420	1.355	34.40	10.18	14.21	25.39
0.13	2.778	1.445	38.78	10.35	13.96	26.84
0.12	3.261	1.565	44.70	10.57	13.71	28.56
0.11	3.947	1.737	53.10	10.90	13.45	30.57
0.10	5.000	2.000	66.00	11.40	13.20	33.00
0.09	6.818	2.454	88.27	12.26	12.95	35.97
0.08	10.714	3.437	136.00	14.13	12.70	39.57
0.07	25.000	7.000	311.00	20.90	12.44	44.43

CHART 3.—NET PRESENT VALUE PER THOUSAND TONS OF ROUGH RICE WITH $S^K = S^I$ (*million Rp.*)

a. Operating at full capacity



b. Operating at 75 percent capacity

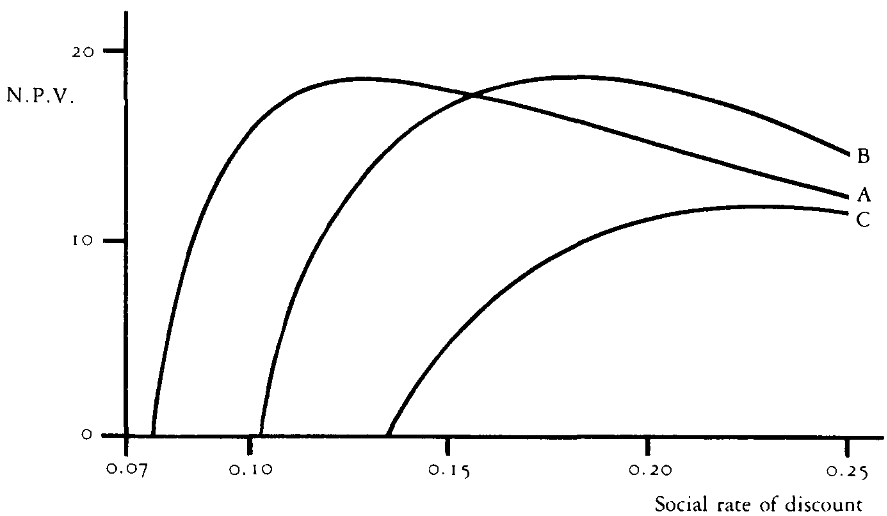
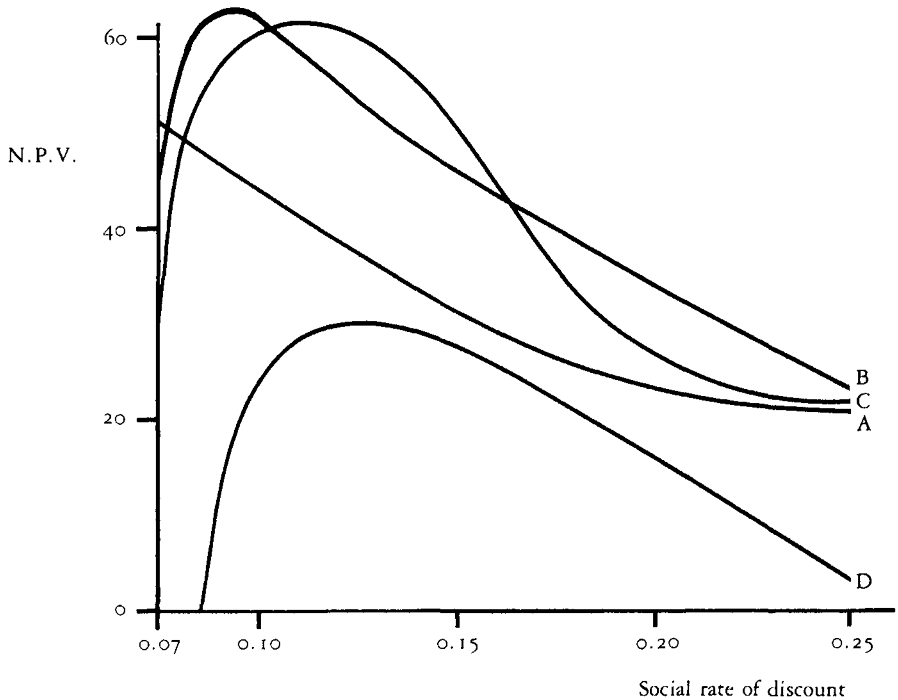


