DETERMINANTS OF PUBLIC INVESTMENT: IRRIGATION IN INDONESIA

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INTRODUCTION

The rate of accumulation of public and private capital is a key factor in economic growth. A number of studies have examined the determinants of private investment in developing countries, but with the exception of early work by Hayami and Kikuchi (1978), there has been little systematic analysis of the determinants of public investment, which accounts for a large share of capital formation. Analyses of private investment behavior have treated public investment as exogenously determined, and have examined whether public investment affects private investment positively, by reducing private costs of investment or increasing the productivity of private investment; or negatively, by crowding out private investment (Gandhi, 1990; Tun Wai and Wong, 1982; Sundarajan and Thakur, 1980). This paper instead examines the determinants of public investment behavior, using the example of government irrigation investment in Indonesia. Irrigation investment accounted for more than one-half of public expenditures in agriculture in the 1980s, and publicly-funded irrigation accounts for 85 percent of irrigated area and 75 percent of rice production in Indonesia (Sudaryanto, et al., 1992; Rosegrant, et al., 1987).

Do governments act as rational social planners, allocating public resources so as to maximize net social returns? This question is explored in this paper, which analyzes public investment behavior in irrigation in Indonesia using a behavioral model adapted from Mundlak (1988), which in turn is a variant on Jorgenson's (1967, 1971) neoclassical investment model. The paper first describes trends in irrigation investment in Indonesia; presents the theoretical investment model; specifies the empirical model, data, and estimation procedures; and then describes the results, followed by a summary and conclusions.

TRENDS IN IRRIGATION DEVELOPMENT

Annual irrigation development expenditures and area completed by type of investment, 1969/70 to 1988/89, are shown in Figures 1 and 2. The annual data is summarized by five-year development plan (Repelita) in Tables 1 and 2. The government irrigation budget is divided into four main categories: new irrigation construction, which includes investment in new reservoir and diversion irrigation systems; rehabilitation of existing irrigation systems; swamp and tidal irrigation, which are small systems with relatively few water control structures that rely on natural flooding or tidal movement for water; and river and flood control. As shown in the figures and tables, the irrigation investment program grew dramatically during the first three Repelitas. Real expenditures in the third plan were more than four times larger than in the first plan. However, expenditures declined by almost 20 percent between Repelita III and Repelita IV.

Rehabilitation received the largest share of expenditures in the first plan, over 40 percent of the total. Although declining in relative importance, rehabilitation expenditures increased substantially in absolute terms through the third plan, but dropped by 32 percent in the fourth plan. Over the course of the first three plans, expenditures on construction of new irrigation systems increased rapidly and received the largest aggregate share of expenditures, averaging 38 percent of expenditures during the first three Repelitas. Real expenditures on new construction increased nearly ten-fold between the first and third plans, before declining by 12 percent in the fourth plan. The swamp and tidal irrigation development program, which received nearly 30 percent of expenditures in the first Repelita, has declined in relative importance to about 5 percent, but received a nearly constant level of expenditures through the first three plans. Like the other programs, swamp and tidal irrigation investment declined sharply in the fourth plan, by 31 percent. After a small initial program, river and flood control received about 30 percent of expenditures over the last three plans, with a decline in expenditure of over 9 percent in the final period.

The completion of physical areas by type of development over the first four Repelitas is shown in Table 2. Area rehabilitated totaled 950,000 ha in the first plan, and declined steadily thereafter to 150,000 in the latest Repelita. Completions of new irrigated area more than doubled between the first and third plans, to 436,000 ha, before declining to 198,000 ha in the fourth plan. Swamp and tidal irrigation peaked at 450,000 ha completed in the third plan, before also declining sharply. Areas brought under river and flood control in the fourth plan were less than half the totals in the third plan.

A number of factors have been hypothesized to cause the large reduction in the irrigation investment program in the fourth plan, including declining oil prices and a slowdown in growth in gross national product (both of which reduce government revenue); and declining world rice prices and increasing costs per hectare of irrigation investment, which reduce the social profitability of investment in irrigation (Rosegrant, et al., 1987). To what extent have these factors caused the reduction in irrigation investment? The next section develops a model of public investment behavior which attempts to explain changes in irrigation investment over time.

THEORETICAL INVESTMENT MODEL

The model of public investment behavior is based on the assumption that the government acts to maximize net social returns over time. First, define the multi-period net returns to investment:

$$R_t = p_t F_t(v_t, K_t) - w_t v_t - q_t(\dot{K}_t + gK_t) \tag{1}$$

where the output of the investment is represented by a production function $F(v, K)$, v is a vector of variable inputs and K is the vector of capital, p is the output price, w is the vector of input prices, q is the vector of prices of capital, $\dot{K}$ is the time derivative of capital K, g is the rate of depreciation, and t denotes the time period.

The decision is formulated as an intertemporal optimization problem in which the government selects the time path of investment that maximizes the expected present value of the stream of net returns R_t.

If r is the discount factor and v_t and K_t are the variable and capital input allocations, the problem is to

$$\underset{(K(t),v(t))}{Maximize}\ E_0\left[\int_0^{\infty} e^{-rt}R(t)dt\right] \tag{2}$$

subject to the initial condition $K(0) = K_0$ and the transversality condition $\lim_{t\to\infty}[e^{-rt}R(t)] = 0$. $E_0(X)$ is the expected value of X conditional on the information set at $t=0$. Assuming certainty equivalence and an interior solution, first order conditions for v_t indicate that along the optimal path, the quantity of input allocated to each technique at t does not affect revenues in subsequent periods. Consequently, the problem can be solved recursively; the first step is to determine optimal input levels $v_t^*=v(s_t)$, where $s_t = (p_t, w_t, K_t)$, the vector of state variables. Because of the recursive nature of the problem, the first stage solution for v_t^* is determined using standard single period-profit maximization procedures equating each input's value marginal product to its real price in each period.

