Economic Performance of Public Investments in Irrigation in India in the Last Three Decades

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Introduction

The economic performance of Indian agriculture has been closely related to changes in agricultural productivity. Increases in agricultural productivity, in turn have been partly attributed to substantial increases in the irrigated area (Meizen-Dick and Rosegrant 2005; Gulati and Narayanan 2003; Vyas in Mundle et al. 2003; Pitman 2002). Agriculture accounts for over 80 % of consumptive water use in India (Pitman 2002), and is at times even recorded to be higher than 90 % (Amarasinghe et al. 2005; Meizen-Dick and Rosegrant 2005). The rise in the irrigated area came about with massive irrigation investments by the government, made with substantial support from the international donor community. These investments began in the 1960s and peaked in the 1980s, but in the early 1990s, public spending in agriculture slowed down and this translated into reduced spending in irrigation (Meizen-Dick and Rosegrant 2005; Gulati et al. 2005; Gulati and Narayanan 2003; Pitman 2002; Fan et al. 1999). Gross capital formation in agriculture declined from an average of 54 % in 1980-1981 to 26 % in 1999-2000 (Mundle et al. 2003). Support from multilateral and bilateral donor agencies also declined over the same period. However, there have been recent efforts to reverse this downward trend in investments in water-related infrastructure, including irrigation (Peacock et al. 2007; World Bank 2004).

The poor economic performance of many past irrigation projects in India may have contributed to the decline in irrigation investment and lending by international financial agencies in the 1990s (Meizen-Dick and Rosegrant 2005; Raju and Gulati 2005; Gulati et al. 2005; Pitman 2002; Jones 1995). Furthermore, the low rates of economic return may have also resulted in diminishing the poverty reduction impact of these irrigation projects (Meizen-Dick and Rosegrant 2005; Kikuchi et al. 2003; Rosegrant and Svendsen 1993). These findings, however, do not suggest that governments should stop investing in irrigation because of the poor economic performance of such projects. This paper shows instead that there are ways to improve economic performance and that governments need not choose between achieving food security (or objectives other than getting high economic returns from projects) and investing in economically unviable irrigation projects.

The proposed river interlinking project will technically make more water available for consumptive and productive uses by diverting water from surplus to deficit basins. With agriculture as the biggest water user, increasing competing demands from other sectors and, the fact, that large proportions of the national and state budgets continue to be invested in the agricultural sector with apparently less growth and economically rewarding results, it is essential that agricultural water projects be well formulated and implemented to ensure greater efficiency and better overall performance including higher productivity.

To formulate better future irrigation projects in India, a comprehensive understanding of irrigation projects and their economic performance relative to those in other countries is important. Project performance is influenced by internal and external project factors, which could be a combination of physical, socioeconomic, institutional and policy factors. Among the internal factors are those that are related to formulation, design and implementation of projects. Specifically, costs of irrigation projects, agricultural productivity (yields and cropping intensity), operation and maintenance, and expected lifetime and gestation period of investments are the key factors. Some of the key external factors, which are beyond project control, are those that define the macro setting and policy environment (e.g., policies on pricing and tariffs for agricultural inputs and outputs and unforeseen changes in the market) of the country where a project is implemented.

This paper uses consistent data from 314 irrigation projects worldwide. The dataset includes 37 projects in India and a total of 91 projects in South Asia. The remainder is from 49 other countries in sub-Saharan Africa (SSA), the Middle East and North Africa (MENA), Latin America and the Caribbean (LAC), South East Asia (SEA), and East Asia (EA). The dataset contains certain key project characteristics and indicators of economic performance, which make it possible to systematically analyze irrigation projects and their performance. Using this dataset, this paper aims to: (1) examine the trends in the performance of irrigation investments in India, and contrast these with the trends in South Asia and the rest of the world; (2) determine the factors that influence the performance of irrigation projects worldwide; and (3) draw lessons for future irrigation investments in India.

This paper is constrained by the fact, that the dataset is based on projects that have been co-financed by the given country and an external funding agency. It does not include projects that were fully funded by a government or those which were solely funded by bilateral agencies. Furthermore, while the projects in the dataset include those with investments in groundwater and conjunctive water use, they do not consider the private investments in groundwater development, which have contributed significantly to the spread of irrigation in the past two decades in South Asia.

In the following sections, we describe the data, trends in economic performance and the profiles of irrigation projects. These are followed by a discussion of the results of a quantitative analysis of the performance of irrigation projects. The last section gives the conclusions and recommendations.

The Data[1]

This paper uses data obtained from various documents of irrigation projects funded by major international development organizations.[2] The project performance audit reports (PPAR) are the main source of data. In cases where the PPARs are not available, the project completion report (PCR) or the implementation completion report (ICR) are used as the next best source of information. In a few cases the staff appraisal reports (SARs), if available, are used to obtain further detailed information on project designs and project sites not cited in PPARs or PCRs.[3]

The dataset contains a total of 314 projects, which are all external funding agency assisted- projects with counterpart funding from recipient governments. A few projects received contributions from bilateral donors as well and a few others had farmers' contributions, but the latter are not quantified in project reports.[4] Of the total, 91 projects are in South Asia and 37 of these are in India. Table 1 gives the distribution of the sample projects according to purpose (new construction or rehabilitation). The total area irrigated by the 37 projects represents approximately 24 % of the 2001 official figure for net irrigated area in India, which is 55 million ha (GOI 2004).

The economic internal rate of return (EIRR) of an irrigation project reported at the project evaluation or completion is used as a measure of performance.[5] This measure is the sum of the discounted stream of benefits net of capital and O&M costs arising from the project. The EIRR is chosen as a performance indicator for two reasons: first, it is the most commonly used indicator of economic performance; second, in projects where no EIRRs are reported, it is possible to estimate them based on project outcomes described in the PCRs and the PPARs,

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[1] This section draws from Inocencio et al. (2007). See Annex Tables 3 and 4 for the data definition and summary list of classifications.

[2] These development agencies are the World Bank (WB) African Development Bank (AfDB) and the International Fund for Agricultural Development (IFAD).

[3] The PPAR, ICR/PCR, SAR are standard documents prepared by international development agencies such as the WB, AfDB, IFAD, and even the Asian Development Bank at each respective phase of a project. A project cycle may begin with feasibility studies followed by a project appraisal (articulated in a formal document called the SAR) where a proposed project is submitted to the lending agency's Board for its approval, implementation (where an ICR/PCR is produced at the end), and evaluation several years after project completion (where a PPAR will then be produced).

[4] Annex tables 1 and 2 include the composition and the details of the projects selected from different regions.

[5] Among indicators to measure the performance of irrigation projects, the most convenient, if not the best, measure is the EIRR. Despite its advantages as a single measure readily available in project reports, Tiffen (1987) gives an account of its shortcomings.

Table 1. Five-year averages (%) and trends in economic performance (EIRR) of irrigation projects by purpose of project, 1965-1999[a]

	Total no. of observations	1965-1969	1970-1974	1975-1979	1980-1984	1985-1989	1990-1994	1994-1999	Time Trend (1965-99)[b]
Asia									
All projects		14	23	15	14	18	25	18	*ns*
	(177)	(6)	(15)	(49)	(49)	(28)	(27)	(3)	
New construction projects		14	18	16	11	11	19		*ns*
	(63)	(4)	(7)	(15)	(23)	(7)	(7)		
Rehabilitation projects		15	28	14	16	21	27	18	*ns*
	(114)	(2)	(8)	(34)	(26)	(21)	(20)	(3)	
South Asia									
All projects		0	18	19	16	17	26	14	*ns*
	(91)	(1)	(9)	(21)	(30)	(17)	(11)	(2)	
New construction projects			20	18	10	14	12		
	(32)		(5)	(7)	(14)	(4)	(2)		- *
Rehabiliation projects		0	14	19	21	17	29	14	*ns*
	(59)	(1)	(4)						
India									
All projects			19	25	14	13	11	14	- **
	(37)		(3)	(10)	(15)	(6)	(2)	(1)	
New construction projects			19	26	10	17	5		
	(20)		(3)	(4)	(9)	(3)	(1)		*ns*
Rehabilitation projects			25	20	9	16	14		
	(17)			(6)	(6)	(3)	(1)	(1)	
ALL REGIONS									
All projects		13	18	13	14	18	21	21	+ ***
	(314)	(11)	(24)	(75)	(86)	(56)	(53)	(9)	
New construction projects		13	14	12	12	12	18	24	+ *
	(126)	(7)	(14)	(31)	(37)	(18)	(14)	(5)	
Rehabilitation projects		13	24	14	15	20	22	18	+ *
	(188)	(4)	(10)	(44)	(49)	(38)	(39)	(4)	

Sources of basic data: Various project documents of the World Bank, African Development Bank and International Fund for Agricultural Development, various years

Notes: [a] The years indicate 'year of project start' rather than year of project completion. Note that projects began in early or mid 1990s were completed only in early 2000. The latest project completion date was 2004

[b] The time trend is a regression of EIRR over year of project star

'+' means the variable is increasing over time while '-' means a decreasing trend

***, **, and * indicate statistical significance of time trends at 1%, 5%, and 10% levels, respectively. *ns* stands for not significant. Figures in parenthesis are number of observations which is not the case for other performance ratings.[6] While this measure does not directly address poverty and livelihood objectives, it captures impact on incomes that should imbed poverty and livelihood considerations. Also, to the extent that appropriate and realistic amounts are allocated for O&M expenditures, this performance measure imbeds sustainability aspects of projects as well.