CHART 4.— NET PRESENT VALUE PER THOUSAND TONS OF ROUGH RICE WITH $S^K = 0.75 + 0.25\ S^I$ (*million Rp.*)

a. Operating at full capacity



b. Operating at 75 percent capacity

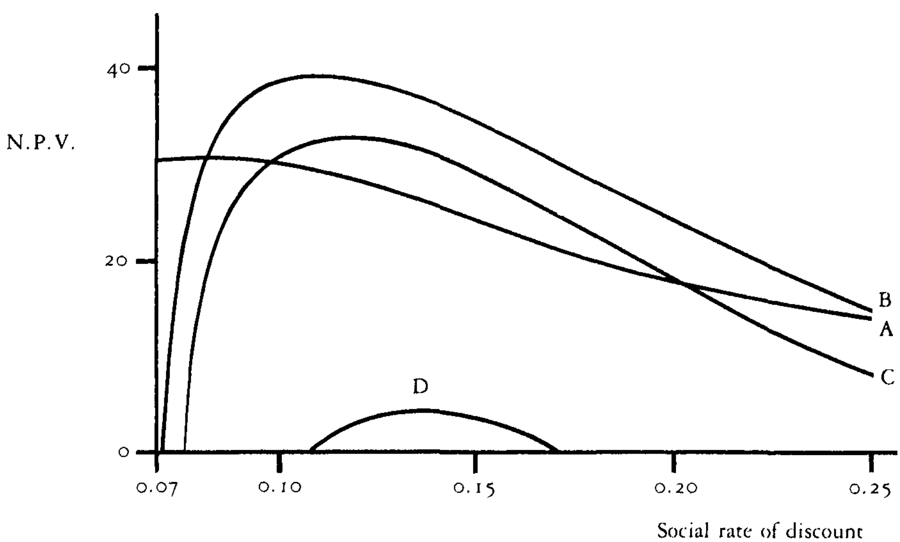
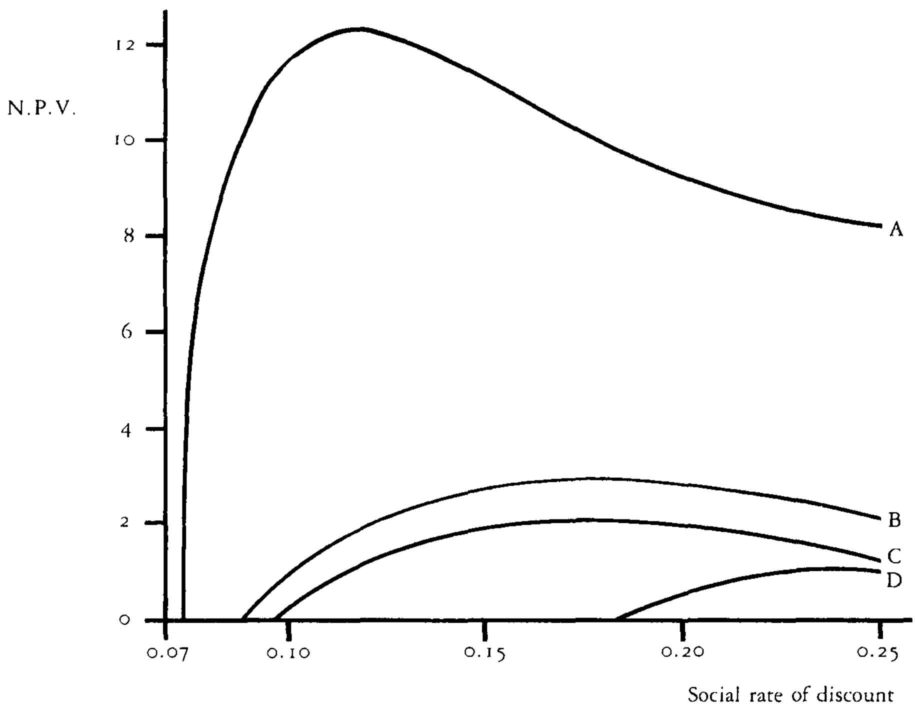