Longer run investment decisions are determined in the second stage of the optimization by choosing K_t to maximize:

$$E_0\left[\int_0^{\infty} e^{-rt}(\pi(s) - q(\dot{K} + gK))dt\right] \tag{3}$$

where $\pi(s) = p_tF_t-w_tv_t^*$, subject to the constraints of (2) and conditioned on the first stage solution for variable inputs. Suppressing it's dependence on s and t, the Euler equation for this problem is:

$$\frac{\partial\pi}{\partial K} - q(r+g) - \dot{q} = 0 \qquad (4)$$

where $\dot{q}$ is the time derivative of q. This equation states that, at optimal capital levels, marginal productivity of capital is equal to user cost. Solving (4) gives the optimal time path of capital $K^{*}=K(z)$, where $z=(s, r, q, \dot{q}, g)$, the relevant exogenous state variables for the investment decisions. Optimal or desired demand for investment is the difference between the optimal level of capital and that currently available:

$$I^{*}(z) = (K^{*}-K) \qquad (5)$$

Determination of Actual Investment

The framework described above derives the optimal or desired capital stock as a function of the specified state variables. The actual stock of capital, however, does not in general adjust instantaneously to changes in the desired stock. Instead, changes in desired capital are transformed into actual investment through a partial adjustment process (McGuirk and Mundlak, 1991; Gandhi, 1990; Clark, 1979; Jorgenson, 1971; Koyck, 1954).

In the partial adjustment model of investment, it is assumed that capital is adjusted toward its desired level by a constant proportion of the difference between desired and actual capital, or more generally, as a weighted average of past levels of desired capital. Using the same notation as above, but restoring the time subscripts, a general partial adjustment model can be defined as follows:

$$(K_t - K_{t-1}) = f(\alpha_t)(K_t^* - K_{t-1}) \tag{6}$$

or

$$I_t = f(\alpha_t)\ I_t^*(z) \tag{7}$$

where I_t is actual investment, and $f(\alpha_t)$ is a function representing the adjustment process in moving from desired levels of capital stock to actual levels of capital stock.

A number of theories have been advanced to explain the partial adjustment model of investment. Eisner and Strotz (1963) first suggested a theory based on the internal costs of adjustment to the firm. In this theory, firms pay a penalty for having a capital stock different from the desired level, and incur adjustment costs in attempting to move to that level. The actual investment is that which minimizes the total costs in the trade-off between having less or more than desired investment and the costs of adjustment (Clark, 1979). Internal adjustment costs include the physical lags in the planning and implementation of desired capital investment.

McGuirk and Mundlak (1991, 1992) and Gandhi (1990), on the other hand, stress the importance of external adjustment costs, such as the availability of resources to the firm or to the government. External resource constraints may be important for both public investment, which relies on tax and other revenues to finance new investment, and for private firms. In developing countries, in particular, the availability of loanable funds may not be fully reflected in the interest rate. With imperfect capital markets, loanable financial resources may be rationed at prevailing interest rates.

The model utilized here decomposes the adjustment costs $f(\alpha_t)$ into the internal costs and the external costs or resource constraints. The internal costs of adjustment, which induce physical lags in implementation of desired investment, are represented by a distributed lag operator. The distributed lag process describes the structure and period of the transformation of desired investment into actual investment.

This process of implementing desired investment, however, is also conditioned on the availability of external resources. The impact of external resource constraints on actual investment take place within the same period, and are assumed to be proportional to the desired or optimal level of new investment (Gandhi, 1990; Blejer and Kahn, 1984; Coen, 1968). Thus,

$$f(\alpha_t) \quad \sum_i^m \alpha_i \, (c_i/I_t^*) + L[\cdot] \tag{8}$$

where the c_i are the resource constraints and $L[\cdot]$ is a distributed lag operator such that $L[X_t(z)] = \sum_{s=0}^{n} \beta_s z_{t-s}$. The resource constraints can include variables such as gross national product or government revenues, if the decision maker is the government; or commercial bank credit to agriculture and rural savings, if the farm is the decision maker.

Substituting equation (8) into (7) provides the relationship between actual and desired investment:

$$I_t = \sum_i \alpha_i c_i + \sum_{s=0}^{n} \beta_s z_{t-s} \qquad (9)$$

The model thus states that actual investment is a function of the availability of financial resources, and of the lagged values of the exogenous determinants of desired investment.

EMPIRICAL SPECIFICATION

For the empirical estimation of the determinants of irrigation investment in Indonesia, investment is disaggregated into the four main categories of new irrigation construction, rehabilitation, swamp and tidal irrigation, and river and flood control. Investment functions are estimated for total irrigation investment and by type of investment. As implied in the theoretical model of public investment behavior, investment in each type of irrigation is estimated as a function of the net profits generated by the investment relative to net profits of other sectors, the costs of investment in irrigation, and the availability of public resources for investment. The investment model is estimated using two alternative definitions of profitability of irrigation. The measures of profitability of investment in irrigation are based on the relative profitability of rice production, which accounts for over 80 percent of irrigated area. The alternative definitions of profitability used are the world price of rice deflated by the manufacturing unit value index; and net rice revenues per hectare (world rice price times rice yield per hectare less fertilizer and labor costs per hectare) deflated by the index of value added per capita in the non-agricultural sector. The latter measure is a proxy for the profitability of resources utilized in the non-agricultural sector.

