RESEARCH REPORT

109

# Costs and Performance of Irrigation Projects: A Comparison of Sub-Saharan Africa and Other Developing Regions

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International Water Management Institute

COMPREHENSIVE Assessment of water management in agriculture

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- Victoria Dam in central hills of Sri Lanka (photo credit: Arlene Inocencio)
- Spillway of Kotmale Dam in central hills of Sri Lanka (photo credit: Mahaweli Authority of Sri Lanka)
- Irrigation canal and paddy field in Indonesia (photo credit: Jasa Tirta II Public Corporation)
- Control structure, smallholder irrigation scheme, South Africa (photo credit: Abdul Kamara)

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# Contents

# Acronyms and Abbreviations

| | |
|---|---|
| ADB-PEO | Asian Development Bank - Post Evaluation Office |
| AfDB | African Development Bank |
| AQUASTAT | FAO's information system on water and agriculture |
| BWDB | Bangladesh Water Development Board |
| CAADP | Comprehensive Africa Agriculture Development Programme |
| CAD | Command Area Development |
| CV | Coefficient of variation |
| EA | East Asia |
| EIRR | Economic internal rate of return |
| FANRPAN | Food, Agriculture and Natural Resources Policy Analysis Network |
| FAO | Food and Agriculture Organization of the United Nations |
| GDP | Gross Domestic Product |
| ICR | Implementation Completion Report |
| IFAD | International Fund for Agricultural Development |
| IFPRI | International Food Policy Research Institute |
| ILRI | International Livestock Research Institute |
| IMF | International Monetary Fund |
| IMT | Irrigation management transfer |
| InWEnt | Internationale Weiterbildung und Entwicklung (Capacity Building International) |
| IWMI | International Water Management Institute |
| LAC | Latin America and the Caribbean |
| MDGs | Millennium Development Goals |
| MENA | Middle East and North Africa |
| MSPs | Multi-sector projects |
| NEPAD | New Partnership for Africa's Development |
| O&M | Operation and Maintenance |
| ODA | Official development assistance |
| OFDA | Office of United States Foreign Disaster Assistance |
| PCR | Project Completion Report |
| PIM | Participatory irrigation management |
| PPAR | Project Performance Audit Report |
| PPP | Purchasing power parity |
| SA | South Asia |
| SADCC | Southern African Development Coordination Conference |
| SAR | Staff Appraisal Report |
| SD | Standard deviation |
| SEA | Southeast Asia |
| SSA | sub-Saharan Africa |
| USAID | United States Agency for International Development |
| WB | World Bank |
| WDI | World Development Indicators |
| WUA | Water users' association |

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# Summary

High investment costs together with declining world prices for food and the perceived failures of many past irrigation projects are the main reasons for the reluctance of development agencies and governments in sub-Saharan Africa (SSA) to invest more resources in irrigation. This study aims to establish systematically whether costs of irrigation projects in SSA are truly high, determine the factors influencing costs and performance, and recommend cost-reducing and performance-enhancing options to make irrigation investments in SSA more attractive.

The study analyzes 314 irrigation projects implemented from 1967 to 2003 in 50 countries in Africa, Asia, and Latin America supported by the World Bank, African Development Bank and the International Fund for Agriculture Development. All data were obtained from Project Completion Reports and Project Performance Audit Reports, complemented with information from Staff Appraisal Reports.

This paper makes three important contributions: (1) it confirms some earlier findings and disproves some popularly-held notions and incorrect perceptions about unit costs and performance of irrigation projects in SSA; (2) it provides empirical support to some existing irrigation investment policies and suggests reconsidering others; and (3) it provides some specific recommendations for future irrigation investments.

Specifically, the popular view that SSA irrigation projects are expensive has to be understood in its proper context. Using simple regional averages, the unit costs in SSA appear higher than those for other regions. However, a careful look at the details reveals that under certain conditions, unit costs of irrigation projects in sub-Saharan Africa are not statistically different from those in non-SSA regions. *Sub-Saharan African projects are not inherently more costly than in other regions*.

This finding suggests that projects should reflect specific characteristics consistent with lower unit investment costs. In terms of project performance, the regression result indicates that once these specific factors are accounted for, SSA projects can perform significantly better than those in South and Southeast Asia. So, despite the relatively higher failure rate in sub-Saharan Africa, if we carefully take into account the factors influencing performance in project planning, it is possible to formulate better performing projects in the region.

The key factors significantly influencing unit irrigation costs include: project size in terms of total irrigated area within a project, average size of irrigation systems within a project, government contribution to investment cost, share of software components in total investment, country's level of development, design and technology factors (crops irrigated, mode of O&M), and implementation factors (cost overrun and 'sizing error'). The factors influencing performance of irrigation projects include: project size and average size of systems, complexity of projects as measured by a number of project components, water availability as proxied by annual rainfall and conjunctive use of surface water and groundwater, country's level of development, farmers' contribution to investment cost, and design and technology factors.

'Project size' is the most important factor determining both unit investment cost and performance of irrigation projects. The larger the 'project size', the lower the unit cost and higher the project performance. These results confirm an earlier finding that "*big projects just do better than small projects.*" At the same time, smaller systems show higher performance, suggesting that *big projects supporting small-scale irrigation systems may be best*.

Irrigation components in multi-sector/sector-wide projects have significant cost-reducing

effects despite the relatively smaller irrigated area compared to purely 'irrigation' projects. This investment option results in lower unit costs, and points to an *opportunity to exploit the economies of scale in big projects even if the area to be irrigated is relatively small* and with potentially greater impact on poverty reduction.

Projects supporting farmer-managed or jointly-managed (with a government agency) irrigation systems have lower unit investment costs and perform better than projects with systems managed solely by government agency. These results provide empirical evidence to support donor and government policies to enhance farmers' roles in project formulation, implementation and operation and maintenance. *Where farmers contribute to project development, projects perform better than those without farmer contribution*.

Higher government contribution to total investment costs lowers unit costs, supporting the efficient-government hypothesis, but does not improve economic performance. There is clearly a need to evaluate the type and quality of government intervention to improve impact on performance of projects. Systems designed for horticultural crops have lower unit project cost and higher project performance than those designed for staple food crop production.

The major recommendations emerging from the study, addressed to governments and investors in sub-Saharan Africa, are:

1. Under the right conditions, irrigation investments in SSA can provide good returns and have significant impacts on agricultural growth. Therefore, as part of a larger package of investments in support of the CAADP, irrigation investments make sense in many instances.

2. Governments and investors should develop relatively large investment projects irrigating bigger areas, to achieve significant economies of scale. This is not a problem for large countries. To be more effective in assisting smaller countries, regional projects (which may include large countries as well) may offer a way to achieve important economies of scale and synergies among countries as well. There is also a strong case for investing in more water storage in sub-Saharan Africa.

3. Small-scale irrigation schemes offer significant performance advantages over large-scale systems within irrigation investment projects. Therefore, large irrigation investment projects supporting many small-scale irrigation schemes are likely to lead to the best results.

4. Both the software and hardware components of irrigation projects are critical. However, underinvesting in software can lead to significantly higher hardware costs and lower project performance. We recommend investing in good planning, design, project management, and supervision, combined with effective training, capacity building and institutional development among future users and managers.