To examine the profiles of projects, each was classified according to its type, purpose, operation and maintenance, major crops grown, project size, project cost, average system size, year of project's commencement, donor appraisal and supervision inputs, time overrun, cost overrun, sizing error, and the relative complexity of the project.

The purpose of a project ranges from the construction of an entirely new project on a land previously not used for agriculture (also known as 'new construction with land opening') to purely rehabilitative purposes (known as 'rehabilitation) like rehabilitating existing projects. In between these two extremes, there are a number of sub-categories including 'new construction from rain-fed area', 'new construction + rehabilitation', and, where rehabilitation is the major component of the investment, 'rehabilitation + new construction'.

The type of project is based on a classification of the physical infrastructure used to capture and convey water. The six types used to classify this dataset are: (a) river-diversion systems without major storage capacity (river-diversion); (b) systems that use river water from dams that have major storage capacity (river-dam-reservoir); (c) tank (i.e., small reservoir) irrigation systems; (d) pump irrigation systems with water from river, pond or lake (river-lift); (e) pump irrigation systems with groundwater (groundwater-lift); and (f) drainage and/or flood control systems. In this last type, excess water is either drained or released from the land area in a controlled manner, with crops being grown on the residual moisture.

For operation and maintenance, the classification is divided into three categories, and they are: (a) entirely by government agency (government agency); (b) partly (usually the headworks and the main/primary canals) by government agency and partly (usually the distribution canals and below) by farmers' groups (government + farmers); and (c) by farmers alone (farmer-managed systems).

The categories for the major crops grown are: (a) paddy (paddy); (b) other cereals such as wheat and maize (cereals); (c) cash crops such as sugarcane and cotton (sugar/cotton); (d) perennial tree crops (tree crops); (e) vegetables (vegetables); and (f) fodder (fodder). This classification is based on the cropping system used in all regions represented in the dataset.

Project size is the total area irrigated by the project, and is the sum of newly constructed and rehabilitated areas, where relevant. An irrigation 'project' is often an aggregate of several 'systems' or schemes. About 20 % of the global sample irrigation projects in the dataset are

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[6] Specifically, for the projects that do not report EIRR, we estimate it as the r that satisfies the following equation:

$$(1 + r)\ m\ K = S\ j=1n\ (R - c)/(1 + r)\ j,$$

where K = unit cost or cost/ha of irrigation construction/rehabilitation, R = return/ha due to irrigation construction/rehabilitation, c = O&M cost/ha, n = life time of the project (assumed 30 years for new construction projects and 15 years for rehabilitation projects), and m = average gestation period of investment.

'single system projects,' i.e., including only one irrigation system.[7] 'Total project cost' is defined as the total irrigation-related investment cost, including investment in both the physical irrigation infrastructure (e.g.,, dams, canals, sluice and measuring devices and roads) and software components (e.g.,, project management, engineering design, agriculture support and institution building).[8] 'Unit cost' is simply the cost of the investments divided by the project size.

The average size of a system is the area in a given project divided by the number of systems therein. The 'year project started' refers to the year in which implementation began, which could be a few months (or even years) after approval by the donor's board. Donor inputs for appraisal and supervision are the relevant personnel staffing effort in terms of weeks, which is not always available. The time and cost overruns are the differences between the actual construction period and costs, and those estimated at the time of project appraisal. The sizing error is the ratio of the difference between the planned and actual irrigated area benefited by the project, to the planned irrigated area, which is taken as a measure of the relative accuracy of the planning and appraisal stages. The number of project components listed in the SAR of a project is taken as a proxy to measure the complexity of the project.

Although our sample projects are all donor-funded projects, without exception the governments of recipient countries mobilize local funds for the projects. The share of government funds is the ratio of the local contribution to the total investment fund. While it would be more accurate to account for farmer contribution as well, most project documents do not quantify this. So, we accounted for this in the dataset as a binary (yes/no) variable. The share of software components is the ratio of the software costs, such as engineering management, technical assistance, agriculture support, research, training, and institutional development, to the total project cost. Conjunctive use of surface and groundwater is included as a yes/no binary variable. Data on the annual rainfall in the project area are usually provided in the SARs. Where no data are available in project reports, we obtained them from FAO AQUASTAT.

Conjunctive use of surface water and groundwater can mean greater water availability and reliability to farmers. A typical case of conjunctive water use in irrigation projects is found in many gravity irrigation projects, where farmers subsequently invest in pumps to supplement surface water from the systems. In our study, however, projects with conjunctive water use are defined as those that include it as a part of the project design. These projects account for over one-third of the global sample.

Two variables are introduced to capture the macroeconomic environments under which the sample projects are designed and implemented: 1) the real gross domestic product (GDP) per capita and 2) the purchasing power parity (PPP) ratio. For both variables, the averages from the project duration are used. The source of data for both variables is the World Bank Database (WDI Online). In the same manner as project costs, the real GDP per capita is expressed in terms of US$ at 2000 constant prices.

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[7] The rest have more than one irrigation system per project. The number of irrigation systems per project varies significantly across projects. The medianis 6 systems in a project while the modeis one.

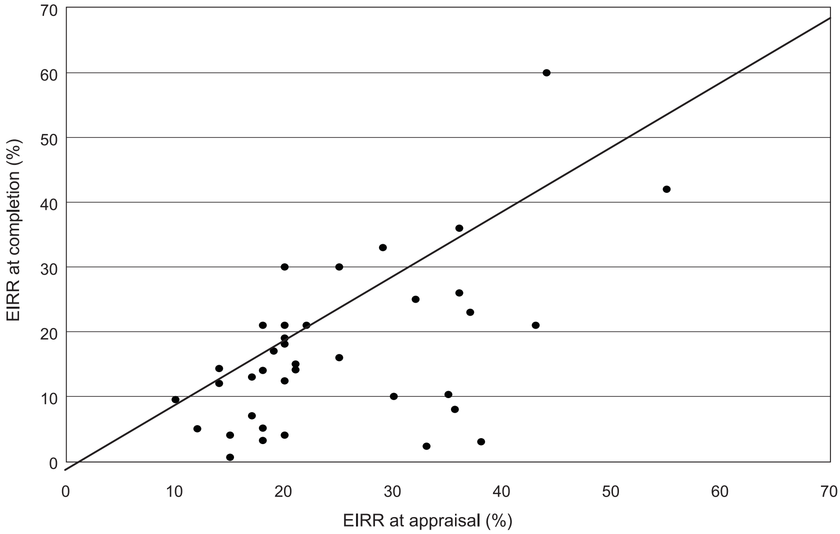
[8] Non-irrigation investment costs such as power generation and non-irrigation components in multi-sector projects are excluded. To make the cost data comparable across projects and over time, we measure the costs in US dollars at constant 2000 prices. When the costs are given only in local currency, we first convert them to current US dollars using the country's official exchange rate for the relevant years. The costs in current US dollars are deflated by the International Monetary Fund's implicit price index for world exports with year 2000 as the base.

Using this dataset and the classifications described above, we examine trends in performance and changing project characteristics over time in India and contrast this to the Asian and global samples.

Trends in Performance and Characteristics of Irrigation Projects

Figure 1 shows the plot of economic returns at appraisal (prior to implementation) versus the actual returns (at completion) for each of the 37 water development projects in India. This figure demonstrates that project appraisals have generally been over optimistic. Less than one fourth of the projects achieved or exceeded their target performance. If we consider the time trend of performance (Table 1), the actual economic returns for the projects in India have been on a significantly downward trend, more so in the case of recently implemented projects. The economic internal rates of return (EIRR) averaged 19 % in the early 1970s and only 14 % in the late 1990s. For rehabilitation projects, the economic returns started high in the 1970s and remained so even in the early 1980s, although the average declined substantially in the second half of the 1990s. It should be noted however, that during that 5-year period there was only one project in the dataset. The data showed a less significant decline for South Asia as a whole, and in the case of rehabilitation projects, the trend was actually positive, although like in India, projects completed in the latter half of the 1990s performed poorly. In this case, there were only two projects, and both were on rehabilitation. For all of Asia there is no significant trend in economic performance of irrigation projects with returns in investments remaining relatively high for all projects over time. In the case of India, the overestimation of economic returns at appraisal or lower completion/audit performance estimates is made worse by the decreasing EIRR trend. This observation is a cause for concern if we see it in the context of the global project sample, where performance is significantly improving over time both for new construction and rehabilitation projects.

Figure 1. Economic returns at appraisal and completion, India (n=37).



Irrigation Project Profile

Table 2 presents the distribution of the 37 sample projects from India and the changes in the profile of projects over time. Classifying according to the type of project shows that the entire sample for India is made up of single-purpose irrigation projects, while those from other countries include a few dual (with power components) and multi-purpose projects with irrigation components. As for purpose, the data show that new construction projects in India have been on the decline. The trends in this type of system show that both tank and groundwater-lift

Table 2. Five-year averages and trends in type of irrigation projects, India, 1970-1999[a].