TABLE 4.—RANKING OF MILLING FACILITIES BY NET PRESENT VALUE PER UNIT OF ROUGH RICE INPUT FOR VARIOUS INCREASES IN THE PRICE OF RICE

Increase in price of rice / Social rate of discount (*i*)	a. With price differential between facilities (*percent*)					b. Without price differential between facilities (*percent*)				
	0	25	50	75	100	0	25	50	75	100
0.25	BCAD/	CBAD/	CBDA/	CBDA/	CBDA/	ABC/D	ABC/D	BACD/	BCAD/	BCAD/
0.24	BCAD/	CBAD/	CBDA/	CBDA/	CBDA/	ABC/D	ABC/D	BACD/	BACD/	BCAD/
0.23	BCAD/	CBAD/	CBDA/	CBDA/	CBDA/	ABC/D	ABC/D	BACD/	BACD/	BCAD/
0.22	BCAD/	CBAD/	CBDA/	CBDA/	CBDA/	ABC/D	ABC/D	BACD/	BACD/	BCAD/
0.21	BCAD/	CBAD/	CBDA/	CBDA/	CBDA/	ABC/D	ABC/D	BACD/	BACD/	BCAD/
0.20	BCAD/	BCAD/	CBAD/	CBDA/	CBDA/	ABC/D	ABC/D	BACD/	BACD/	BCAD/
0.19	BCA/D	BCAD/	CBAD/	CBDA/	CBDA/	ABC/D	ABC/D	BACD/	BACD/	BCAD/
0.18	BCA/D	BCAD/	CBAD/	CBDA/	CBDA/	ABC/D	ABC/D	BAC/D	BACD/	BCAD/
0.17	BCA/D	BCAD/	CBAD/	CBDA/	CBDA/	ABC/D	ABC/D	BAC/D	BACD/	BACD/
0.16	BCA/D	BCAD/	CBAD/	CBDA/	CBDA/	ABC/D	ABC/D	ABC/D	BACD/	BACD/
0.15	BAC/D	BCAD/	CBAD/	CBAD/	CBDA/	ABC/D	ABC/D	ABC/D	BACD/	BACD/
0.14	BAC/D	BCAD/	BCAD/	CBAD/	CBDA/	AB/CD	ABC/D	ABC/D	BAC/D	BACD/
0.13	BAC/D	BCA/D	BCAD/	CBAD/	CBAD/	AB/CD	ABC/D	ABC/D	ABC/D	BACD/
0.12	ABC/D	BAC/D	BCAD/	CBAD/	CBAD/	AB/CD	ABC/D	ABC/D	ABC/D	ABC/D
0.11	ABC/D	BAC/D	BCA/D	BCAD/	BCAD/	AB/CD	AB/CD	ABC/D	ABC/D	ABC/D
0.10	AB/CD	ABC/D	BAC/D	BCA/D	BCAD/	A/BCD	AB/CD	AB/CD	ABC/D	ABC/D
0.09	A/BCD	AB/CD	ABC/D	BAC/D	BAC/D	A/BCD	A/BCD	AB/CD	AB/CD	AB/CD
0.08	A/BCD	A/BCD	AB/CD	AB/CD	AB/CD	A/BCD	A/BCD	A/BCD	A/BCD	AB/CD
0.07	/ABCD	/ABCD	A/BCD	A/BCD	A/BCD	/ABCD	/ABCD	A/BCD	A/BCD	A/BCD

CHART 5.—NET PRESENT VALUE PER MILLION Rp. OF INVESTMENT COST
(*million Rp.*)