5. We recommend maximizing farmers' effective involvement in all stages of irrigation system development and management, from the beginning. Maximizing farmers' contributions to the development of their systems (consistent with their capacity) combined with farmers taking significant management responsibility for the completed scheme usually results in lower costs and higher performance.

6. We recommend paying very careful attention to the issue of types of crops to be grown. In general, irrigation schemes used only for staple crops are more expensive and have lower performance. Irrigation systems designed for high-value cash crops are cheaper and show higher performance.

7. Wherever conditions are favorable, the design of irrigation schemes should allow for conjunctive use of surface water and groundwater, as it improves performance.

This recommendation reinforces the importance of providing a reliable water supply for successful irrigation.

8. We recommend that irrigation be included as a component in multi-sector projects. Regional and collaborative approaches that take advantage of economies of scale in multi-sector projects with irrigation are likely to result in higher performance. However, these projects must be carefully designed to avoid being overly complex, as this does reduce performance.

9. We recommend that donors and governments, under the auspices of NEPAD, sponsor a systematic research program to identify how to optimize the poverty-reduction impacts of irrigation investments in sub-Saharan Africa.

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## Introduction

Many governments, donors, and investors, rallying around the New Partnership for Africa's Development (NEPAD), share the basic premises that rapid growth in agriculture is required in sub-Saharan Africa (SSA) to meet the ambitious Millennium Development Goals (MDGs) and other agreed targets for poverty alleviation and food security. Many, but not all, also agree with the premise of NEPAD's Comprehensive Africa Agriculture Development Programme (CAADP) that since irrigation and other forms of water management for agriculture are prerequisites for agricultural intensification, much of the required growth will depend on new investment in this sector, and that if SSA is to meet its poverty reduction and food security targets, investment must be increased substantially, and innovative approaches to agricultural water development that enhance prospects for sustainable returns on investment must be found.[1]

High irrigation investment costs together with declining world food prices and the perceived failures of many past irrigation projects are believed to be the main reasons for reluctance of international financial and development agencies and SSA governments to invest more resources in irrigation. Evidence from Asia suggests that the decline in world rice prices and increasing real costs per hectare (ha) of new irrigation development contributed to the decline in lending for irrigation by international financial agencies and diminished poverty reduction impacts of irrigation projects (Kikuchi et al. 2003; Rosegrant and Svendsen 1992; Aluwihare and Kikuchi 1991).

Earlier technical studies on irrigation in SSA (FAO 1986; van Steekelenburg and Zijlstra 1985; Aviron Violet et al. 1991; Brown and Nooter 1992; Jones 1995; various WB Technical Papers) report higher investment costs of irrigation compared with North Africa and other regions. Jones (1995), reviewing the experience of the World Bank in irrigation development for a few decades, estimated that the average unit cost for 191 irrigation projects was US$4,800 per ha in 1991 prices. The average for the whole of Africa was US$13,000 per ha while that for SSA was US$18,000 per ha. These figures are often compared with the US$1,400 per ha for South Asia (SA) or the US$4,000 per ha for East Asia (EA), and Latin America and the Caribbean (LAC).

On the other hand, there are sporadic studies showing relatively cheaper irrigation projects in SSA with average unit costs comparable to Asia (SADCC 1992; IFAD 2000; World Bank-AFTS2 2004). Also, Olivares (1990)

[1] This perspective is at the core of CAADP (NEPAD 2003) and endorsed in the report by the Commission for Africa (2005).

reports that irrigation investment cost in SSA is not necessarily higher than in other regions. Based on an analysis of 125 WB-funded irrigation projects implemented in various regions of the world from 1973 to 1985, he shows that if project size, rainfall, per-capita income, and the year of Board approval are taken into account, the cost of irrigation in SSA is not significantly higher than in other regions.[2] This assertion is of interest because it provides an important qualification to earlier general claims of higher average unit cost in SSA. If this result can be confirmed, then options for formulating cheaper irrigation projects for SSA can be identified by applying lessons learned from past irrigation experience both in the region and in other developing regions in the world.

While Jones (1995) provides comparable irrigation cost figures for a fairly large sample of WB funded projects worldwide for different regions, different delivery systems, different types of projects, and different crops irrigated, he does no further analysis on project costs beyond showing the average unit costs by various classifications. The work cited by Olivares (1990), though potentially useful, used a much smaller sample. Other available reports also use too few projects to make definitive observations, or are based on anecdotal evidence without any systematic analysis of irrigation costs.

This study aims to fill this gap, using a much larger sample of irrigation projects, through systematic statistical analyses, which are absent in the previous studies. Specifically, it provides answers to the following questions:

(1) Is the persistent perception among international donors and people concerned that the cost of irrigation projects is absolutely higher, and the performance of the projects is lower, in SSA than in other regions reasonable?

(2) If so, what factors explain high irrigation cost and poor performance in SSA?

(3) Are there options to reduce the investment costs and enhance the performance of irrigation projects in SSA?

(4) What should be the future course of irrigation development in SSA?

We approach these questions using the data obtained from a sample of 314 irrigation projects implemented in various developing regions worldwide with financial assistance from the WB, AfDB and IFAD.

The next section discusses the data and variables used in this study. This is followed by profiles of irrigation projects and trends over time. To understand the costs of irrigation projects in SSA, we first establish whether these projects are more expensive relative to other regions, compare projects according to performance, and look at changes over time. We then examine factors determining unit costs and performance of irrigation projects by conducting regression analyses using the entire sample of projects. The last section sums up the lessons and recommends options for reducing irrigation investment costs while improving project performance in sub-Saharan Africa.

[2] Olivares (1990) cited a study on cost of irrigation development that was apparently never published.

## The Data[3]

For this study, we compiled a database using a total of 314 irrigation projects. The population from which we draw these sample projects is the irrigation projects that have been funded by the WB supplemented in SSA with data from other donors. The apparent concentration on WB projects was due to WB's relatively good archive of irrigation project documents which this research was given access to. A weakness of the WB archive, however, is that the number of irrigation projects it has funded in SSA, the region of our prime concern, is not as large as compared to other developing regions. We attempt to rectify this weakness by extending the SSA population to include irrigation projects funded by the AfDB and the IFAD. Another point to be remarked is that the 'irrigation project' here is defined as a project in which irrigation is included as a project component, regardless of whether it is a major or minor component.

The selection of sample projects from the population thus defined depends on data availability. Although there are slight differences in reporting formats among the donors, the formulation, implementation and evaluation of an irrigation project, like any other development project funded by the donors, are recorded in the Staff Appraisal Report (SAR), the Project Completion Report (PCR) or the Implementation Completion Report (ICR), and the Project Performance Audit Report (PPAR). We take the data on the investment cost, accomplishment and performance of irrigation projects from the *ex-post* reports of PCRs, ICRs, or PPARs. Since a PPAR is prepared after a project has been in operation for a certain length of time sufficient for performance evaluation, it is preferable to take the cost and other performance-related data from PPARs. However, in case PPARs are not available, we use the PCRs or the ICRs, as the second best source of cost and performance information. We also refer to SARs, if available, for detailed information on project design and project sites not reported in PCRs or PPARs. We only selected irrigation projects for which either the PCR (ICR) or PPAR was available.

The 314 sample projects are listed at the end of this report in Appendix A, table A1, with basic project specifications. All of these projects are public projects co-funded by the government of the respective country where they were implemented. There are some projects which are financed jointly by a few international donor agencies and/or bilateral donors. No privately funded irrigation project is included.