Characteristics	70-74	75-79	80-84	85-89	90-94	95-99	Time Trend (1970-99)[b]
Type of project							
*Irrigation (%)	100	100	100	100	100	100	
Irrigation and power project (%)							
Multi-sector project (%)							
Purpose of project							
New construction with land opening (%)							
New construction from rain-fed farm (%)	67	10	40	33	50		*ns*
New +Rehabilitation (minor) (%)	33	30	20	17			- ***
Rehabilitation + New (minor) (%)		10		17			+ ***
*Rehabilitation (%)		50	40	33		100	*ns*
Type of system within a project							
*River diversion (%)		40	40	17		100	*ns*
River-dam-reservoir (%)	67	30	33	33	100		*ns*
River-lift system (%)							
Tank (%)			7	17			+ ***
Groundwater-lift system (%)		10	20	33			+ **
Drainage/flood control (%)	33	20					- ***
Type of O&M							
*Government-managed (%)	100	100	93				- ***
Jointly managed by government and farmers			7	17	100	100	+ ***
Farmer-managed system (%)							
Major crop irrigated							
*Paddy (%)	67	70	20	33	50	100	- *
Other cereals (%)	33	30	60	67	50		+ **
Sugar/cotton (%)			13				*ns*
Tree crops			7				*ns*
Vegetables							
Fodders							
Number of observations	3	10	15	6	2	1	37

Sources of basic data: Various project documents of the World Bank, various years

Notes: [a] Projects are grouped according the year the project started

[b] Linear time trend, estimated by regressing each variable over time (year of projection start)

'+' indicates a positive or increasing trend, '-'indicates a negative or decreasing trend

***, **, and * indicates that the trend is statistically significant at 1 %, 5 %, and 10 % levels, respectively. *ns* stands for not significant. The observation unit for trend estimation is the individual project for continuous variables and the 5-year average for dummy variables systems are on the rise while drainage/flood control projects have significantly decreased. Consistent with the government’s adopted policy of giving farmers increased roles in managing irrigation systems, the share of solely government-managed systems shows a negative trend while joint management by government and farmers is becoming the preferred mode of operation and maintenance (O&M). In terms of crops irrigated, while India is still predominantly irrigating paddy, there is a rising trend in the number of projects for other cereals and with paddy on the decline. In 1980-1984, there was a limited amount of crop diversification, with shifts into primarily sugarcane, cotton and tree crop, but no similar projects have been implemented since.

Table 3 presents the key characteristics of irrigation projects in India from the compiled project data. This table shows the size of projects in terms of total area irrigated, average size of systems

Table 3. Five-year averages and trends for key project characteristics, India, 1970-1999[a].

Characteristics	70-74	75-79	80-84	85-89	90-94	95-99	Time Trend (1970-99)[b]
Size/scale							
Project size (in terms of total irrigated area, ‘000 ha)[c]	133	322	352	265	112	2,300	+ **
Average size of systems within projects (‘000 ha)[c]	133	92	60	12	47	1,150	*ns*
Number of project components	8	7	7	7	4	4	*ns*
Project financing							
Share of government fund in total investment cost (%)	71	51	44	50	39	56	- *
Farmer’s contribution (% of projects with farmer contribution)	67	10			50		- **
Identification, formulation, planning factors							
Bank input for appraisal (staff weeks)	61	44	102	144	240	231	+ ***
Gestation period (months)	22	31	20	38	38	29	*ns*
Planned/actual irrig. area shortfall (%)	17	-70	6	-60	18		*ns*
Share of software component in total investment cost (%)	10	13	13	17	1	45	*ns*
Water availability/supply							
Annual rainfall (mm)	682	970	1,062	1,052	700	700	*ns*
Conjunctive use of water (% of projects)		60	33	17	50		*ns*
Implementation factors							
Bank input for supervision (staff weeks)	70	53	148	260	269	308	+ ***
Cost overrun (% to total investment cost)	80	12	2	15	19	-2	- *
Time overrun (years)	0.3	0.4	1.7	0.7	-3.0	-2.0	*ns*
Number of observations	3	10	15	6	2	1	37

Sources of basic data: Various project documents of the World Bank, various years

Notes: [a] Projects are grouped according to the year they started

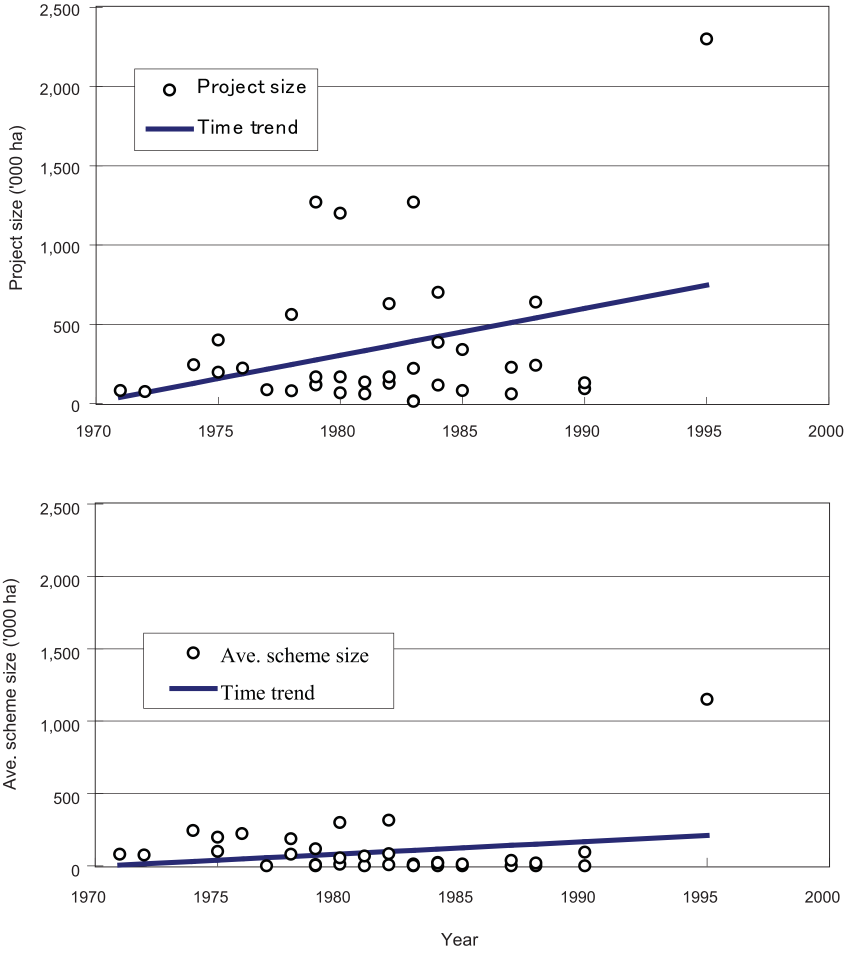
[b] Linear time trend estimated by regressing each variable over time (year of projection start); ‘+’ indicates a positive or increasing trend, ‘-‘indicates a negative or decreasing trend; ***, **, and * indicates that the trend is statistically significant at the 1 %, 5 %, and 10 % levels, respectively. ‘*ns*’ stands for not significant. The observation unit for trend estimation is the individual project for continuous variables and the 5-year average for dummy variables

[c] Removing the Haryana Water Resources Consolidation Project in the project size time trend regression makes the positive coefficient insignificant. The effect on the average system size however, is the reverse, with the negative coefficient becoming statistically significant at 5% level of significance. That is, without the Haryana 1995 project in the sample, the project size is *not* significantly increasing over time while the average system size is significantly declining

within projects, project financing, design-related and implementation factors. The trend in 'project size' shows that irrigation projects in India have become significantly larger in the last three decades. Figure 2 clearly shows these trends. However, if the Haryana Water Resources Consolidation (HWRC) project, which has an extremely large total rehabilitated irrigation area, is excluded in the trend analysis, the time effect on 'project size' remains positive but no longer statistically significant. 'Average system sizes' on the other hand, have remained relatively constant but removing the HWRC project in the sample makes the decreasing trend for this variable significant. Projects do not appear to be getting more complicated with the number of components not evidently changing, as shown by the statistically insignificant time trend.

It is interesting to observe that over time, the contribution of the government to total project cost has steadily declined from a high average of 71 % in 1970-1974 to an average of about 45 % in the 1990s. The decline in government counterpart funding in irrigation projects is consistent with the decline in budget allocation for irrigation from the central government and irrigation expenditures of the states, especially since the 1980s. Gulati and Narayanan (2003) and Pitman (2002) also show the same trend. For the same period, and rather surprisingly, projects with farmers contributing to development are declining as indicated by the statistically significant

Figure 2. Trends in project size and average scheme size, India (n=37).



negative time trend. This is an unexpected trend given that elsewhere development agencies and governments are in agreement that farmers should be encouraged to share in the development cost of irrigation projects and thereby increase their sense of ownership of the project.

Among the planning and implementation parameters from which we obtained data, the donors' staff inputs for appraisal and supervision have significantly increased over time. More staff time was spent on projects in the 1990s than in the 1970s or 1980s with an average of about 60 staff weeks in the early 1970s to over 230 staff weeks in the late 1990s. In fact, not only are appraisal and supervision inputs increasing, they are substantially higher in India than in the sample irrigation projects elsewhere. The pattern for appraisal staff inputs could be a reflection of the desire of the external funding agency to ensure better quality projects, including more stringent environmental requirements. And the increase in staff inputs for supervision could result in more trouble-shooting or hurdles to overcome at the implementation stages.

Cost and time overruns are often cited as the key factors affecting project costs and expected economic returns (Pitman 2002, Jones 1995). The data show that for India, cost overruns have been significantly declining over time from a high average of 80 % in 1970-1974 to an average of 12 % in the 1990s. This observation implies that projects are completed within the originally approved or agreed budgets and yet we see the EIRR declining, suggesting that factors other than cost overruns must be influencing this decline in economic returns. No significant pattern is observed for time overrun, although World Bank's (WB) sector evaluations surmise that it is an important factor in overall project performance (Pitman 2002, Jones 1995).