For the total investment function, the cost measure is the area-weighted real average cost per hectare across the four types of irrigation development, while the investment functions by type of investment utilize the real cost per hectare for each type of irrigation development. The proxy variables for the availability of public resources are the real gross national product per capita; and the real world price of oil. The latter variable is included because of its large impact on government revenues, and on availability of foreign exchange. The model is specified in general form as follows:

$$IRREXP_{it} = \alpha_{i0} + \alpha_{i1}\, GNPC_t + \alpha_{i2}\, POIL_t + \sum_{s=0}^{n} \beta_{is}\, WPRICE_{t-s} + \sum_{s=0}^{n} \theta_{is}\, COSTHA_{i,\,t-s} + \mu_t \qquad (10)$$

where $IRREXP_i$ is the expenditures on irrigation of type i, $GNPC$ is the per capita gross national product, $POIL$ is the real world price of oil, $WPRICE$ is the real world price of rice, $COSTHA_i$ is the real cost per hectare of irrigation development of type i, and μ_t is the stochastic error term. Alternatively, $REVRICE$, the net rice revenue per hectare deflated by the index of value added per capita in the non-agricultural sector, is utilized in place of WPRICE as the measure of returns to irrigation.

The general form of the distributed lag cannot be effectively estimated because of the loss of degrees of freedom and multicollinearity between the price and cost variables in time t and the lagged values of these variables. In order to make the problem tractable, a structure is imposed on the distributed lag based on the construction process of irrigation projects.

The actual specification of the lag structure is an empirical question. Among the lag structures widely used in the literature are rational, Koyck, and polynomial distributed lags. In the analysis here, the lag structure can be determined based on observation of the actual physical implementation process for irrigation systems. The lag process in irrigation construction suggests a polynomial distributed lag of degree two. Lags in the irrigation development process include lags between project appraisal and approval, between approval and initiation of construction, and between initiation and completion (Svendsen and Ramirez, 1990). As a result of this process, expenditures on a project generally follow a quadratic polynomial distribution, with relatively small but increasing expenditures in the early years; large expenditures in the middle years of construction, as the headworks and main canals are constructed; and then declining expenditures as secondary and tertiary canals are completed (Figure 3). In order to estimate investment models consistent with the stylized facts of the irrigation construction process, the β_{is} and θ_{is} in equation (10) are therefore restricted to be on a polynomial of degree two and length n. Suppressing the subscript i for type of irrigation for clarity of presentation,

$$\beta_s = b_0 + b_1 \; s + b_2 \; s^2, \qquad s = 1, \ldots, n \tag{11}$$

$$\theta_s = c_0 + c_1 \; s + c_2 \; s^2, \qquad s = 1, \ldots, n \tag{12}$$

Substituting (11) and (12) into equation (10) gives

$$\begin{aligned} IRREXP = \alpha_0 + \alpha_1 \; GNPC_t + \alpha_2 \; POIL_t \sum_{s=0}^{n} (b_0 + b_1 s + b_2 s^2) \; WPRICE_{t-s} \\ + \sum_{s=0}^{n} (c_0 + c_1 s + c_2 s^2) \; COSTHA_{t-s} + \mu_t \end{aligned} \tag{13}$$

or

$$\begin{aligned} IRREXP = \alpha_0 + \alpha_1 \; GNPC_t + \alpha_2 \; POIL_t + b_0 \; ZWPRICE_{0t} \\ + b_1 \; ZWPRICE_{1t} + b_2 \; ZWPRICE_{2t} + c_0 \; ZCOSTHA_{0t} \\ + c_1 \; ZCOSTHA_{1t} + c_2 \; ZCOSTHA_{2t} + \mu_t \end{aligned} \tag{14}$$

where

$$ZWPRICE_{0t} = \sum_{s=0}^{n} WPRICE_{t-s}; \qquad ZWPRICE_{1t} = \sum_{s=0}^{n} s \; WPRICE_{t-s};$$

$$ZWPRICE_{2t} = \sum_{s=0}^{n} s^2 \; WPRICE_{t-s}; \qquad ZCOSTHA_{0t} = \sum_{s=0}^{n} COSTHA_{t-s};$$

$$ZCOSTHA_{1t} = \sum_{s=0}^{n} s \; WPRICE_{t-s}; \qquad ZCOSTHA_{2t} = \sum_{s=0}^{n} s^2 \; COSTHA_{t-s}$$

Thus, irrigation expenditures ($IRREXP_t$) are estimated as a function of the constructed variables $ZWPRICE_{jt}$ and $ZCOSTHA_{jt}$, and the resulting estimates of b_j and c_j are utilized in equations (11) and (12) to compute estimates of β_s and θ_s.

Lags in irrigation construction vary from project to project depending upon the size and type of the project, location, and efficiency of the construction process. The final step in specification of the empirical model is determination of the length of the lag. Use of F-Tests for goodness-of-fit introduces a substantial upward bias in lag length (Maddala, 1988). The Schwarz posterior probability criterion for model selection is therefore utilized instead of the F-test. The Schwarz criterion incorporates both a measure of precision of the estimates and a measure of parsimony in model parameterization and therefore eliminates the upward bias in choosing the lag length (Ramanathan, 1989; Judge, et al., 1980). Based on the Schwarz criterion, a lag length of five years is utilized for rice price and revenue in the total investment, new irrigation construction, rehabilitation, and river and flood control investment equations, and a three year lag length is used in the swamp and tidal investment equation. For the capital cost variable, a five year lag is utilized in the swamp and tidal irrigation investment equation, and six years in all other equations.