Table 1 lists the data items we obtained from the project reports and use in the analysis of this study. We begin our explanation on the data items from the classification of irrigation projects, starting from the middle part of the table. Needless to say, the cost of irrigation projects could vary significantly across different project types as well as different project purposes. There are various types of projects in which irrigation is either a major or a minor component. In this study, we distinguish three types of irrigation-related projects: projects which are meant for irrigation alone (irrigation), projects which are for both irrigation development and power generation (irrigation and power), and multi-sector projects with irrigation as one of the project components, such as integrated rural development projects (multi-sector).

The purpose of irrigation projects also varies from one project to another. The project costs can be substantially different according to project purpose. We dichotomize the purpose of irrigation projects into two basic categories: (a) new construction, and (b) rehabilitation. While a 'new' construction project is defined as one which creates newly irrigated cultivated land, a 'rehabilitation' project is defined as one which

[3] This section and the section: *Profiles of the Sample Irrigation Projects* are technical in nature, explaining the data used in this study and the basic characteristics of the sample irrigation projects. Readers who are not interested in technical details may skip them and jump to section: *Understanding Costs of Irrigation Projects in SSA.* While reading the following sections, however, readers may find it useful to refer back to table 1 in this section, which lists the data items/variables used in this study.

TABLE 1.
Data items/variables used in this study and their definition.

| Data items/variables | | Description |
|---|---|---|
| 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$ at 2000 prices (Deflator; IMF world export price index) |
| Total hardware cost | | Total project cost less software costs, including only hardware-related investment costs, such as dam, canal, drainage, irrigation road, sluice, water gate, flume, etc. In US$ at 2000 prices |
| Unit total cost | | Total project cost divided by project size |
| Unit hardware cost | | Total hardware cost divided by project size |
| EIRR | | Economic internal rate of return at project completion/audit (%) |
| Project size | | Total project area = total irrigated area benefited by a project |
| Average size of systems | | Average command area of irrigation systems involved in a project Project size/number of irrigation schemes involved in the project |
| Year project started | | |
| Bank input for appraisal | | Staff weeks spent for appraising the projects |
| Bank input for supervision | | Staff weeks spent for project monitoring and supervision |
| Time overrun | | The difference between the actual project completion and the planned completion year at appraisal (number of years) |
| Cost overrun | | The ratio of the difference between actual and planned investment to the planned one (%) |
| Sizing error | | The ratio of the difference between planned and actual irrigated area benefited by the project to the planned irrigated area |
| Number of project components | | Number of project components listed in appraisal report |
| Share of government funds | | Share of government funds in total investment (%) |
| Share of software components | | Share of such software components as engineering management, technical assistance, agriculture support and institution building in total investment (%) |
| Farmers' contribution | | Whether or not farmers contribute to the project investment |
| Conjunctive use of water | | Whether or not using surface water and groundwater conjunctively |
| Annual rainfall | | Annual rainfall in the project area (millimeter) |
| GDP per capita | | GDP per capita during the project period (US$ in 2000 prices) |
| PPP ratio | | Ratio of purchasing power parity conversion factor to official exchange rate during the project period |
| Type of project | Irrigation | Project for irrigation alone |
| | Irrigation and power | Project for irrigation and electric power generation |
| | Multi-sector | Multi-sector projects including irrigation components |

(Continued)

TABLE 1. (Contnued)
Data items/variables used in this study and their definition.

| Data items/variables | | Description |
|---|---|---|
| Purpose of project | New construction with land opening | New irrigation construction projects converting unused land into irrigated fields |
| | New construction from rainfed area | New irrigation construction projects converting rainfed 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 storage capacity which can irrigate up to 5,000 ha |
| | River-lift | Pump system with water from river, pond or lake |
| | Groundwater-lift | Pump system with groundwater |
| | Drainage/flood control | Drainage/flood control system generally without water take-in from outside the system |
| Mode of O&M after project | Government agency alone | O&M by government agency alone |
| | Government agency with farmers | O&M with government agency and farmers' organizations (water users' groups) |
| | Farmer-managed system | |
| Major crops | Paddy | |
| | Cereals | Wheat, maize and other cereals |
| | Sugar/cotton | |
| | Tree crops | |
| | Vegetables | |
| | Fodder | |
| Region | East Asia | |
| | Southeast Asia | |
| | South Asia | |
| | Latin America and the Caribbean | |
| | Middle East and North Africa | |
| | sub-Saharan Africa | |
| Donor[a] | WB | World Bank |
| | AfDB | African Development Bank |
| | IFAD | International Fund for Agricultural Development |

*Note:* [a] major donor agency; a co-financed project is listed under the major donor rehabilitates, improves, modernizes and/or extends existing irrigation systems. Within each category, there can be large diversities. For new construction, two sub-categories are identified: (a) one creates newly irrigated area converting from wild land (new construction with land opening), and (b) the other from rainfed cultivated land (new construction from rainfed area). The degree of diversity can be larger for rehabilitation projects, which range from major rehabilitation/modernization projects with large investments in physical hardware, to water management/O&M improvement projects with major emphasis on institutional, software aspects of irrigation systems. In this study, we group these wide-ranging rehabilitation projects into three sub-categories: (a) major rehabilitation/modernization projects in which the extent of newly created irrigated land area[4] exceeds the existing irrigated land area to be rehabilitated (new construction + rehabilitation); (b) major rehabilitation/modernization projects in which the size of newly created irrigated land area is less than the existing irrigated land area being rehabilitated (rehabilitation + new construction);[5] and (c) purely rehabilitation/improvement projects with no extension of irrigated land area (rehabilitation).

Given the five purposes of irrigation projects explained above, when we refer to just two categories for the whole sample, *new construction projects* and *rehabilitation projects*, we mean the former consisting of 'new construction with land opening', 'new construction from rainfed area' and 'new construction + rehabilitation,' and in the latter, 'rehabilitation + new construction' and 'rehabilitation.' In what follows, unless otherwise specified, the terms new construction and rehabilitation are defined in this way.

Another classification of irrigation projects is by type of irrigation systems constructed or rehabilitated. Six types are identified: (a) river-diversion systems without major storage capacity (river-diversion), (b) systems which use river water with dams and 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 generally without water being taken in from outside the systems (drainage/flood control). In the sixth type, drainage/flood control system, water is used for crop cultivation by draining excess water out of the system area, rather than taking in water from outside the system.[6]

The project reports also include information on how the irrigation systems constructed or rehabilitated are to be operated and maintained (O&M) after the completion of the projects. The mode of O&M at project completion can be grouped into three categories: (a) entirely by government agency (government agency alone), (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 with farmers), and (c) by farmers alone (farmer-managed systems).

Irrigation projects are also classified according to major crops grown. We identify six crop groups: (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). We draw our sample projects from the following major developing regions in the world: (a) sub-Saharan

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[4] Note the difference between an increase in irrigated cultivated land area in stock terms (or command area) and an increase in irrigated planted area in flow terms on the same extent of irrigated cultivated land area in stock terms. The latter results in an increase in the cropping intensity, or multiple cropping, which is often the single most important objective of rehabilitation/improvement/modernization projects.

[5] The first and second sub-categories include irrigation projects having new construction and rehabilitation as separate components in a project.