For the Indian data there is no significant trend in the unit costs of the projects over time, while in the case of the rehabilitation projects in Asia and both rehabilitation and new projects in the global samples, the unit costs have been declining (Table 4). These trends may in part explain the relatively lower performance of the investments in India. Interestingly, Gulati et al. (2005), using data on capital costs for irrigation development projects in India from 1964-1965 and 1995-1996, show unit costs to have been increasing. The authors explain the rise in capital cost as due to exhaustion of easier or favorable sites and the shift to relatively more difficult ones, increased expenditures on rehabilitation and environmental protection, and leakage in capital funds (Gulati et al. 2005). The difference in trends between this study and that presented by Gulati et al. (2005) may be explained by the differences in the type of data used and the assumptions made in the calculations.[9] The state-level and India-wide annualized costs in Gulati et al. (2005) could be reflecting a number of state and country-related factors that are not captured in our data.

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[9] Specifically, Gulati et al. used: (1) state-level and India-wide annualized costs of projects and in their project-specific analysis, examined in detail only three large projects which were started in the sixties and late seventies (Chambal Stage I in Rajasthan, Indira Gandhi Nahar Pariyojana Stage I and II (Rajasthan) and Upper Krishna Project in Karnataka) while this study uses project-level data and costs are not annualized for the 37 projects. The state and India-wide annualized costs are likely to include not only World Bank funded projects but also those which are funded by other donors and even those which could be fully funded by the states and the Government of India; and (2) basic data from various issues of the Combined Finance and Revenue Accounts of the Union and State Governments in India (CAG) which were then adjusted for inflation, gestation lag between the time of investment and completion of irrigation command areas and a social discount rate of 5%, while this study uses data from project performance audit or completion/implementation reports (PPAR or PCR/ICR) for each of the 37 projects which were then adjusted for inflation and converted to US dollars using the official exchange rates. This study did not adjust for gestation lag because it used both actual project costs and total irrigated areas at project completion.

Table 4. Five-year averages and trends in unit irrigation investment costs of projects by project purpose, UUS$/ha at 2000 prices), 1965-1999[a].

	1965 -69	1970 -74	1975 -79	1980 -84	1985 -89	1990 -94	1994 -99	Time Trend (1965-99)[b]
Asia								
All projects	3,278	3,159	3,398	5,037	1,350	1,168	2,822	*ns*
New construction projects	3,446	5,240	6,211	9,118	3,353	2,763		*ns*
Rehabilitation projects	2,942	1,338	2,158	1,427	682	609	2822	– ***
South Asia								
All projects	5,096	2,474	1,695	2,338	832	1,179	3,929	*ns*
New construction projects		3,019	2,782	4,283	1,357	4,310		*ns*
Rehabilitation projects	5,096	1,792	1,151	635	671	483	3,929	*ns*
India								
All projects		4,434	923	2,432	1,005	4,558	193	*ns*
New construction projects		4,434	1,649	3,775	1,486	7,421		*ns*
Rehabilitation projects			439	418	524	1,695	193	*ns*
All Regions								
All projects	3,527	3,589	6,593	5,960	3,703	3,605	5,120	+ ***
New construction projects	3,976	5,099	11,449	9,803	4,836	6,671	7,504	*ns*
Rehabilitation projects	2,742	1,476	3,172	3,058	3,167	2,504	2,139	– **

Sources of basic data: Various project documents of the World Bank, African Development Bank and International Fund for Agricultural Development, various years

Notes: [a] The year indicates 'year of project start' rather than year of project completion
[b] The time trend is a regression of log of unit cost over year of project start
'+' means the variable is increasing over time while, '-'means a decreasing trend
***, **, and * indicates statistical significance of time trends at the 1 %, 5 %, and 10 % levels, respectively
ns stands for not significant

Project Performance by Size of System

The sizes of projects and systems have been closely linked to performance. A number of reports strongly associated performance with the scale of either project or system (Inocencio et al. 2007; Pitman 2002; Jones 1995). Certain studies cited reviews of many failed large public irrigation 'projects' or poor performance of large-scale irrigation 'systems' (e.g., Peacock et al. 2007; Pitman 2002; Jones 1995).[10]

Focusing on the average size of systems within irrigation projects, the data do not support the above association of scale and performance. Table 5 shows that the differences in economic performance between major and minor systems or between medium and minor systems are not

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[10] Jones cited earlier reviews of a number of World Bank funded large irrigation projects especially in the 1970s-1980s which performed poorly. These earlier assessments must have contributed to the pervasive thinking that large projects were generally failures.

Table 5. Economic performance of irrigation projects by scale (%), 1965-1999[a].

Characteristics	Major	Medium	Minor	Major vs. Minor[b]	Medium vs. Minor[b]
Asia					
All projects	18	12	18	*ns*	< (*)
	(110)	(14)	(53)		
New construction projects	14	3	14	*ns*	< (*)
	(40)	(2)	(21)		
Rehabilitation projects	20	14	20	*ns*	< (*)
	(70)	(12)	(32)		
South Asia					
All projects	17	16	19	*ns*	*ns*
	(49)	(6)	(36)		
New construction projects	13	-1	17	> (*)	
	(17)	(1)	(14)		
Rehabilitation projects	20	20	20	*ns*	*ns*
	(32)	(5)	(22)		
India					
All projects	16	22	18	*ns*	*ns*
	(26)	(2)	(9)		
New construction projects	13	-	21	*ns*	-
	(15)	0	(5)		
Rehabilitation projects	20	22	16	*ns*	*ns*
	(11)	(2)	(4)		
All Regions					
All projects	17	14	15	> (**)	*ns*
	(166)	(41)	(107)		
New construction projects	14	13	13	*ns*	*ns*
	(59)	(20)	(47)		
Rehabilitation projects	19	15	16	> (***)	*ns*
	(107)	(21)	(60)		

Sources of basic data: Various project documents of the World Bank, African Development Bank and International Fund for Agricultural Development, various years

Notes: [a] The years indicate ‘year of project start’ rather than year of project completion

[b] ‘>’ indicates that on average, the first group has performed better than the second group

‘<’ indicates that on average, the second group showed better performance than the first group; whether the difference in averages between two groups are statistically significant is examined using the t-test for mean difference; statistical significance of the results are indicated by asterisks in parenthesis

***, **, and * indicate that the difference is statistically significant at the 1 %, 5 %, and 10 % levels, respectively

ns stands for not significant

statistically significant for India.[11] It is interesting to note that for Asia as a whole, minor systems are shown to have consistently done better than medium-scale systems. Quite in contrast, for South Asia’s new construction projects, and for the global sample (except for the

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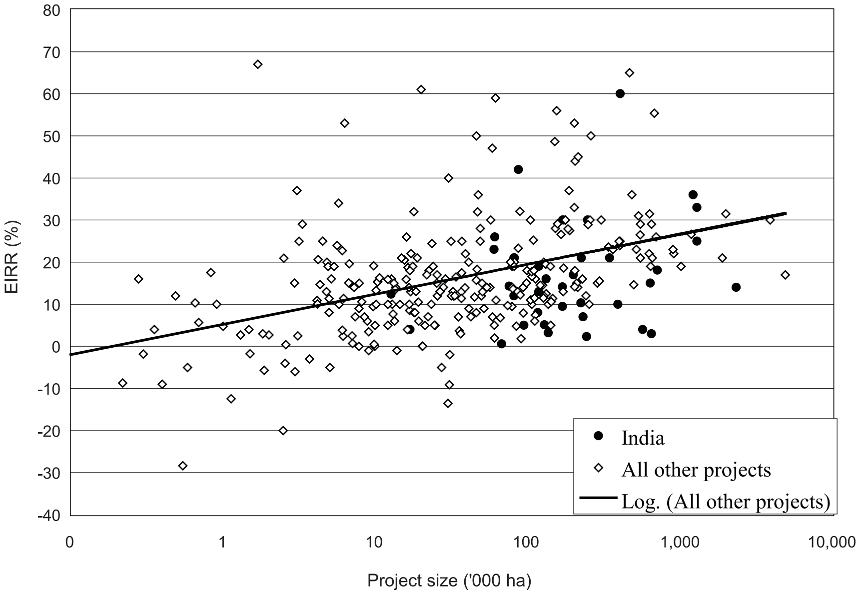
[11] We use the following definitions for scale of irrigation ‘systems’ (which are different from ‘project’ scale): a major system has an area above 10,000 ha; medium system has an area ranging from 2,000-10,000 ha; minor system has an area below 2,000 ha (Peter 2003).

new construction projects), major systems are shown to have significantly higher economic returns.[12]

On project size, Figure 3 shows that while a number of large projects have less than 10 % EIRR, larger projects obtained higher than 10 % EIRR. This pattern clearly holds for India's irrigation projects. So, the assertion that large projects are bound to fail cannot be supported by these data because small projects are more likely to perform poorly than large irrigation projects.

Figure 3. Project size and EIRR of irrigation projects, global sample (n=314).



Project Performance by Mode of Operation and Maintenance for Irrigation Systems

With governments devolving O&M responsibilities to farmers' groups a) to reduce their fiscal burden, b) increase the sense of ownership among farmers and c) improve viability and sustainability of projects — water user associations have been organized more aggressively during the past three decades. While many studies (e.g., Shah et al. 2002; Barker and Molle 2005) offer bleak pictures of the status and performance of these water user associations, Table 6 shows that for the India sample, no significant difference in economic performance is observed between jointly-managed and solely government-managed irrigation systems.

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[12] As will be discussed in section 4 on the regression results, the higher economic returns for major systems are largely due to the fact that most large projects have large average system sizes which must be pulling up the average EIRR for major systems. When the impact of large 'projects' is isolated from the effect of 'average system size', minor systems are shown to do better than major systems.

Table 6. Economic performance of irrigation projects by type of O&M (%), 1965-1999[a].