DATA AND ESTIMATION PROCEDURES

The variables utilized in the various specifications of the regression model are defined in Table 3. The sources for the basic data are as follows: (a) Directorate General for Water Resource Development (DGWRD), Ministry of Public Works for real annual expenditures on new irrigation construction and real capital costs per hectare for irrigation development; (b) Central Bureau of Statistics (CBS) for real gross national product, net revenue per hectare for rice, and the index of value added per capita in the non-agricultural sector (c) the World Bank for the real world price of rice and the real world price of oil. The data covers the period 1964-88.

All estimated equations showed statistically significant serial correlation. Estimation of the total investment equation was therefore undertaken using generalized least squares with correction for serial correlation. The set of equations by type of investment were estimated as a system, using Zellner's generalized least squares estimator for seemingly unrelated regressions, with correction for serial correlation. In each equation, rho was estimated using the maximum likelihood estimator suggested by Beach and MacKinnon (1978).

RESULTS

The estimated equations for the price and revenue models are presented in Tables 4-5, and the estimated elasticities of irrigation investment with respect to the exogenous variables computed from these equations are shown in Tables 6-7. The results are in general excellent, and confirm the strong impact of relative profitability and resource or financial constraints on public investment in irrigation in Indonesia. The signs of the estimated parameters are in most cases as predicted by the theoretical model and highly significant, and the R^2 range from 0.84 to 0.98 (Tables 4-5). There is little to choose from between the price and revenue models: the goodness-of-fit is virtually the same, and the estimated elasticities are similar. While the results overall strongly support the hypothesized effects, the results that differ from prior expectations also provide interesting insights.

For example, for the swamp and tidal irrigation equation under both price and revenue formulations, most of the signs of the estimated parameters and the long term elasticities are unexpected (Tables 4 and 5). Per capita GNP, price of oil, price of rice, and rice revenue all have negative long term effects on swamp and tidal irrigation investment. A possible explanation for these results is that investment in swamp and tidal irrigation is guided more by social welfare goals other than by maximization of social returns. Swamp and tidal irrigation investments have been undertaken mainly in conjunction with the "transmigration" program, which seeks to relocate rural families from the densely populated island of Java to other islands. The government may be operating so as to maintain incentives for transmigrants by increasing swamp and tidal irrigation expenditure levels as compensation during periods of declining rice prices or income levels.

The equations for total irrigation, new irrigation, rehabilitation, and river and flood control all show positive effects on investment in time *t* of an increase in the cost per hectare of irrigation during time periods *t* and/or *t-1* (Tables 4 and 5). This relationship seems counterintuitive, but is in fact plausible. An increase in the cost per unit of investment will have two effects: first, the increased unit cost of new projects will be reflected also in an increased per unit cost of on-going projects, which will have the effect of increasing the total expenditures in the on-going portfolio of construction; second, as predicted in the model, there will be an induced shift out of irrigation and into more profitable investments. The positive impact of cost increases on expenditures in the initial years indicates that the first effect is dominant in those years. In the long run, though, the relative profitability effect dominates (Tables 6 and 7).

The negative effect of price in period *t* on investment in period *t* in several of the equations is likely explained by the tendency that, in the short run, a price increase will cause diversion of government expenditures from investment to consumption expenditures. Due to the political importance of stable rice prices, the immediate response of the Indonesian government to a rice price increase may be to divert funds from irrigation and other long term investments to the financing of rice imports to relieve short term price pressure. In the longer run, the expected positive impact of the price increase on investments dominates for total irrigation and new irrigation construction, but the diversion-of-funds effect dominates for rehabilitation.

The elasticities of irrigation investment with respect to per capita GNP range from 2.00 to 3.11 for total irrigation, new irrigation construction, and rehabilitation, and 4.81-6.45 for river and flood control. While the elasticities are large, they do not seem excessive, since a small percentage change in per capita GNP generates large shifts in government revenues relative to irrigation expenditures. The impact of the world price of oil on irrigation investments is also substantial: with the exception of the negative elasticity for swamp and tidal irrigation (see above), the investment elasticities with respect to the price of oil range from 0.38 to 0.79 (Tables 6-7) for the different types of irrigation.

The long run elasticity of response for new irrigation construction, river and flood control, and total irrigation investment to world prices are 1.00, 4.03, and 1.04, respectively (Table 6). The price elasticities are negative for rehabilitation and swamp and tidal irrigation, as discussed above. The investment elasticities with respect to revenues are similar to the price elasticities: 1.02, 3.31, and 0.83 for new construction, river and flood control, and total irrigation investment, respectively; and negative for the other two types of irrigation (Table 7).

Finally, the long run elasticities of investment with respect to the capital costs of irrigation are negative for all types of irrigation, in either model specification. The elasticity of total investment with respect to capital cost is -1.04 in the price model and -1.05 in the revenue model, and ranges from -0.70 to -1.93 for different types of irrigation and different models (Tables 6-7).

SUMMARY AND CONCLUSIONS

This paper presented a partial adjustment model of public investment behavior based on the neoclassical investment model, and applied it to public irrigation investment in Indonesia. In the model, desired investment in irrigation is a function of the profitability of investment in irrigation relative to other investments; and actual investment adjusts over time to desired levels, conditioned on the external costs of adjustment represented by financial resource constraints, and the internal costs of adjustment, which induce physical lags in the implementation of desired investment.

The results are consistent with the hypothesis that the Indonesian government acts as a social planner, maximizing net social benefits in the allocation of resources to irrigation investment subject to resource constraints. The government is highly responsive to both economic incentives and resource constraints in determining investment levels. The long run elasticities of response of total irrigation investment and new irrigation construction with respect to world rice prices are about 1.00, and with respect to capital costs of irrigation are -1.04 to -1.35.