[6] If the term 'irrigation' is narrowly defined as taking in water artificially from outside the system, it may sound awkward to call such systems as 'irrigation' systems. In this paper, the term is broadly defined as using water artificially for crop cultivation.

Africa (SSA), (b) Middle East and North Africa (MENA), (c) Latin America and the Caribbean (LAC), (d) South Asia (SA), (e) Southeast Asia (SEA), and (f) East Asia (EA). The last classification of the sample projects is by donor: (a) WB, (b) AfDB, and (c) IFAD.

Of the 24 data items left to be explained in table 1, the first four from the top are the central ones in this study, related to the cost and the performance of irrigation projects. For irrigation cost, we prepare two variables. First, the total project cost of an irrigation project is defined as the total *irrigation-related* investment cost, including both investment in physical irrigation infrastructure (e.g., dams and canals) and investment in software components (e.g., agriculture supports and institution building); but excluding non-irrigation investment cost (e.g., power generation and non-irrigation components in sector-wide projects).

Second, the total hardware cost is obtained by subtracting the software components from the total project cost, and therefore consists of all the costs related to physical components, such as civil works for irrigation structures (e.g., dam, canal, and irrigation road) and facilities (e.g., sluice, water gate and measuring device), and all the related equipment and materials. Irrigation projects need both software and hardware components. The total hardware cost is expected to measure the 'bare' cost of constructing/rehabilitating physical irrigation infrastructure.

Project size is measured by the irrigated area which is benefited by an irrigation project; irrigated area newly constructed in the case of a new construction project, and irrigated area rehabilitated in the case of a rehabilitation project. Dividing the total project cost by the project size, we obtain the unit total cost, i.e., the cost of an irrigation project per hectare of irrigated area constructed/rehabilitated. The unit hardware cost is derived similarly. The unit total cost is the variable that is usually used to measure how expensive, or how cheap, an irrigation project is in comparison with other projects. To make the cost data comparable across projects, across countries, and over time, we measure the costs in US$ at 2000 constant prices. In case the costs are given only in local currency, we first convert them to current US dollars using the official exchange rate of the respective country in respective years. The costs in current US dollars are then deflated by the International Monetary Fund's implicit price index for world exports.

We use the Economic internal rate of return (EIRR) of irrigation projects as a measure of project performance.[7] The PCR/ICR or PPAR often record the performance rating of projects, for outcome, sustainability, and institutional development, among others. We do not use this information, mainly because this information is missing in many projects, and where missing, it is difficult for us to reconstruct the rating. Instead, we use the EIRR as a performance indicator of projects, partly because it is highly correlated with the overall rating of projects and partly because, even if it is missing, we can estimate it as long as the project outcomes are described in the PCRs and the PPARs. For the projects that do not report EIRR, we estimate it as the 'r' that satisfies the following equation (1):

$$(1 + r)^m K = \Sigma_{j=1}^{n}(R - c)/(1 + r)^j \qquad (1)$$

where K = unit cost/ha of irrigation construction/rehabilitation, R = return/ha due to irrigation construction/rehabilitation,[8] c = O&M cost/ha, n = lifetime of the project (assumed 30 years for new construction projects and 15 years for rehabilitation projects), and m = average gestation period of investment.

[7] Among indicators to measure the performance of irrigation projects, the most convenient, if not the best, measure is the economic internal rate of return (EIRR). Despite its advantages as a single measure readily available in project reports, we should also be aware of its shortcomings (Tiffen 1987).

[8] The return due to an irrigation project is measured by the increase in gross value-added in agricultural production which is generated by the project. For an illustration of how the returns from irrigation projects are estimated, see, for example, Aluwihare and Kikuchi (1991).

In addition to the data items explained thus far, our database includes 16 more items that may affect the cost of irrigation projects, of which 14 were obtained from the project reports and two from other sources. Most projects have more than one irrigation system.[9] The average size of systems is obtained by dividing the size of a project by the number of irrigation systems involved in it. The year the project started needs no explanation. The bank inputs for appraisal and supervision are 'labor' inputs by the donor agencies' staff for project appraisal and supervision measured in terms of weeks.[10] The time overrun measures the degree to which the actual construction period exceeds the planned construction period at the time of appraisal. Likewise, the cost overrun measures the degree to which the actual investment cost exceeds the planned cost at appraisal. The sizing error is defined as the ratio of the difference between planned and actual irrigated area benefited by a project, to the planned irrigated area, by which we intend to measure the degree of design errors committed in the planning or appraisal stage. 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, the governments of recipient countries mobilize local funds for the projects without exception. The share of government funds is the ratio of the local contribution to the total investment fund. 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. The farmers' contribution to the investment fund and the conjunctive use of surface water and groundwater are both yes/no binary variables.[11] 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.

The last two variables, the GDP per capita and the PPP (Purchasing Power Parity) ratio, are introduced to capture the macroeconomic environments under which the sample projects are designed and implemented. For both variables, the averages over the project duration are adopted. The source of data for both variables is the World Bank Database (WDI Online). In the same manner as for the project costs, the GDP per capita is expressed in terms of US$ at 2000 constant prices.

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[9] About 20 percent of our sample irrigation projects are 'single system projects,' i.e., including only one irrigation system. The rest involve more than one irrigation system per project. The number of irrigation systems per project varies significantly across projects: its mean, median and mode are 1346, 6, and 1, respectively.

[10] This information on staff inputs is missing for quite a few sample projects.

[11] It would be more informative to use the share of farmers' contribution to the total fund instead of the binary variable. However, many projects do not report this information.

## Profiles of the Sample Irrigation Projects

Our 314 sample irrigation projects are from 50 countries in the six developing regions (table 2). Forty-five of these are from 19 countries in SSA. Before examining whether the cost of irrigation projects is higher in SSA than in other developing regions, we provide an overview of the sample irrigation projects, examining differences and similarities of SSA projects in comparison with non-SSA regions.[12]

Table 2 shows a salient feature of the sample irrigation projects in SSA compared with other regions: projects in SSA are relatively more scattered and thinly spread. Except for Madagascar and Sudan where irrigated

TABLE 2.
Number of irrigation projects included in the database, by region and country.

| Sub-Saharan Africa | | Middle East and North Africa | | South Asia | |
|---|---|---|---|---|---|
| Burkina Faso | 1 | Algeria | 4 | Bangladesh | 17 |
| Cameroon | 1 | Egypt | 11 | India | 37 |
| Chad | 3 | Iran | 2 | Nepal | 12 |
| Ethiopia | 3 | Jordan | 1 | Pakistan | 16 |
| Guinea-Bissau | 1 | Morocco | 10 | Sri Lanka | 9 |
| Kenya | 1 | Syria | 2 | Total | 91 |
| Lesotho | 1 | Tunisia | 14 | | |
| Madagascar | 7 | Yemen | 7 | Southeast Asia | |
| Malawi | 1 | Total | 51 | Burma | 7 |
| Mali | 3 | | | Indonesia | 27 |
| Mauritania | 3 | Latin America and the Caribbean | | Laos | 1 |
| Mauritius | 1 | Brazil | 7 | Malaysia | 12 |
| Niger | 4 | Chile | 1 | Philippines | 13 |
| Nigeria | 1 | Colombia | 6 | Thailand | 7 |
| Senegal | 4 | Dominican Republic | 2 | Vietnam | 1 |
| Sudan | 5 | Ecuador | 4 | Total | 68 |
| Tanzania | 2 | Guyana | 3 | | |
| The Gambia | 2 | Mexico | 14 | East Asia | |
| Zambia | 1 | Peru | 3 | China | 13 |
| | | Uruguay | 1 | Korea | 5 |
| Total | 45 | Total | 41 | Total | 18 |
| | | | | Grand total | 314 |

[12] In this section, we do not look at differences among the regions in the non-SSA regions. Readers who are interested in the differences can refer to Appendix A, Tables A2 to A4.

agriculture has been practiced for some time, no country in SSA has over five irrigation projects in our sample.