Characteristics	Government-managed systems	Government and farmer managed systems	Farmer - managed systems	Government vs. Government+ Farmer managed systems[b]	Government+ Farmer vs. Farmer-managed systems[b]
Asia					
All projects	14	18	25	< (*)	< (*)
	(79)	(73)	(25)		
New construction projects	14	12	18	*ns*	*ns*
	(31)	(24)	(8)		
Rehabilitation projects	15	21	28	< (**)	< (*)
	(48)	(49)	(17)		
South Asia					
All projects	17	17	25	*ns*	*ns*
	(52)	(29)	(10)		
New construction projects	15	13	10	*ns*	*ns*
	(21)	(9)	(2)		
Rehabilitation projects	18	19	29	*ns*	< (*)
	(31)	(20)	(8)		
India					
All projects	17	14		*ns*	
	(32)	(5)			
New construction projects	16	5			
	(19)	(1)			
Rehabilitation projects	20	17		*ns*	
	(13)	(4)			
All Regions					
All projects	13	18	22	< (***)	< (*)
	(161)	(115)	(38)		
New construction projects	12	15	17	*ns*	*ns*
	(72)	(42)	(12)		
Rehabilitation projects	15	19	24	< (***)	*ns*
	(89)	(73)	(26)		

Sources of basic data: Various project documents of the World Bank, African Development Bank and International Fund for Agricultural Development, various years

Notes: [a] The years indicate 'year of project start' rather than year of project completion

[b] '>' indicates that on average, the first group has performed better than the second group

'<' indicates that on average, the second group showed better performance than the first group; whether the difference in means between two groups are statistically significant is examined using the t-test for mean difference; statistical significance of the results are indicated by asterisks in parenthesis

***, **, and * indicate that the difference is statistically significant at the 1 %, 5 %, and 10 % levels, respectively

ns stands for not significant

The same is true for South Asia. For Asia and the global sample of projects, the analysis shows that irrigation systems jointly managed by government and farmers' organizations have done better than solely government-managed systems. Also, solely farmer-managed systems are shown to have done better than jointly-managed systems, although there are no such systems in the Indian sample of projects.

Determinants of Performance of the Global Irrigation Project Sample[13]

The observations in Paper 3 provide adequate motivation to do further analysis on the performance of irrigation projects. Paper 3 uses trend analysis and comparison of mean values to show changes over time and similarities among sets of projects. A more systematic and robust analysis is required to properly establish the factors determining economic performance. An analysis of the global sample of 314 projects should help us gain broader insights on the performance factors. By making use of the full sample, India benefits from the experience and knowledge gained in irrigation investments in other countries and regions. The insights from such an analysis should be more retrospective while also forward looking, and should guide policymakers, implementors and development agencies in India in formulating a new generation of better performing and more viable irrigation projects.

The Regression Model

To explain the variations in the performance of irrigation projects, we apply the regression analysis, which determines the factors that influence economic internal rates of return (EIRR) of irrigation projects. The EIRR of the projects is the dependent variable regressed over a set of all the other variables in the dataset. To let our data 'speak for itself,' a Box-Cox model, which is the most flexible among linear regression models, is used. A general Box-Cox model for the EIRR analysis can be written as (Box and Cox 1964; Greene 2003: Ch.9):

$$Y_j^{(\theta_1)} = \alpha_0 + \sum_{k=1}^{K} \alpha_k X_{kj}^{(\lambda_1)} + \sum_{\ell=1}^{L} \beta_\ell Z_{\ell j} + \varepsilon_j \qquad (1)$$

where Y is the dependent variable (EIRR) subject to a Box-Cox transformation with parameter, θ_1, i.e., $Y^{(\theta_1)} = (Y^{\theta_1} - 1) / \theta_1$; X_k (k = 1, 2, …, K) are the transformed explanatory variables using a Box-Cox transformation with parameter λ_1, i.e., $X_k^{(\lambda_1)} = (X_k^{\lambda_1} - 1) / \lambda_1$; Z_ℓ (ℓ = 1, 2, ..., L) are the untransformed explanatory variables; and $\varepsilon \sim N(0, \sigma^2)$. Since the EIRR takes a non-positive value, the Box-Cox parameter for the dependent variable is assumed to be unity (i.e., $\theta = 1$).

The variables that are continuous and without non-positive values are selected for Xs, i.e., explanatory variables subject to the Box-Cox transformation. The rest of the explanatory variables are Z's, which are further divided into two groups. The variables in the first group, time overrun, cost overrun, and sizing error, are continuous variables with non-positive values, for which we assume $\lambda = 1$, i.e., the original linear form. The variables in the second group consist of binary dummy variables; 1 if applicable and 0 if not. For category variables from various typologies of projects, the variables which serve as the base or reference are omitted in the regression. These are: 'irrigation', 'rehabilitation', 'river diversion', 'government-managed system', 'paddy', 'South Asia' for the regional dummies, and 'WB' for donor dummies, respectively.

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[13] This section draws from Inocencio et al. (2007).

From the Box-Cox equation, the elasticity of the EIRR with respect to a transformed variable is given as:

$$\frac{\partial(Y)}{\partial X_k}\frac{X_k}{(Y)} = \alpha_k\left(\frac{X_k^{\lambda_1}}{Y^{\theta_1}}\right) \tag{2}$$

where X_k (k = 1, 2, 3… K) is a transformed explanatory variable. Similarly, the elasticity with respect to untransformed variables is given as:

$$\frac{\partial(Y)}{\partial Z_\ell}\frac{Z_\ell}{(Y)} = \beta_\ell\left(\frac{Z_\ell}{Y^{\theta_1}}\right) \tag{3}$$

where Z_l (l = 1, 2… L) is an untransformed explanatory variable. The elasticities are evaluated at the mean for continuous variables and at unity for binary variables.

Estimation Results

Table 7 reports the EIRR regression results. Note that the elasticity is computed only for variables that have statistically significant coefficients. The regression shows that the following factors are significant determinants of the performance of irrigation projects: a) project size and average size of systems; b) number of project components which is a proxy for complexity

Table 7. Box-Cox regression and elasticity of determinants of economic performance of global irrigation projects, (n=314).

Explanatory variables	Regression coefficients		
	Coefficients	Test values	Elasticity
Transformed:			
Project size	5.113 ***	35.97	0.319
Average size of systems	-0.696 **	3.784	-0.043
Year project started	-2.009	0.792	
Bank input for supervision	-2.361 **	4.276	-0.147
Number of project components	-4.324 ***	8.889	-0.270
Share of government fund	0.680	0.192	
Share of soft components	0.656	0.831	
Annual rainfall	2.566 **	4.045	0.160
GDP per capita	-6.530 ***	10.20	0.181
PPP	0.537	0.756	
Untransformed:			
Time overrun	-0.218	0.406	
Cost overrun	0.237	0.028	
Sizing error	0.009	0.777	
Farmers’ contribution	2.968 *	2.686	
Conjunctive use of water	2.900 *	2.811	
Irrigation and power	1.776	0.307	

(Continued)

Table 7. Box-Cox regression and elasticity of determinants of economic performance of global irrigation projects, (n=314) *(Continued)*.

Explanatory variables	Regression coefficients		Elasticity
	Coefficients	Test values	
Multi-sector project	2.428	0.699	
New construction w/land opening	-0.994	0.102	
New construction from rain-fed	-3.522 *	3.261	0.220
New + Rehabilitation	-0.108	0.003	
Rehabilitation + New	0.757	0.184	
River-dam-reservoir	2.344	1.875	
Tank	2.670	0.417	
River-lift	-2.702	1.437	
Groundwater-lift	1.258	0.249	
Drainage/flood control	0.254	0.011	
Government + farmer group	4.081 ***	7.523	0.255
Farmer-managed system	5.253 **	5.061	0.328
Cereals	1.019	0.306	
Sugar/Cotton	-1.797	0.480	
Tree crops	6.135 *	3.480	0.383
Vegetables	7.572 ***	6.120	0.472
Fodders	19.988 ***	9.603	1.247
AfDB	-4.051	0.980	
IFAD	-13.830 **	5.146	-0.863
East Asia	8.264 **	4.799	0.516
Southeast Asia	1.800	0.536	
Latin America & Caribbean	6.752 **	4.535	0.421
Middle East & North Africa	6.595 **	5.541	0.411
Sub-Saharan Africa	9.222 ***	10.16	0.575
Constant	17.192		
λ	-0.088	-1.350	
θ			
σ	10.314		
Log likelihood	-1178		
Number of sample	314		

Sources of basic data: Various project documents of the World Bank, African Development Bank and International Fund for Agricultural Development, various years

Notes: [a] Test statistics for regression coefficient follow the ÷2 distribution with the degree of freedom of 1, while those for the Box-Cox parameters follow the standard normal distribution
***, **, and *, indicate that the coefficients are statistically significant at the 1 %, 5 %, and 10 % level, respectively
[b] For continuous variables, elasticity is estimated at their means, and for binary variables, setting the variable unity
Elasticity is shown only for the variables that have significant coefficients

of projects; c) annual rainfall and conjunctive use of surface and groundwater, which are proxies for water availability; d) real GDP per capita, which is a proxy for a country's level of development; e) farmers' contribution to investment cost; and f) some design and technology factors.

Project Size and Average Size of System

The EIRR regression analysis reveals that project size, as measured by the total area irrigated by an investment project, is the most important factor determining the performance of irrigation projects. The larger the project size, the higher the economic returns. This result confirms an earlier finding of Jones (1995) that "big projects just do better than small projects." From Inocencio et al. (2007), project size is shown as a critical determinant of the cost. The significant impact of project size on economic returns could be through its impact on project cost and the economies of scale effect.