It has been argued that such a strong public investment response to rice prices could lead to a costly cyclical process in prices and production: low prices drive down long term investment, which then lead to reduced production and upward pressure on prices, and an upward cycle in investment, destabilizing prices and production (Hayami and Kikuchi, 1978; Levine, et al., 1989). However, the relatively long lags estimated here in investment response to prices imply gradual adjustments in investment to changing prices over time. At any given point in time, the investment level is in effect a function of long run average rice price and average capital costs per hectare, conditioned on availability of resources. The relatively gradual long term adjustment process will tend to dampen the cyclical effects arising from investment response to changing rice prices.

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Figure 1. Irrigation Development Expenditures, Indonesia, 1969/70 to 1988/89, at 1975/76 prices.

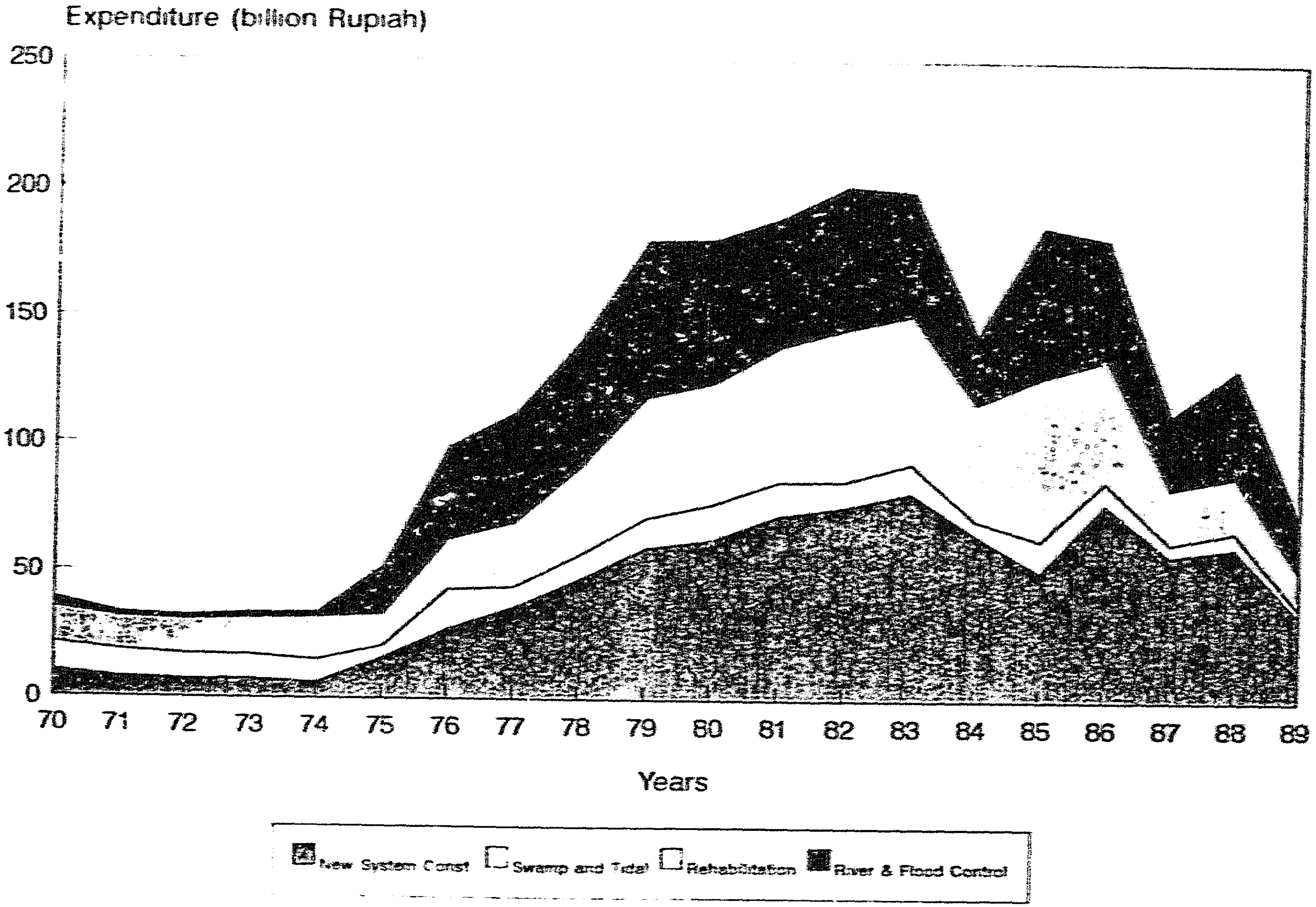

Figure 2. Area Completed under Irrigation Development Programs, Indonesia, 1969/70 to 1988/89.