About 90 percent for both the entire and SSA samples are primarily ‘irrigation’ projects (table 3). ‘Irrigation and power’ projects and ‘multi-sector projects with irrigation components’ make up the remaining 10 percent. Reflecting the relatively recent history of irrigation development in SSA compared to non-SSA regions, the share of new construction projects for the SSA sample is larger than that of rehabilitation projects. Another

TABLE 3.
Number of sample projects by type of project, by other category, by region and the difference between SSA and non-SSA.

| | Sub-Saharan Africa | | Non-sub-Saharan Africa | | Total | Z-test[a] |
|---|---|---|---|---|---|---|
| | No. | (%) | No. | (%) | No. | SSA vs non-SSA |
| Type of project | | | | | | |
| Irrigation | 40 | ( 89 ) | 240 | ( 89 ) | 280 | |
| Irrigation and power | 1 | ( 2 ) | 11 | ( 4 ) | 12 | |
| Multi-sector projects with irrigation | 4 | ( 9 ) | 18 | ( 7 ) | 22 | |
| Purpose of project | | | | | | |
| New construction with land opening | 9 | ( 20 ) | 8 | ( 3 ) | 17 | *** |
| New construction from rainfed area | 7 | ( 16 ) | 52 | ( 19 ) | 59 | |
| New construction + Rehabilitation | 10 | ( 22 ) | 40 | ( 15 ) | 50 | |
| Rehabilitation + New construction | 4 | ( 9 ) | 65 | ( 24 ) | 69 | ** |
| Rehabilitation | 15 | ( 33 ) | 104 | ( 39 ) | 119 | |
| Type of irrigation systems involved in project | | | | | | |
| River diversion | 19 | ( 42 ) | 97 | ( 36 ) | 116 | |
| River-dam-reservoir | 4 | ( 9 ) | 69 | ( 26 ) | 73 | ** |
| Tank | 1 | ( 2 ) | 7 | ( 3 ) | 8 | |
| River-lift (or pond or lake) | 14 | ( 31 ) | 23 | ( 9 ) | 37 | *** |
| Groundwater-lift | 4 | ( 9 ) | 47 | ( 17 ) | 51 | |
| Drainage/flood control | 3 | ( 7 ) | 26 | ( 10 ) | 29 | |
| Mode of O&M after project | | | | | | |
| Government agency alone | 26 | ( 58 ) | 135 | ( 50 ) | 161 | |
| Government agency with farmers | 17 | ( 38 ) | 98 | ( 36 ) | 115 | |
| Farmer-managed | 2 | ( 4 ) | 36 | ( 13 ) | 38 | * |
| Major crop grown | | | | | | |
| Paddy | 29 | ( 64 ) | 136 | ( 51 ) | 165 | * |
| Cereals | 4 | ( 9 ) | 82 | ( 30 ) | 86 | *** |
| Sugar/cotton | 8 | ( 18 ) | 17 | ( 6 ) | 25 | * |
| Tree crops | 0 | ( 0 ) | 15 | ( 6 ) | 15 | * |
| Vegetables | 4 | ( 9 ) | 15 | ( 6 ) | 19 | |
| Fodder | 0 | ( 0 ) | 4 | ( 1 ) | 4 | |
| Conjunctive use | 2 | ( 4 ) | 98 | ( 36 ) | 100 | *** |
| Farmers’ contribution | 8 | ( 18 ) | 43 | ( 16 ) | 51 | |
| Donor | | | | | | |
| WB | 28 | | 262 | | 290 | N/A |
| AfDB | 12 | | 7 | | 19 | N/A |
| IFAD | 5 | | 0 | | 5 | N/A |
| Total | 45 | ( 100 ) | 269 | ( 100 ) | 314 | N/A |

*Notes:* [a] Z-test applied for the differences in ratio. ***, **, and * indicate that the ratio differences are statistically significant at the 1, 5, and 10 percent level, respectively.

N/A = not applicable

characteristic of SSA is a large proportion of 'new construction with land opening'. For both the non-SSA and the SSA samples, the most common irrigation system is 'river-diversion.' The second most common type in non-SSA regions is 'river-dam-reservoir,' whereas it is 'river-lift' in SSA. The high share of 'river-lift' systems is a salient feature of SSA irrigation projects in comparison with other regions. The major mode of O&M after project completion is by 'government agency alone' for SSA as well as for other regions.

The majority of sample irrigation systems grow cereals as the main crop. Specifically, more than 50 percent of the sample grows rice as the main, if not the only crop. In SSA, more than 60 percent of sample irrigation systems are 'rice systems,' followed by 'sugar/cotton systems' and 'vegetable systems.' 'Sugar/cotton systems,' or systems for cash crops, are almost exclusively 'cotton systems' in SSA. These 'cotton systems' are the oldest systems in this region; projects to construct or rehabilitate these systems were implemented earlier than the 'rice systems.' In contrast, 'vegetable systems' in SSA are relatively recent.[13] Many of these 'vegetable systems' are quite modern, using sprinkler/drip irrigation, while most of the 'cotton systems' as well as 'rice systems' are traditional gravity irrigation with canals and farm ditches.[14] The conjunctive use of surface water and groundwater is practiced in more than one-third of the non-SSA sample projects, but in only 4 percent in SSA. The share of projects where beneficiary-farmers contribute to the investment fund is comparable between SSA and non-SSA.

## New Construction Projects versus Rehabilitation Projects

Of the 314 sample irrigation projects, 126 are new construction projects and 188 are rehabilitation projects, some profiles of which are shown by region in table 4. A salient feature of irrigation projects in SSA is that the average project size is significantly smaller than in non-SSA. On average, the project size in SSA is nearly one-seventh of that in non-SSA for new construction projects and one-fifth for rehabilitation projects. The differences between SSA and non-SSA are all statistically highly significant. It is also remarkable that on average rehabilitation projects are significantly larger than new construction projects in all regions. The same pattern is observed for the average sizes of irrigation systems involved in a project.

The year projects started shows another salient feature of SSA projects: irrigation projects in SSA are relatively more recent than elsewhere. On average, the starting year in SSA is about 2.5 years more recent than in non-SSA, both for new construction and rehabilitation projects, the differences between the two regions all being significant.[15] Within the same regions, new construction projects significantly precede rehabilitation projects also by about 2.5 years in both SSA and non-SSA.

The international donor agencies spend around 100 staff weeks per project for project appraisal and supervision during project implementation, and there is no significant difference in this respect between SSA and non-SSA, except the bank input for supervision

[13] In SSA, the average starting years of the projects with 'cotton systems,' 'rice systems' and 'vegetable systems' are 1982, 1984 and 1993, respectively, and the differences between them are all statistically significant. The same pattern is observed in non-SSA regions as well but to a lesser extent.