The significant economy of scale of project size could be attributed primarily to engineering economies of scale in formulating and implementing irrigation projects (Inocencio et al. 2007; Jones 1995). Larger projects are supposed to attract better managers, and implementing agencies may have more incentive to be cost-efficient given the relatively higher profile and greater public attention (Jones 1995). In production processes, an economy of scale arises when there are indivisible inputs. Huge excavation machinery and dump vehicles for constructing dams and other physical irrigation structures are indivisible. More importantly, capable human resources, such as planners, design engineers, construction engineers, administrators, managers, contractors, consultants, government agency officials, foremen, and farmers' organizations are all indivisible scarce resources that are indispensable in irrigation projects. The strong economies of scale in irrigation projects suggest the importance of these scarce inputs.

'Average size of systems' within irrigation projects has a significant performance-reducing impact. This result implies that the smaller the size of the irrigation system, the better the expected economic returns. One possible explanation for this seemingly contradictory result with the positive impact of project size could be the management advantage in smaller systems over larger ones. With potentially fewer farmers to coordinate within each system, smaller systems compared with large systems would be relatively easier to manage. That is, while economies of scale are very important at the project level, at the system (within each project) level better economic performance can be attributed to better management, which may characterize small irrigation systems (ADB-PEO 1995).

Some reports have argued that poor performance and success cases have been observed for both large and small irrigation projects (e.g., Rosegrant and Perez 1995; Brown and Nooter 1992; Adams 1990). They argue that scale appears to be less important in determining the success of the project than how it is managed. Our analysis indicates that, as far as the scale of irrigation projects is concerned, there are large economies of scale. However, it also suggests that at the 'system' or scheme level, how projects are managed appears to be more important than their scale.[14]

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[14] If we take projects in the global sample with over 50,000 ha (an arbitrary 'large' project cut-off size) with a minimum of 100 systems (a relatively large number of systems) within each project and a maximum irrigation system size of 50 ha (an arbitrary 'small' system cut-off size), at least six projects in South Asia qualify for the 'large project yet small systems' category: four projects in Bangladesh (the Shallow Tubewell and Low-lift Pump Irrigation, the Deep Tubewell II project, Northwest Tubewell, and Shallow Tubewell project); and two in India (the West Bengal Agricultural Development Project and Minor Irrigation Project). Using this definition, other examples in South Asia and Latin America are a mixture of village irrigation, low-lift pump irrigation, rural development, national irrigation rehabilitation, natural resources management and irrigation development, and land-water conservation. Project sizes range from 11,000 to 46,000 ha while the corresponding system sizes range from an average of 8 to 35 ha.

As shown in Table 3, India's project size is significantly increasing over time while no pattern is established for the average system size. The increasing project size appears consistent with the regression result. However, removing the Haryana Water Resources Consolidation project from the sample, the increasing project size trend becomes insignificant while the declining of the average size of system over time becomes significant.

Number of Project Components

The number of project components is intended to capture the degree of project complexity. The result showing a significant negative impact on EIRR is quite intuitive. The more complex a project becomes, the more likely that it will have lower economic returns. For India, the 5-year averages in Table 3 show projects to have fewer components over time, however, no statistically significant trend is established.

External Funding Agency Staff Input for Supervision

Input of staff from the external funding agency for supervision has a negative impact on the project's performance: the larger the staff input for supervision, the lower the economic returns. A caution on this variable is that it may be introducing a simultaneous problem in the regression equation, i.e., the external funding agency input for supervising a project may be larger because the performance of the project is poor, or the performance of a project may be better because the external funding agency spends more staff time on the project. The data reveal that the former is the case.[15] That is, the data apparently capture the higher supervision inputs required for troubled projects, which are likely to perform poorly.

This variable is of interest given the fact that in India, external funding agency staff supervision is shown to be significantly increasing over time and substantially higher than projects in other countries or regions. Supervision inputs appear to proxy for implementation difficulties, which may be pulling down economic returns. The regression result points to the need to carefully understand the underlying reasons for the high supervision inputs in India. Pitman (2002) identifies the sources of difficulties in implementation to include institutional and political factors. Specifically, he cites that in India, projects suffer from inadequate advanced preparation, incomplete engineering designs, insufficient staffing, land acquisition and resettlement, and procurement.

Annual Rainfall and Conjunctive Use of Surface Water and Groundwater

We take annual rainfall in the area where an irrigation project is located as a proxy measure for water availability. For the global level analysis this variable has a positive impact on economic performance, i.e., the higher the annual rainfall, the better the project performance (Table 7). This result suggests that there is a causal link between the amount of rainfall and project performance. Increased water availability and easier access to water translate to higher yields and higher economic returns.

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[15] The exclusion of this variable alters a little the results of the regression analysis. This observation suggests that the bias due to simultaneous nature of regression equation, if any, is not large.

The result of our global analysis shows that conjunctive water use improves project performance significantly. Irrigation projects that use surface water and groundwater conjunctively have higher economic returns than those which use single sources, even without considering the private development of groundwater, which is not captured in this analysis. In the sample projects in India, no significant trend is observed for annual rainfall and projects with conjunctive water use.

Real Gross Domestic Product (GDP) Per Capita

An increase in the real national per capita income is shown to significantly reduce the economic performance of irrigation projects. This result says that higher income countries tend to have poorly performing projects. Interestingly, the elasticity of economic performance for this variable is largest among the continuous variables used in the analysis. These findings are important, because they suggest that targeting poorer countries makes better investment sense as projects will be economically more effective.

As economies develop the agriculture sector's contribution to the economy declines. This process usually accompanies increasing income as well as a disparity in productivity between the agriculture sector and the non-agriculture sector, the former being left behind. Such a situation leads to agricultural protectionism policies where farmers in high-income countries get more support and subsidies. Implementation of high-cost and low-performance projects is justified on the grounds of protecting disadvantaged farmers, overshadowing economic merits.

India's increasing real GDP per capita and its declining economic returns from public investments in irrigation over time appear consistent with this result. The explanation above seems still not completely relevant for India considering that she is still not exactly a high-income country. However, if we take into account India's relatively heavily subsidized agriculture sector, which simulates the above mentioned characteristic of high subsidies in high income countries, the result becomes logical.[16]

Farmers' Contribution to Investment Cost

Where farmers contribute to project development, projects perform better than those without farmer contribution. The promotion of farmers' contribution to irrigation projects has been pursued more eagerly since the 1980s as a part of a strategy to adopt more participatory approaches. This policy is believed to lead to a greater sense of ownership among the beneficiaries of irrigation systems constructed/rehabilitated by the project, and results in more sustainable projects while reducing the financial burden of the implementing agencies. Evaluations of this policy have shown that farmer contribution leads to more successful participatory processes and greater successes of irrigation projects (Bruns 1997). The result in this study confirms these earlier findings, and supports a policy that encourages farmers to

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[16] See, for instance, Raju and Gulati (2005) and Gulati and Narayanan (2003) on subsidies in Indian agriculture and irrigation.

contribute to the project cost, on the grounds that it serves as an incentive to use the investment funds more effectively for the farmers' needs and priorities.

Contrary to expectation, India shows a declining pattern for projects with farmers' contribution to investment cost. This trend may reflect either of two things: 1) that the government was reluctant to fully implement such a policy for fear of burdening farmers beyond their means or 2) there were attempts to implement but farmers succeeded in resisting such policies and, as such, more projects ended up with just the government and an external funding agency covering the investment cost.

New Constructions from Rain-fed Areas

Among the projects by purpose, new constructions from previously rain-fed areas show a significantly negative impact on economic returns relative to pure rehabilitation projects, i.e., former has a lower economic performance than pure rehabilitation projects. This difference in performance can be attributed to spill over effects from the cost side given the large economies of scale and the fact that cost as an important variable in the estimation of economic returns. Also, from the global regression analysis, total irrigated area is found to be a major factor influencing performance. In our sample, pure rehabilitation projects happen to be generally bigger in total irrigated area than new constructions from rain-fed areas. India is not shown to be implementing more projects of the type of new constructions from rain-fed areas, but such projects are proposed under the NRLP. What this analysis shows is that new constructions are not likely to perform better than rehabilitation projects, and that therefore, a more careful evaluation is warranted.

Mode of O&M for Systems

Another important variable that has a significant impact on performance is the mode of O&M for irrigation systems after completion of the project. A clear shift in the mode of O&M in irrigation systems from 'government-managed' to 'government+farmer-managed' and 'farmer-managed system' is observed from the global data. The participation of farmers in irrigation projects and system management, through the establishment of water users' associations (WUAs), has been central to the efforts to improve project performance and sustainability of irrigation systems in the last two decades (Merrey 1997; Vermillion 1995, 1991; Vermillion and Johnson 1995). The regression results show that projects with farmer-managed systems perform better than those that are solely government-managed. Also, projects with O&M shared by the government irrigation agency and farmer-beneficiaries through WUAs perform better than those that are solely government-managed. The poor irrigation management by a government monopoly reflects the lack of accountability and incentive to deliver quality service and water supply. This is exacerbated by the absence of a link between irrigation quality, revenues generated from irrigation service fees and staff incentives (Gulati and Narayanan 2003; Gulati et al. 2005). The existence of well-established and operational WUAs has been associated with better maintenance of systems and more efficient water deliveries, which in turn have led to higher yields and better economic performance of irrigation projects (Raju and Gulati 2005; Gulati et al. 2005; Gulati and Narayanan 2003).