a. Operating at full capacity



b. Operating at 75 percent capacity

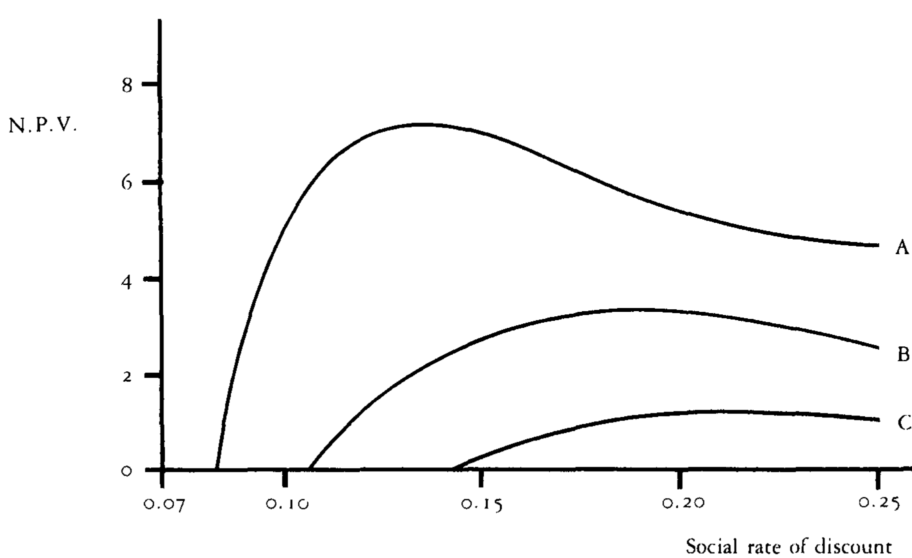


TABLE 5.—RANKINGS OF MILLING FACILITIES BY NET PRESENT VALUE PER UNIT OF ROUGH RICE INPUT FOR VARIOUS REDUCTIONS IN SOCIAL COSTS OF CAPITAL

Social rate of discount (i)	Reduction in cost of capital (*percent*)				
	20	40	60	80	100
0.25	CBAD/	CBDA/	CDBA/	BCBA/	DCBA/
0.24	CBAD/	CBDA/	CDBA/	DCBA/	DCBA/
0.23	CBAD/	CBDA/	CDBA/	DCBA/	DCBA/
0.22	CBAD/	CBDA/	CDBA/	DCBA/	DCBA/
0.21	CBAD/	CBDA/	CDBA/	DCBA/	DCBA/
0.20	BCAD/	CBDA/	CDBA/	DCBA/	DCBA/
0.19	BCAD/	CBDA/	CDBA/	DCBA/	DCBA/
0.18	BCAD/	CBDA/	CBDA/	DCBA/	DCBA/
0.17	BCAD/	CBDA/	CBDA/	DCBA/	DCBA/
0.16	BCAD/	CBAD/	CBDA/	DCBA/	DCBA/
0.15	BCAD/	CBAD/	CBDA/	DCBA/	DCBA/
0.14	BCAD/	CBAD/	CBDA/	CDBA/	DCBA/
0.13	BCA/D	CBAD/	CBDA/	CDBA/	DCBA/
0.12	BCA/D	CBAD/	CBDA/	CDBA/	DCBA/
0.11	BAC/D	BCAD/	CBDA/	CDBA/	DCBA/
0.10	ABC/D	BAC/D	CBAD/	CDBA/	DCBA/
0.09	AB/CD	BAC/D	BCAD/	CBDA/	DCBA/
0.08	A/BCD	AB/CD	BAC/D	CBAD/	DCBA/
0.07	A/BCD	A/BCD	A/BCD	ABC/D	DCBA/

of capacity. In Chart 4 it is assumed that $S^K = 0.75 + 0.25S^I$, but otherwise the same assumptions are made as in panels (a) and (b) of Chart 3, respectively. In Chart 5 we assume that current investment cost constrains the government's investment behavior, so net present value is divided by investment cost (in Rp. millions). Otherwise, the same assumptions are made as in panels (a) and (b) of Charts 3 and 4.