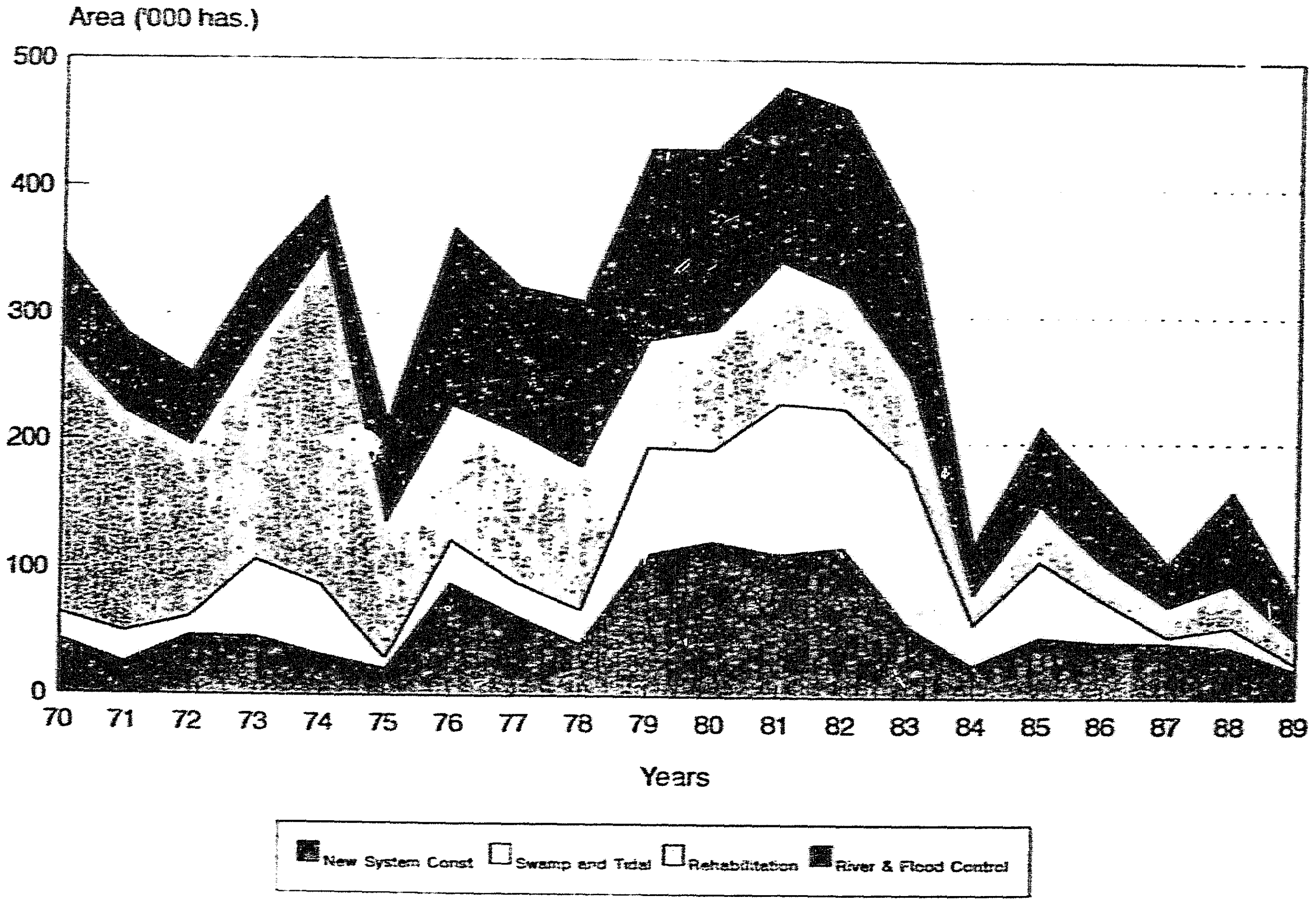

Figure 3. Stylized pattern of expenditure on irrigation construction, from inception (year t-n) to completion (year t).

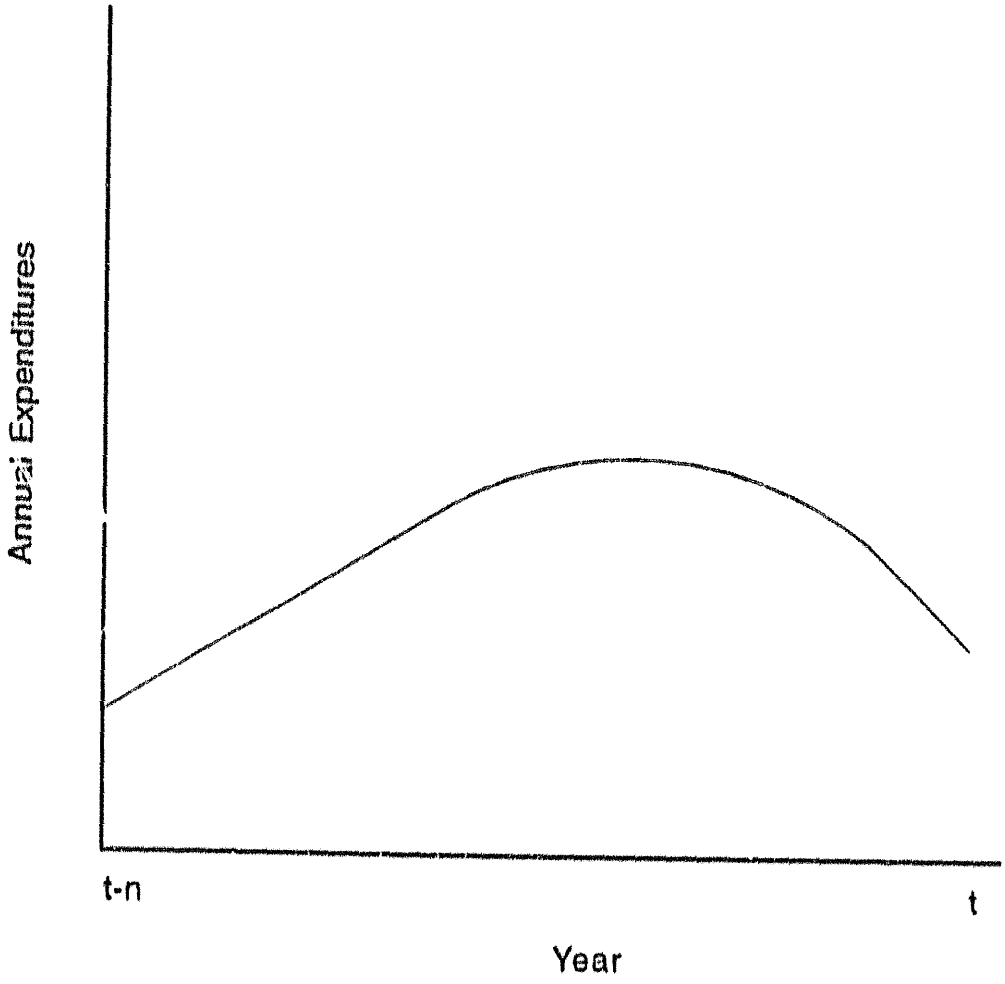

Table 1. Real irrigation development expenditure, Indonesia, by type of development, Repelita I through Repelita IV, 1975/76 prices.