One can see from Table 2, that India’s solely government-managed systems are declining while systems jointly managed by the government and farmers are increasing. The Government of India has adopted institutional reforms that shift more responsibilities to farmers by establishing WUAs. In fact, efforts in this direction began as early as the 1970s and were accelerated significantly in the mid-1980s. From the sixth to the ninth ‘5-year plans’, participation of farmers in various aspects of management of the irrigation system has been recognized as important, and endorsed and promoted as a central strategy in irrigation development and management. In the 1999-2000 central government budgets, a one-time management subsidy was given to states to form WUAs. However, many studies have pointed out how the process has been slow in taking off and the difficulties in making WUAs work, which range from institutional to technical and social (Gulati et al. 2005; Raju and Gulati 2005; Barker and Molle 2005; Gulati and Narayanan 2003; Shah et al. 2002; Vermillion 1991, 1995; Vermillion and Johnson 1995). The results in this paper do not claim that these difficulties and problems are non-existent but looking at the projects’ economic performance, systems with farmers involved in O&M have done better than those that were solely government-managed. These results reinforce the recommendation of Gulati et al. (2005) that farmers should be treated as clients, shareholders or as co-managers of irrigation systems rather than just beneficiaries. Farmers’ organizations will in fact play a more significant role in O&M of systems if treated as co-managers.

A better understanding of the factors that influence the participation of farmers in WUAs and the WUA’s viability should help turn around this slow progress. Gulati et al. (2005) identified the factors that can positively influence farmer participation as follows: (a) where a minor system serves mostly one village rather than multiple villages; (b) sites with temples or religious centers;[17] (c) large command areas that are closer to markets; and (d) presence of community organizers or potential leaders.

Irrigated Crops

In terms of the type of crops irrigated, systems irrigating vegetables, tree crops, and fodder are shown to perform better than those irrigating paddy. As a result of irrigation development since the 1960s and the subsequent success of the green revolution since the 1970s, the price of rice has been declining sharply in real terms since the early 1980s. This trend in turn resulted in the historic low-profitability of rice production over the last two decades. In contrast, price prospects are much better for fruits, vegetables and livestock products, the demand for which increases as the economy develops. Better price prospects for fruits, vegetables, and livestock products that use fodder contribute to the higher project performance of these systems when compared to the rice systems. Systems that irrigate high-value crops enjoy higher economic returns because of the higher profitability of the crops irrigated.

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[17] Sites with religious centers are said to have a greater chance of organizing systems for irrigation with the centers themselves becoming the focal points for local social capital.

Agriculture diversification in India began in the 1980s but gathered momentum in the 1990s (Joshi et al. 2007, 2005). Rising income, changing relative prices between cereals and high-value agriculture, increasing urbanization and infrastructure and more open trade policies are among the factors identified to have driven this change (Joshi et al. 2007).

From our data, the trends in India's irrigated crops (Table 2) show that paddy irrigation is declining while irrigation for other cereals is rising. Despite policy pronouncements encouraging the shift to high-value crops, it appears that the country has still a long way to go to realize significant diversification levels. While not discounting the associated risks and difficulties in irrigating high-value crops, such as vegetables and even tree crops and fodder, our results show that systems irrigating these crops have done significantly better than those irrigating paddy. This is an opportunity that India can seriously consider and take advantage of.

Joshi et al. (2007) have established the determinants of crop diversification. Among the factors identified are: a) infrastructure development as captured by markets and roads; b) technology as captured by irrigated area; c) the relative profitability of horticultural commodities; d) the proportion of smallholders; e) climate as captured by the amount of rainfall; and f) demand-side factors such as urbanization and per capita income. The paper suggests that assured markets and good road networks are key determinants that could stimulate agricultural diversification in favor of high-value crops, as they maximize profits and minimize uncertainty in output prices. Interestingly, the higher the technology adoption for the production of cereal crops as proxied by irrigation, the less was the diversification in favor of high-value commodities. This particular factor points to the potential of diversification in areas where less water is available. Also, another significant finding is that high-value commodities are usually produced by small farmers.

To promote agricultural diversification and meet the demand for high-value commodities, Gulati et al. (2007) recommend improvement of incentives, institutional reforms and increased investment. Specifically, improving incentives basically means 'getting the prices right' by adjusting the high and guaranteed prices for staple grains and reducing subsidies on power, irrigation and fertilizers, and reallocating the funding to basic infrastructure development, excluding irrigation. Reforming institutions include 'getting the markets right' by leveling the playing field, improving land-use and credit access, reinvigorating technology development and dissemination, and promoting improved food-safety and quality. As for the required investment, the authors suggest more investment in roads and markets, electricity supply, information and communication technologies (ICT), and improving the climate for private investment.

Regional Effects

South Asia has the lowest EIRR among all regions with the exception of South East Asia. This means that, once the factors with significant impacts on performance are accounted for, irrigation projects in South Asia, generally, have lower economic returns than those in SSA, MENA, LAC and East Asia. This is another cause for concern, especially if we consider that India's EIRR is significantly decreasing over time. There is however, a potentially significant opportunity for addressing and reversing these trends of the relatively low and declining EIRR.

Lessons from the Global Experience and the Way Forward for India's Irrigation Sector

Summary and Conclusions

This paper offers certain insights on irrigation projects in India based on a consistent set of data for 314 irrigation projects implemented in developing countries worldwide in the last four decades. The database includes 37 projects for India, which accounts for 24 % of the official irrigated area in 2001, a significant sub-set. We examined trends in the economic performance of irrigation investments in India, determined the factors that influenced performance of the global sample and drew lessons for future irrigation projects in India.

Our analysis indicates that the performance of irrigation investments in India by the government and key external funding agencies has been declining with time, whereas at a global level they have, in fact, been on an upward trend. No significant trend is established for the unit cost of the sample irrigation projects in India, implying that cost may have little to do with the decline in project performance or that factors other than costs must have more dominating effects. Having said that however, another recent study that used annualized data found that state-level and India-wide unit costs are increasing.

The share of the Indian Government in total investment cost has declined relative to that of the external funding agencies. Projects with farmers contributing to their development too are declining. The decline in government counterpart funding in irrigation projects is consistent with the decline in the budget allocation of the central government for irrigation and the irrigation expenditures of the states, especially since the 1980s (Gulati and Narayanan 2003). The declining pattern for projects with farmers' contribution to investment cost may reflect either of two things: 1) that the government was reluctant to fully implement such a policy for fear of burdening the farmers beyond their means or 2) there were attempts to implement but farmers succeeded in resisting such policies and more projects ended up with just the government and an external funding agency covering the investment cost.

This paper finds that as far as irrigation project size (in terms of total irrigated area) is concerned, there are underlying significant economies of scale. To assert that large-scale projects are bound to fail cannot be supported by the data, because small projects are more likely to perform poorly in comparison with large irrigation projects. Furthermore, rehabilitation projects perform better than new irrigation projects developed in previously rain-fed areas.

However, our results also suggest that at the system or scheme level, how projects are managed appears to be more important than scale. The increasing project size or total irrigated area trend in India appears consistent with the regression result. However, if the trend is adjusted by taking out the Haryana Water Resources Consolidation (HWRC) project from the sample as it has an extremely large total rehabilitated irrigation area, the increasing project size trend becomes insignificant while the trend in average system size decreases significantly. The declining pattern for average size of system in India (without HWRC in the India sample) is consistent with the result on average size of system of the global analysis.

Supervision by the staff of external funding agencies was shown to be significantly increasing over time, and substantially higher in India's projects than those in other countries or regions. This observation could reflect serious implementation constraints that however, have to be properly understood and addressed if projects are to succeed. Among the cited sources of difficulties in implementation are; inadequate advanced preparation; incomplete engineering designs; insufficient staffing; land acquisition and resettlement; and procurement. The declining cost overruns, while not directly affecting economic performance, is a good indication that efforts toward improving implementation are succeeding.

The current trend of the systems in India are the same as those in global systems, i.e., wholly government-managed systems are declining and those jointly managed by government and farmers are increasing. While there are no systems that are solely managed by farmers in the Indian sample, systems that do not involve any government agency are reported in the global sample to perform the best. The Government of India has embraced this policy of shifting more responsibilities to farmers by establishing WUAs. However, several reports have pointed out that while the process of implementing such a policy has been very slow, it has also been increasingly difficult to ensure the viability of the WUAs themselves.

The trends in India's irrigated crops show that paddy irrigation is declining while irrigation for other cereals is rising. Despite policy pronouncements encouraging the shift to high-value crops, it appears that the country is yet to realize such crop diversification. While not discounting the associated risks and difficulties in irrigating high-value crops, systems irrigating these crops have done significantly better than those irrigating paddy. This is an opportunity that India can seriously consider and take advantage of.

In terms of type of project by purpose, the trends in India appear to be consistent with the global regression results with investments declining in new construction projects from rain-fed areas and increasing in pure rehabilitation projects, the latter of which have relatively higher economic returns. The trends in the type of system show that both tank and groundwater-lift systems are on the rise while drainage/flood control projects are decreasing significantly. While not having direct impacts on economic returns, investments in these types of system may have adverse environmental impacts, which would in turn impact on water quantities and eventually on irrigation performance.

Recommendations

What are the lessons from the global sample for India? The analysis shows that public investments in large irrigation projects do perform positively from an economic perspective. Furthermore, larger projects tend to do better than the smaller scale investments. While investments in such projects have diminished recently, further investments of this type are proposed under the NRLP and are part of the overall justification of the planned inter-basin transfers. While such investments have been shown to have a positive economic performance and could be appropriate components of specific transfers, this is only true for those projects that are primarily connected with the rehabilitation of existing systems. The same does not hold true where projects have been developed on previously rain-fed lands, and such new constructions have generally performed poorly. Furthermore, given that this analysis does not incorporate the role of private sector investments in groundwater development, this factor needs to be further examined to determine whether the economic performance was greater where investments were made to support groundwater irrigation, such as groundwater recharge.