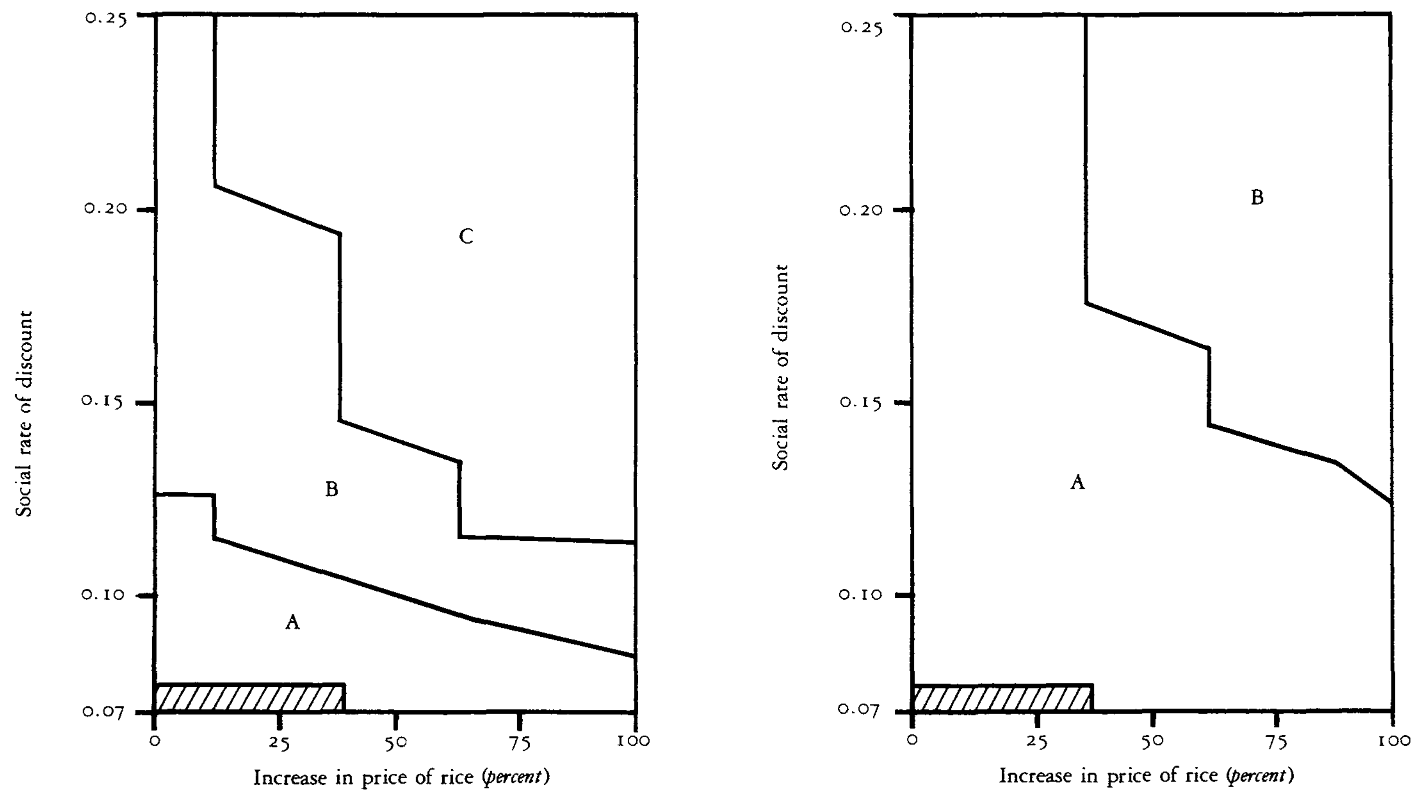
The rice prices presented in Table 1 are suspect on two grounds. First, they are based on 1971 rice prices, which are well below current (1976) prices, and may well prove to be below the long-term mean price in real terms. Second, the prices in Table 1 assume substantial price differentials between the rice produced by the four facilities. Although Weitz-Hettelsater (1972) made similar assumptions, there is little evidence to support these differentials.[10] It is of some interest to see the implications of relaxing both of these assumptions.

[10] There is evidence, however, in support of a price differential between hand-pounded and milled rice. See Timmer (7).

Chart 6.—Acceptance Regions for Rice-Milling Facilities When Price of Rice is Varied—Normalizing by Rough Rice Input

a. With price differential between facilities

b. Without price differential between facilities



In Table 4 we summarize the relationship between net present value per unit of rough rice input, for each technique, and the social rate of discount, for various increases in rice prices. For each rate of discount and each assumed increase in rice prices (zero, 25, 50, 75, and 100 percent), we present the ranking of techniques according to net present value per unit of rough rice input. The position of the slash (/) in each ranking indicates the change from positive to negative values. Panel (a) of Table 4 assumes that price differentials between techniques are as in Table 1, while panel (b) assumes that the price of the rice produced by all facilities is the same as that for technique (A). These results are summarized further in the two acceptance diagrams presented in Chart 6. These diagrams show the optimal technique for each combination of social rate of discount and percent increase in the price of rice. Panels (a) and (b) relate to panels (a) and (b) of Table 4, respectively. The shaded areas indicate regions in which N_k is negative for all techniques. When this exercise is repeated for net present value per unit of investment cost, technique (A) proves to be optimal for all discount rates (for which N.P.V. using technique (A) is positive in Chart 3(a)), and for all increases in the price of rice within the above range