[14] The same applies to non-SSA regions. Though there are none in the SSA sample, 'tree crop systems' which are mostly orchard systems, are similar to 'vegetable systems' in that they are also relatively recent and adopt modern irrigation facilities such as drip irrigation.

[15] We tried to obtain as many projects as possible in our sample, but it is by no means inclusive of all the projects funded by the WB. In non-SSA, many earlier projects are missing because of non-availability of PCR/PPAR. In SSA, however, nearly all the projects implemented are included in our sample. Altogether, the difference in the starting year between SSA and non-SSA should be longer than as recorded in table 4. In our sample, the first irrigation projects in SSA started in 1973, while elsewhere they start in 1965.

TABLE 4.

Properties of irrigation projects by purpose of projects, by region, and difference between SSA and non-SSA, and between new construction and rehabilitation projects (N=314)[a].

| | Total | | | New construction projects | | | Rehabilitation projects | | | t-test[b] | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | t-test[b] | | | t-test[b] | | | t-test[b] | | |
| | Sub-Saharan Africa | Non-SSA | SSA vs non-SSA | Sub-Saharan Africa | Non-SSA | SSA vs non-SSA | Sub-Saharan Africa | Non-SSA | SSA vs non-SSA | New vs rehab in SSA | New vs rehab in non-SSA |
| Project size (1,000 ha) | 29 | 195 | *** | 10 | 68 | *** | 54 | 269 | *** | * | *** |
| Average size of systems (1,000 ha) | 8 | 44 | *** | 6 | 26 | *** | 11 | 54 | ** | | ** |
| Year project started | 1984.4 | 1982.5 | ** | 1983.4 | 1981.0 | * | 1985.8 | 1983.4 | ** | * | *** |
| Bank input for appraisal (staff weeks) | 91 | 107 | | 79 | 90 | | 109 | 116 | | | ** |
| Bank input for supervision (staff weeks) | 101 | 118 | | 102 | 99 | | 99 | 129 | * | | *** |
| Time overrun (years) | 1.9 | 1.7 | | 2.0 | 1.8 | | 1.7 | 1.6 | | | |
| Cost overrun (%) | 9 | 7 | | 16 | 9 | | -1 | 5 | | | |
| Sizing error (%) | 22 | -3 | *** | 15 | 10 | | 31 | -11 | *** | ** | |
| Number of project components | 5.8 | 6.9 | | 6.0 | 7.0 | * | 5.6 | 6.9 | * | | |
| Share of government funds (%) | 24 | 48 | *** | 28 | 48 | *** | 20 | 48 | *** | * | |
| Share of software components (%) | 33 | 21 | *** | 35 | 18 | *** | 32 | 23 | *** | | *** |
| Annual rainfall (mm) | 719 | 1,195 | *** | 698 | 1,149 | *** | 747 | 1,222 | *** | | |
| GDP per capita (US$ in 2000 prices) | 378 | 1,136 | *** | 317 | 1,227 | *** | 462 | 1,081 | *** | | |
| PPP ratio | 0.46 | 0.42 | | 0.46 | 0.42 | | 0.46 | 0.43 | | | |
| EIRR (%) | 12 | 17 | *** | 11 | 14 | | 14 | 18 | | | *** |

*Notes:* [a] New construction projects include 'new construction with land opening,' 'new construction from rainfed area,' and 'new construction + rehabilitation.' Rehabilitation projects include 'rehabilitation + new construction' and rehabilitation.

[b] t-test applied for the differences in mean. ***, **, and * indicate that the mean differences are statistically significant at the 1, 5, and 10 percent level, respectively.

N = number of observations

rehab = rehabilitation

of rehabilitation projects, for which non-SSA projects absorb significantly more staff time than SSA projects. In non-SSA, rehabilitation projects require significantly more staff input than new construction projects.

In SSA, on average, the time overrun in project implementation is 1.9 years and the cost overrun is 9 percent, both with no significant difference compared to those in non-SSA. These levels seem to be lower than what one expects after hearing popular condemnations of irrigation projects. However, it should be noted that the variation in these variables is very large across projects. In the case of cost overrun, the highest is 254 percent, while the lowest is -94 percent.[16] The sizing error is another indicator that is expected to measure the degree of poor design and/or poor implementation of projects. For all projects, this measure is 22 percent in SSA, significantly higher than in non-SSA, mainly because the sizing error is very large in SSA rehabilitation projects.[17] The number of project components, expected to measure the degree of complexity of irrigation projects, varies little across regions, but for both new construction and rehabilitation projects, this variable is significantly smaller in SSA than in non-SSA.

The share of government funding in SSA is significantly lower than in non-SSA. This share is particularly low for SSA rehabilitation projects. The opposite is the case for the share of software costs in the total investment - projects in SSA are characterized by a very high share of software components, compared to those elsewhere. In non-SSA, the share of software components is significantly higher for rehabilitation projects. The irrigation projects in SSA are situated in areas where the annual rainfall is relatively low as compared to those in non-SSA. The GDP per capita in 2000 constant prices shows that irrigation projects have been implemented in SSA countries which are significantly poorer than in non-SSA. In SSA, as well as in non-SSA, the Purchasing Power Parity (PPP) ratio is less than unity, indicating currency undervaluation.

For the whole sample, EIRR, a measure of the project performance, is significantly lower in SSA than in non-SSA. Comparing new construction projects with rehabilitation projects, EIRR tends to be higher for the latter. In non-SSA, the performance is significantly better for rehabilitation projects than for new construction projects. It should be noted that for both types of project, the variation in EIRR is largest in SSA among the development regions.

## Trends in Irrigation Projects over Time

In the previous section we have observed the profiles of irrigation projects by region, pooling all the sample projects implemented at different points in time. However, irrigation projects have experienced remarkable changes over time in many respects (table 5).

[16] The negative cost overrun, or cost 'underrun,' implies that the actual expenditure is lower than planned. Cost underruns can occur if a project is poorly designed and/or the implementing agency does not have the capacity to carry out the project as planned. In such cases, a project may be either terminated abruptly or its scope reduced substantially, leaving many project components unfinished or the project size reduced. Of the total sample projects, about 50 percent have cost underruns. If we exclude the underruns, the average cost overrun increases to 40 percent.

[17] Rehabilitation projects in SSA for which the sizing error is very serious are, for instance, Tombali Rice Development Project in Guinea-Bissau (84%), Lake Chad Polders Project (81%), White Nile Pump Schemes Rehabilitation Project in Sudan (75%), Manantali Dam Project in Senegal/Mauritania/Mali (74%), and Rice Development Project in the Gambia (72%).