Type of Development	Repelita I 1969-73	Repelita II 1974-78	Repelita III 1979-83	Repelita IV 1984-88
	billion Rp			
Rehabilitation	73.7	138.8	263.4	179.5
New construction	38.3	185.7	358.0	315.5
Swamp/tidal	150.0	50.1	54.6	37.6
River and flood control	9.9	207.8	237.2	215.6

Source: Ministry of Public Works, DGWRD.

Table 2. Physical area completed, Indonesia, by type of development, Repelita I through Repelita IV.

Type of Development	Repelita I 1969-73	Repelita II 1974-78	Repelita III 1979-83	Repelita IV 1984-88
	------------	'000 ha	------------	
Rehabilitation	953.5	527.8	394.7	151.7
New construction	191.2	325.9	436.2	197.9
Swamp/tidal	178.7	179.2	454.5	120.3
River and flood control	289.4	613.7	578.5	256.0

Source: Ministry of Public Works, DGWRD.

Table 3. Definition of variables for estimation of irrigation investment functions. All variables are on an annual basis, 1964-1988.

Variable	Definition
$IRREXP_i$	Real expenditures on new irrigation construction, thousand US$, 1985 prices, by type of investment.
WPRICE	Real world rice price, Thai 5% broken, FOB Bangkok, US$/mt, 1985 prices.
COSTHA	Real capital costs per ha for new irrigation construction, thousand US$/ha, 1985 prices.
POIL	Real price of oil, Saudi Arabian OPEC Market Crude, US$/barrel, 1985 prices.
GNPC	Gross national product per capita, US$, 1985 prices.
REVRICE	Net rice revenue deflated by the index of value added per capita in the non-agricultural sector.

Table 4. Parameter estimates for irrigation investment equations, price model. t-values in parentheses.

	Parameter Estimates for Irrigation Investment Equations, By Type of Investment				
	Total Irrigation	New Irrig. Construction	Rehabilitation	Swamp/Tidal Irrigation	River & Flood Control
CONSTANT	1320012.09 (-2.36)	-478502.40 (-2.45)	-67545.23 (-0.43)	258407.70 (8.10)	-1254570.77 (-15.80)
GNPC	3533.64 (5.27)	1307.60 (2.94)	864.73 (3.04)	-251.18 (-5.44)	2205.83 (5.92)
POIL	13793.62 (7.56)	5652.64 (3.69)	7260.70 (5.70)	-350.07 (-0.08)	3181.07 (2.33)
WPRICE					
(0)	-136.70 (-2.06)	-59.18 (-1.12)	-136.99 (-5.14)	-23.95 (-1.44)	89.08 (2.23)
(-1)	165.16 (3.27)	52.87 (1.24)	-69.78 (-3.37)	23.67 (3.56)	212.10 (7.01)
(-2)	342.27 (7.83)	118.62 (3.02)	-16.37 (-0.[illegible]9)	20.95 (3.16)	276.26 (10.60)
(-3)	394.63 (9.69)	136.25 (3.81)	21.16 (1.16)	-32.13 (-2.28)	281.56 (11.71)
(-4)	322.25 (7.90)	107.58 (3.29)	42.83 (2.22)	-	228.00 (9.70)
(-5)	125.12 (2.49)	32.01 (0.63)	48.65 (2.05)	-	115.57 (4.09)
COSTMA					
(0)	1459.27 (8.39)	43.33 (3.12)	9.95 (1.07)	-2.74 (-0.80)	50.11 (4.80)
(-1)	234.67 (2.04)	10.24 (0.97)	-9.13 (-1.53)	-3.32 (-1.68)	-4.14 (-0.64)
(-2)	-605.35 (-4.92)	-14.04 (1.30)	-22.18 (-3.52)	-5.00 (-1.86)	-37.17 (-4.98)
(-3)	-1060.80 (-8.48)	-29.53 (-2.73)	-29.21 (-4.96)	-7.80 (-3.15)	-48.99 (-6.92)
(-4)	1131.67 (11.64)	-36.20 (-3.93)	-30.20 (-8.08)	-11.70 (-4.31)	-39.59 (-6.92)
(-5)	-817.07 (-9.88)	-34.00 (-4.51)	-25.17 (-4.64)	-16.72 (-2.63)	-8.98 (-1.51)
(-6)	-119.70 (-0.67)	-23.15 (1.98)	-14.12 (-1.02)	-	42.85 (-3.04)
R^2 (predicted/observed)	0.98	0.92	0.93	0.85	0.95
rho	-0.58	-0.15	-0.63	-0.73	-0.45

Table 5. Parameter estimates for irrigation investment equations, revenue model. t-values in parentheses.