CHART 7.—ACCEPTANCE REGIONS FOR RICE MILLING FACILITIES WHEN COST OF CAPITAL IS VARIED—NORMALIZING BY ROUGH RICE INPUT

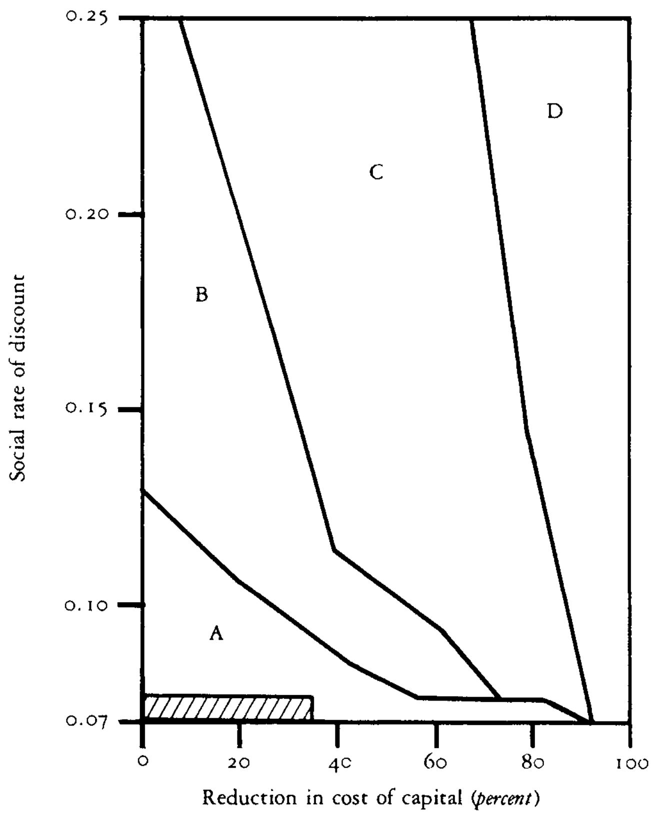


Table 5 contains summarized rankings of techniques according to net present value per unit of rough rice input when the shadow price of capital used in Chart 3(a) is reduced by degrees until capital becomes a free good. The intent of this table is to show the implications of concessionary loans of capital from external sources tied to specific forms of investment. It is assumed, however, that there are no differences in the terms on which loans are made for specific techniques. These results are summarized in the acceptance diagram in Chart 7. This exercise is not repeated for net present value per unit of investment cost since the availability of capital at concessionary rates is inconsistent with investment cost being the binding constraint on government investment behavior.

CONCLUSIONS

The most critical issue affecting the choice of technique in public sector rice milling in Indonesia appears to be the assumption we make about the constraints facing public investment: (a) if a project is defined to be a unit of capital expenditure on rice-milling facilities—implying that investment cost is the binding constraint—the optimal technique is the Small Rice Mill (A); (b) if a project is defined to be a unit of rough rice transferred from hand-pounding to mechanical milling—implying that the supply of rough rice is the binding constraint—the optimal choice could be any of the four techniques, depending on the other assumptions (e.g., rice prices and sources of capital) and on value judgments (e.g., the social rate of discount) that are made.

Considering case (b), the optimal choice will be the Large Bulk Facility (D) only if capital tied to investment in rice milling is available from external sources on terms so concessionary as to make capital virtually a free good. The Small Bulk Facility (C) is most likely to be optimal if the social rate of discount is high and the price of milled rice is expected to be higher than indicated in Table 1. The Large Rice Mill (B) will be favored by low rice prices and social rates of discount exceeding 12 percent, while the Small Rice Mill is favored by low rice prices and low social rates of discount.

We refrain from recommending any specific technique, since our general conclusion is that "it all depends on . . .". This conclusion is important because there is a tendency among engineers and economists alike to apply simplistic rules of thumb to questions of choice of technique. The results of this study suggest that formal economic analysis of the issues involved is not simply helpful; it is indispensable.

CITATIONS

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