TABLE 5.
Evolution of irrigation projects over time, SSA and non-SSA regions.[a]

| | SSA | | | | Non-SSA | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1970s | 1980s | 1990s | Trend[b] | 1960s | 1970s | 1980s | 1990s | Trend[b] |
| Number of irrigation projects | 12 | 26 | 7 | | 11 | 87 | 116 | 55 | |
| Project size ('000 ha) | 17 | 40 | 8 | | 78 | 105 | 179 | 393 | +*** |
| Average size of system ('000 ha) | 13 | 8 | 0.3 | -* | 40 | 35 | 36 | 74 | |
| Bank input for appraisal (staff weeks) | 67 | 86 | 153 | | 18 | 69 | 122 | 145 | +*** |
| Bank input for supervision (staff weeks) | 88 | 81 | 193 | | 33 | 90 | 129 | 155 | +*** |
| Time overrun (years) | 2.3 | 2.0 | 0.9 | | 3.3 | 2.2 | 1.6 | 0.9 | - *** |
| Cost overrun (%) | 46 | 0 | -26 | -** | 38 | 30 | -6 | -9 | - *** |
| Sizing error (%) | 30 | 22 | 6 | -* | -4 | -2 | 0 | -12 | |
| Number of project components | 7.9 | 4.8 | 5.9 | -** | 5.5 | 7.4 | 7.2 | 6.0 | |
| Share of government funds (%) | 34 | 23 | 15 | -** | 68 | 57 | 42 | 41 | - *** |
| Share of software components (%) | 23 | 33 | 54 | +*** | 19 | 17 | 22 | 28 | +*** |
| Annual rainfall (mm) | 506 | 750 | 967 | +** | 1235 | 1366 | 1187 | 933 | - *** |
| PPP ratio | 0.52 | 0.43 | 0.46 | -* | 0.53 | 0.48 | 0.41 | 0.34 | - *** |
| GDP per capita (US$ in 2000 prices) | 366 | 289 | 730 | | 1369 | 1078 | 1073 | 1312 | |
| EIRR (%) | 4 | 13 | 22 | +** | 13 | 16 | 16 | 21 | +** |
| Irrigation and power project (%) | 8 | 0 | 0 | | 9 | 6 | 2 | 5 | - * |
| Multi-sector project (%) | 0 | 15 | 0 | | 0 | 2 | 3 | 22 | +** |
| New construction project (%) | 83 | 42 | 71 | | 64 | 40 | 38 | 25 | - ** |
| River-dam-reservoir system (%) | 8 | 8 | 14 | | 55 | 26 | 22 | 27 | - ** |
| River-lift system (%) | 33 | 35 | 14 | -** | 27 | 7 | 9 | 5 | - * |
| Groundwater-lift system (%) | 0 | 8 | 29 | +*** | 9 | 11 | 19 | 25 | +** |
| Drainage/flood control system (%) | 17 | 4 | 0 | -* | 0 | 15 | 9 | 4 | |
| O&M by government with farmers (%) | 8 | 35 | 100 | +*** | 9 | 32 | 35 | 51 | +*** |
| Farmer-managed system (%) | 8 | 4 | 0 | | 0 | 9 | 11 | 27 | +*** |
| System with conjunctive use (%) | 0 | 0 | 29 | +** | 27 | 29 | 38 | 47 | +*** |
| Farmers' contribution to fund (%) | 17 | 8 | 57 | +** | 0 | 10 | 17 | 25 | +*** |
| System for sugar/ cotton (%) | 17 | 23 | 0 | -* | 27 | 6 | 5 | 5 | - ** |
| System for tree crops (%) | 0 | 0 | 0 | | 0 | 2 | 5 | 13 | +*** |
| System for vegetables (%) | 0 | 4 | 43 | +** | 18 | 1 | 9 | 4 | |

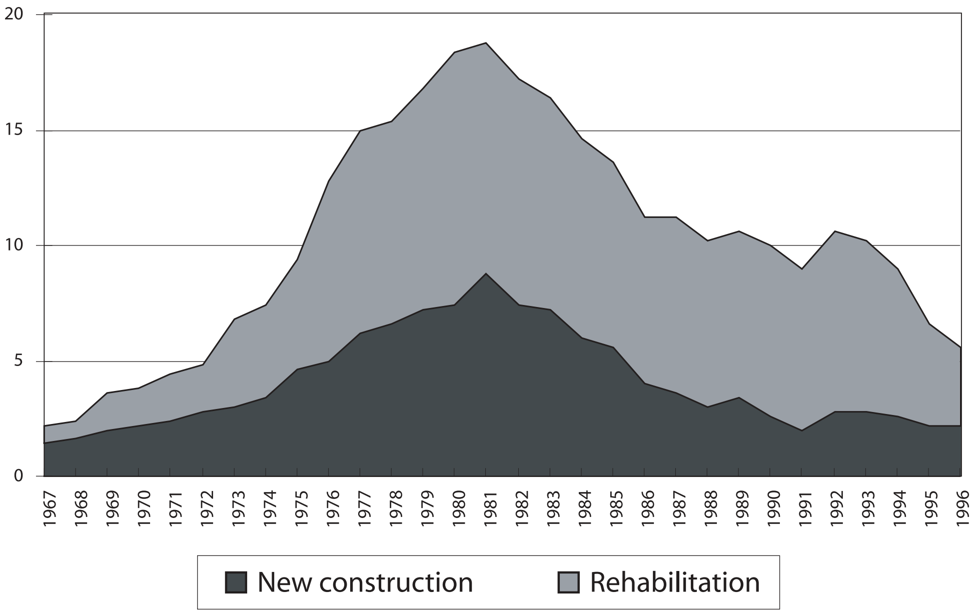
*Notes:* [a] Projects are grouped according to the start date of the project.

[b] Linear time trend estimated by regressing each variable to time; if positive +, and if negative, -. ***, **, and * indicate that the trend is statistically significant at the 1, 5, and 10 percent level, respectively. The observation unit for trend estimation is individual projects for continuous variables and half-decade averages for dummy variables.

The number of irrigation projects by time period shows a clear time trend, not linear but an inverted-V shaped one: it first increases towards a peak in the early 1980s then declines (figure 1). As pointed out by Rosegrant and Svendsen (1992) and Kikuchi et al. (2003), unprecedented high food prices during the two food crises in the 1970s induced huge irrigation investments in developing countries. With a few years time lag, many new construction and rehabilitation projects cluster around the late 1970s and early 1980s. Figure 1 also shows that since the late 1970s, more rehabilitation projects were implemented. The clearly declining trend in the percentage share of new construction projects for non-SSA in table 5 supports this observation statistically. This shift in investment to rehabilitation projects may be a reflection of a deliberate change by the WB, motivated by higher returns and lower investment requirements for rehabilitation compared with new construction projects (Jones 1995; Kikuchi et al. 2003).

For people concerned with irrigation projects in developing countries, the most interesting trend in table 5 would be the one for EIRR of irrigation projects, which is positive and statistically significant. The variation in EIRR across projects is large even in a given time period, but on average the performance of irrigation projects has been improving. Figure 2 plots all sample projects for EIRR and year started. At a glance, the large variation in EIRR across projects is apparent, and it appears no systematic trend exists over time. However, the slope of the time trend fitted to the data is positive and highly significant.[18]

FIGURE 1.
Number of sample irrigation projects by the year projects started, 1967-1996, five-year moving averages.