	Parameter Estimates for Irrigation Investment Equations, By Type of Investment				
	Total Irrigation	New Irrig. Construction	Rehabilitation	Swamp/Tidal Irrigation	River & Flood Control
CONSTANT	-936640.00 (-6.17)	-401970.00 (-3.14)	1498.76 (0.03)	263604.60 (6.58)	-965035.68 (9.92)
GNPC	2698.70 (2.92)	1052.30 (2.00	906.81 (2.55)	-259.45 (-4.94)	1644.33 (3.11)
POIL	15177.00 (6.32)	5813.30 (3.16)	7709.85 (5.47)	-293.38 (-0.72)	3577.22 (1.98)
PEVRICE					
(0)	-270.49 (-2.60)	-87.71 (-1.22)	-197.61 (-5.33)	-36.85 (-1.52)	22.50 (0.35)
(-1)	131.83 (1.62)	60.97 (1.01)	-120.73 (-4.14)	27.91 (2.72)	207.57 (4.17)
(-2)	377.26 (5.32)	149.64 (2.60)	-57.93 (-2.19)	26.13 (2.89)	311.62 (7.16)
(-3)	465.80 (7.10)	180.29 (3.39)	-9.05 (-0.35)	-42.20 (-2.22)	334.65 (8.39)
(-4)	397.45 (6.08)	152.92 (3.20)	25.85 (0.93)	-	276.66 (7.17)
(-5)	172.21 (2.14)	67.53 (1.25)	46.77 (1.35)	-	137.65 (2.96)
COSTMA					
(0)	1595.30 (6.60)	49.67 (2.92)	-1.82 (-0.15)	-2.64 (-0.74)	66.11 (4.33)
(-1)	362.47 (2.13)	17.02 (1.20)	-9.98 (-1.40)	-3.70 (-1.72)	4.52 (0.48)
(-2)	-508.76 (-3.20)	-7.88 (0.63)	-16.86 (-2.68)	-5.52 (-1.92)	-34.72 (-3.81)
(-3)	-1018.41 (6.89)	-25.03 (-2.15)	-22.48 (-3.95)	-8.11 (-3.15)	-51.59 (-5.81)
(-4)	-1116.33 (-10.81)	-34.44 (-3.71)	-26.83 (-7.85)	-11.46 (-3.98)	-46.11 (-7.14)
(-5)	952.68 (11.29)	-36.09 (-5.12)	-29.89 (-5.54)	-15.57 (-2.25)	-18.26 (-2.67)
(-6)	-377.39 (-1.88)	-29.99 (2.60)	-31.69 (2.21)	-	31.94 (1.92)
R^2 (predicted/observed)	0.97	0.91	0.92	0.84	0.93
rho	-0.50	-0.11	-0.58	-0.70	-0.36

Table 6. Elasticity of irrigation investment with respect to GNP per capita, the world price of oil, the world price of rice, and capital cost per hectare of irrigation (price model).

	Parameter Estimates for Irrigation Investment Equations, By Type of Investment				
	Total Irrigation	New Irrig. Construction	Rehabilitation	Swamp/Tidal Irrigation	River & Flood Control
GNPC	2.61	3.11	2.15	-1.57	6.45
POIL	0.42	0.52	0.74	-0.09	0.38
WPRICE, Long Run	1.04	1.00	-0.33	-0.08	4.03
WPRICE					
(0)	-0.12	-0.15	-0.40	-0.17	0.30
(-1)	0.14	0.14	-0.20	0.17	0.72
(-2)	0.29	0.30	-0.05	0.15	0.93
(-3)	0.34	0.35	0.06	-0.23	0.92
(-4)	0.28	0.28	0.12	-	0.77
(-5)	0.11	0.08	0.14	-	0.39
COSTHA, Long Run	-1.04	-1.35	-1.68	-1.75	-0.70
COSTHA					
(0)	0.74	0.69	0.14	-0.10	0.77
(-1)	0.12	0.16	-0.13	-0.12	-0.06
(-2)	-0.31	-0.23	-0.31	-0.19	-0.57
(-3)	0.54	-0.47	-0.41	-0.29	-0.75
(-4)	-0.38	-0.58	-0.42	-0.43	-0.61
(-5)	-0.42	-0.55	0.35	-0.62	-0.14
(-6)	-0.06	-0.37	-0.20	-	0.66

Table 7. Elasticities of irrigation investment with respect to GNP per capita, the world price of oil, the net revenue per hectare of rice, and capital cost per hectare (revenue model).

	Parameter Estimates for Irrigation Investment Equations, By Type of Investment				
	Total Irrigation	New Irrig. Construction	Rehabilitation	Swamp/Tidal Irrigation	River & Flood Control
GNPC	2.00	2.34	2.26	-1.62	4.81
POIL	0.46	0.53	0.79	-0.08	0.43
REVRICE, Long Run	0.83	1.02	-0.68	-0.14	3.31
REVRICE					
(0)	-0.18	-0.17	-0.43	-0.20	0.06
(-1)	0.09	0.12	-0.26	0.15	0.53
(-2)	0.25	0.29	-0.13	0.14	0.80
(-3)	0.30	0.35	-0.02	-0.23	0.86
(-4)	0.26	0.30	0.06	-	0.71
(-5)	0.11	0.13	0.10	-	0.35
COSTHA, Long Run	-1.05	-1.07	-1.93	-1.74	-0.74
COSTHA					
(0)	0.81	0.80	-0.03	-0.10	1.01
(-1)	0.18	0.27	-0.14	-0.14	0.07
(-2)	-0.26	-0.13	-0.23	-0.20	-0.53
(-3)	-0.52	-0.40	-0.31	-0.30	-0.79
(-4)	-0.59	-0.55	-0.37	-0.42	-0.71
(-5)	-0.48	-0.58	-0.42	-0.58	-0.28
(-6)	-0.19	-0.48	-0.43	-	0.49