The policy of giving farmers increased roles in the operation and management of irrigation systems have had mixed results. Most of the available evidence are at the micro level or are scheme-specific and, as such, cannot give a clear recommendation on whether this policy agenda should be continued or not. More studies have reported the problems of such policies and why programs such as irrigation management transfers cannot or do not work. The result in this paper is in line with more recent evidence, which shows the more promising and positive impacts of greater farmer participation in irrigation O&M, in terms of enhancing project performance. The direction of the government and donors in encouraging more farmer participation, with the former providing supporting roles, should be continued. However, while the results provide support for such a policy, the inherent difficulties and challenges in making participatory initiatives work should not be underestimated. Building capacities and stronger farmer groups require considerable time and resources, which the government and donors should invest in, in order for projects to be sustainable.

The idea of shifting from largely food cereal production to higher value crops has been initially met with less interest by decision-makers, yet has been occurring on the ground. Farmers are believed to be inflexible in shifting from one crop to another, especially since such diversification entails higher risks, which farmers cannot afford and requires greater technical skills that most farmers are said not to have. However, this paper provides empirical support to the policy of crop diversification in irrigation projects and indicates that, it is in the direction of achieving better project economic performance. Yet, this argument is not implying that the government can encourage diversification without taking into account various factors. Complementary public investments in basic infrastructure such as roads and access to information, input and output markets, and access to financial capital, should reduce the attendant risks for farmers and serve as incentives to take advantage of the opportunity and benefit from investments in irrigating higher value crops.

While this paper offers certain key investment areas, which can be pursued by the Government of India and the international development community, it has not addressed the role of the private sector in agricultural water development and management. This knowledge should complement the recommendations espoused in this paper. From the above, it is clear therefore, that there are areas that would need further and careful study, particularly with regard to ensuring the economic performance of major investments in irrigation in the context of inter-basin transfers, and increasing water scarcity.

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Annex Table 1. Total area irrigation by projects in sample, 1965-1999[a].

	Total number of irrigation projects	Total area irrigated (‘000 ha)
Asia		
All projects	177	42,960
New construction projects	63	5,016
Rehabilitation projects	114	37,944
South Asia		
All projects	91	29,065
New construction projects	32	3,467
Rehabiliation projects	59	25,598
India		
All projects	37	13,006
New construction projects	20	2,527
Rehabilitation projects	17	10,479
All Regions		
All projects	314	53,684
New construction projects	126	7,105
Rehabilitation projects	188	46,578

Sources of basic data: Various project documents of the World Bank, African Development Bank and International Fund for Agricultural Development, various years

Notes: [a] The years indicate ‘year of project start’ rather than year of project completion

Annex Table 2. List of sample projects, India (n=37).

Project title	Year project started	Total project area under new construction (ha)	Total project area under rehabilitation (ha)	Total irrigation cost in 2000 prices (million US$)
Kadana Irrigation Project	1971	80,540		421.1
Pochampad Irrigation Project	1972	75,000		530.5
Chambal Command Area Development Project (Rajasthan)	1975		197,000	136.7
Chambal Command Area Development Project (Madhya Pradesh)	1976		222,635	59.8
Rajasthan Canal Command Area Development Project	1974	136,000	108,000	243.7
Goodavari Barrage Project	1975		400,000	112.4
West Bengal Agricultural Development Project	1977	86,100		77.7
Andhra Pradesh Irrigation and CAD Composite Project	1978		560,764	240.0
Periyar Vaigai Irrigation Project	1978	17,100	63,200	62.2
First Maharashtra Composite Irrigation Project	1979	87,000	30,000	246.4
Karnataka Irrigation Project	1980	97,330	69,900	553.4
Orissa Irrigation	1979	60,000	57,000	136.9
Gujarat Medium Irrigation Project	1979	134,400	33,600	406.2
Punjab Irrigation Project	1980		1,200,000	371.7
Haryana Irrigation Project	1979		1,270,000	237.5
Uttar Pradesh Public Tubewells Project	1981	60,225		44.4
Gujarat Irrigation II Project	1981	41,766	93,173	271.6
Maharashtra Irrigation II Project	1980	66,800		582.3
Karnataka Tanks Irrigation Project	1983	16,800		69.8
Mahanadi Barrages Project	1982		167,000	143.1
Madhya Pradesh Medium Irrigation Project	1982	127,617		222.7
Kallada Irrigation and Tree Crop Development Project	1983	12,600		149.7
Madhya Pradesh Major Irrigation Project	1982	360,000	269,000	495.3
Haryana Irrigation II Project	1983		1,270,000	242.6
Second Uttar Pradesh Public Tubewells Project	1984	385,000		241.2
Chambal (Madhya Pradesh) Irrigation II Project	1983		221,000	49.4
Maharashtra Water Utilization Project	1984		115,203	61.8
Upper Ganga Irrigation Modernization Project	1984		701,000	275.1
Periyar Vaigai Irrigation II Project	1985	7,500	73,600	69.5
Gujarat Medium Irrigation II Project	1985	279,696	60,804	471.3
West Bengal Minor Irrigation Project	1987	59,500		93.0
National Water Management Project	1988		640,000	164.3
Bihar Public Tubewell Project	1988		240,320	110.4
Maharashtra Composite Irrigation III Project	1987	227,800		344.4
Upper Krishna Irrigation Project (Phase II)	1990	93,513		694.0
Haryana Water Resources Consolidation Project	1995		2,300,000	442.8
Punjab Irrigation and Drainage Project	1990	15,000	115,719	221.5
Total		2,527,287	10,478,918	9,296.6

Annex Table 3. Definition of variables used in the regression analysis of the global irrigation project sample.

Variables	Definition
Total project cost	Total irrigation-related investment which includes both physical irrigation infrastructure and software components (e.g., agriculture supports and institution building); excludes non-irrigation costs (e.g., power generation and non-irrigation components in sector-wide projects), in US$ million at 2000 prices (Deflator; IMF world export price index)
Unit cost	Total project cost divided by project size (US$ 000/ha)
EIRR	Economic internal rate of return at project completion or audit (%)
Project size	Total project area = total irrigated area benefited by a project (000 ha)
Average size of systems	Average command area of irrigation systems involved in a project (project size/number of irrigation schemes involved in the project) (000 ha)
Year project started	The year the implementation of the project started
Bank input for supervision	Staff weeks spent for project monitoring and supervision
Time overrun	The number of years between the project completion and the planned completion year in appraisal
Cost overrun	The ratio of the actual investment to the palnned one in appraisal (%)
Sizing error	The ratio of the difference between planned and actual irrigated area benefited by the project to the planned irrigated area (%)
No. of project components	Number of project components listed in appraisal report, taken as a proxy to measure the complexity of the project
Share of government fund	Share of government fund in total investment (%)
Share of soft components	Share of such software cost components as engineering management, technical assistance, agricultural support and institution building in total investment (%)
Farmers' contribution[a]	Whether or not farmers contribute to the project investment
Conjunctive use of water[a]	Whether or not surface water groundwater is used conjunctively
Annual rainfall	Annual rainfall in the project area (mm), obtained from SAR, or from the FAO Aquastat
GDP per capita	GDP per capita during the project period (US$ in 2000 prices)
PPP	Purchasing power parity converstion factor to official exchange rate ratio during the project period

Note: [a] A binary variable with the value of '1' if the characteristic is present and '0' if absent

Annex Table 4. Classifications of the global sample of irrigation projects.

Classification[a]	Description
Type of project	
Irrigation	Project for irrigation alone
Irrigation and power	Project for irrigation and electrical power generation
Multi-sector	Multi-sector projects including irrigation components
Purpose of project	
New construction with land opening	New irrigation construction projects converting unused land into irrigated fields
New construction from rain-fed area	New irrigation construction projects converting rain-fed fields into irrigated ones
New construction + Rehabilitation	Newly constructed area > rehabilitated area
Rehabilitation + New construction	Rehabilitated area > newly constructed area
Rehabilitation	Irrigation rehabilitation / modernization projects without newly created area
Type of irrigation system	
River-diversion	Without major storage capacity
River-dam-reservoir	With a major storage capacity
Tank	With tank as the major source of irrigation water
River-lift	Pump system with water from river, pond or lake
Groundwater-lift	Pump system with groundwater
Drainage / flood control	Systems where water is used by draining excess water out of the system area
Mode of O&M after project	
Government agency alone	O&M by government agency alone
Government + farmer	O&M with government agency and farmers' organizations (water users' groups)
Farmer-managed system	Systems managed by farmers with minimal intervention by government agencies
Major crops irrigated	
Paddy	
Cereals	Wheat, maize and other cereals
Sugar/Cotton	
Tree crops	
Vegetables	
Fodder	
Region	
SSA	sub-Saharan Africa including 19 countries
MENA	Middle East and North Africa including 8 countries
SA	South Asia including 5 countries
SEA	South-East Asia including 7 countries
EA	East Asia including 2 countries
LAC	Latin America and Caribbean including 9 countries
Donor[b]	
WB	World Bank
AfDB	African Development Bank
IFAD	International Fund for Agricultural Development

Notes: [a] Underlined items are used as the base variable in each variable group when these binary variables are used as dummy variables in regression analysis

[b] Major donor agency; co-financing project is listed under the major donor