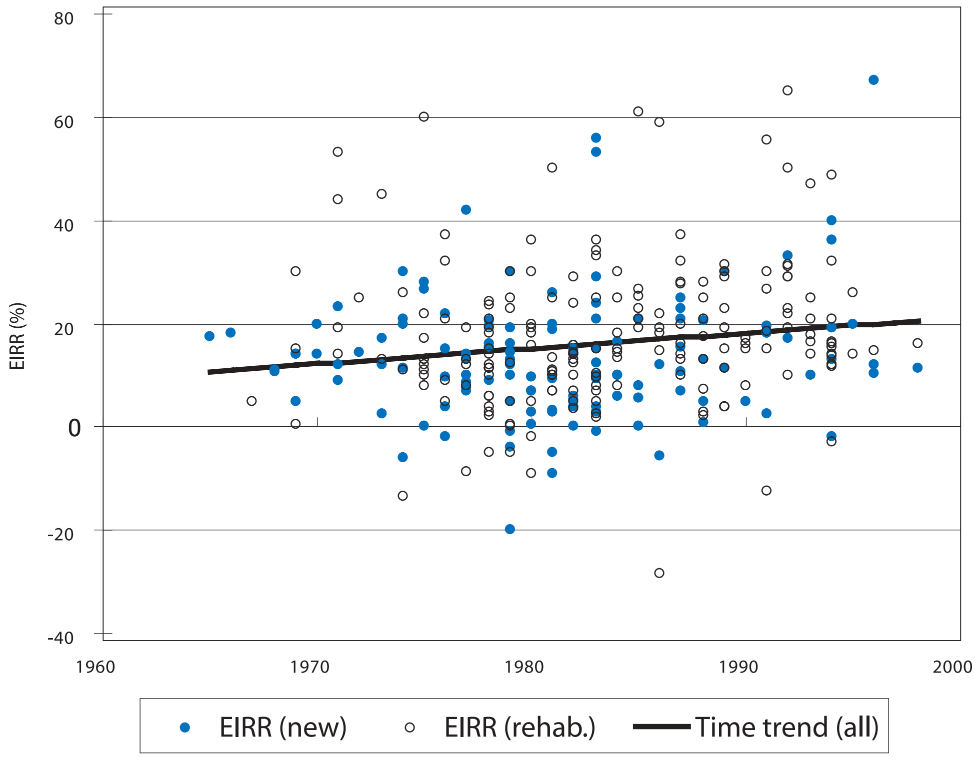



[18] A simple regression equation fitted to the data in figure 2 is estimated as follows:

$$EIRR = \underset{(210)^{***}}{-577} + \underset{(0.106)^{***}}{0.299}\ \text{Year project started} \qquad R^2 = 0.0249$$

where figures in parenthesis are standard errors, *** means that the regression coefficient is different from 0 at the 1 percent significance level, and $R^2$ stands for the coefficient of determination. It must be noted that, when observed by region, this improvement over time in project performance is significant only in three regions, EA, LAC and SSA. No significant time trend is observed in SA, SEA and MENA.

FIGURE 2.
The performance of irrigation projects as measured by EIRR of the projects (N=314).




*Notes:* rehab. = rehabilitation projects
N = number of observations

For non-SSA, we find many variables, the time trends of which are consistent with this favorable trend. Bank inputs for project appraisal and supervision have increased significantly, suggesting that the international donor agencies paid far more deliberate attention in appraising and implementing irrigation projects in the 1980s and 1990s than in the 1960s and 1970s. The trends for time and cost overrun are negative and significant. These observations suggest that lessons, which the international donor agencies and the governments have learned from past projects, have been effectively taken up for better project design and implementation.

The steady shift in the mode of O&M in irrigation systems constructed or rehabilitated from 'government agency alone' to 'government with farmers' and further to 'farmer-managed system' is clear and significant. The positive trend of the share of software components in total investment is another demonstration of increasing attention to the institutional aspects of project design, implementation and O&M after project completion. The trend toward more projects with farmers' contribution to the investment may be contributing to the higher project performance through the greater sense of ownership and commitment of farmers to the projects. The increasing trend for systems which use surface water and groundwater conjunctively may also be contributing to improved project performance.

The trend for project size is positive and highly significant statistically: from the late 1960s to the 1990s, the size of irrigation projects has increased tremendously. As mentioned earlier, project size is an important determinant of project performance (Jones 1995). If so, this increase in project size should have contributed, to a large extent, to the improvement in project performance. The trend in the share of government funds relative to total investment is negative and highly significant. The non-availability of counterpart funds is a commonly cited problem, indicating the difficulty of the recipient country governments to contribute to the projects as desired (Jones 1995; ADB-PEO 1995). The negative trend of this variable suggests that international donors' policy to increase the government contribution in project funding has not been succeeding.

Among the types of projects, the share of irrigation and power projects has been declining. Behind such a trend may be a surge of resistance against large-scale dam development arising from environmental concerns: a difficulty that the irrigation sector around the world has been facing in recent decades. Instead, the share of multi-sector projects, such as integrated rural development projects with an irrigation component, has been increasing. Among the types of irrigation systems, the share of groundwater-lift (pump) systems has been increasing, while that of river-dam-reservoir systems and river-lift systems has been decreasing. Similarly, the share of sugarcane/cotton systems has been declining, while that of tree crop systems has been increasing.

The last two variables with significant time trends are annual rainfall and PPP ratio. The negative trend for rainfall may imply that irrigation development in non-SSA has shifted from relatively wetter areas and therefore relatively easier sites, to relatively dryer areas and therefore more difficult sites. The negative trend for PPP ratio indicates that the degree of currency undervaluation in the countries where the irrigation projects are implemented has been increasing.

The pattern of time trends for SSA is fairly similar to the one for non-SSA, including the inverted-V shape distribution of the number of projects over time. This is remarkable, if we take into account the fact that our SSA sample is small and subject to large variation. For some variables, the trend is the same in SSA as in non-SSA, but it is not statistically significant because of the large variation. For example, the degree of time overrun has been reduced over time, as in non-SSA, but the trend is not statistically significant at the conventional significance levels.

There are, however, important exceptions to this statement. Contrary to the non-SSA case, no trend is found for the size of irrigation projects in SSA, while a declining trend is observed for the average size of systems within irrigation projects. There is also no clear trend for the share of new construction projects, reflecting the fact that, compared to non-SSA, more potential for new construction remains in SSA. Unlike in non-SSA, the reduction in sizing error over time is significant in SSA. In the case of annual rainfall, the trend is significant as in non-SSA, but with the opposite sign; on average, irrigation projects in SSA have shifted from relatively dry areas to relatively wet areas.

## Understanding Costs of Irrigation Projects in SSA

We have thus far observed the characteristics and changes in irrigation projects implemented in developing countries during the last four decades, except for the costs of irrigation projects. In this section, we turn our attention to the main theme of this study, i.e., the costs of irrigation projects.

### Are SSA Projects More Expensive?

Table 6 summarizes the unit costs of irrigation projects for SSA and other regions by purpose of project. As explained earlier, the unit total cost is defined as the total irrigation-related project costs divided by the project size.

TABLE 6.
Average unit cost of irrigation projects by region and by purpose of project.[a]

| Region | All sample projects | | New construction[b] | | Rehabilitation[c] | |
|---|---|---|---|---|---|---|
| | Unit total cost | Unit hardware cost | Unit total cost | Unit hardware cost | Unit total cost | Unit hardware cost |
| | … US$/ha (in 2000 prices) … | | | | | |
| All regions | 5,021 | 3,901 | 8,213 | 6,511 | 2,882 | 2,151 |
| **Sub-Saharan Africa** | **11,828** | **8,188** | **14,455** | **10,473** | **8,233** | **5,059** |
| Non-SSA | 3,882 *** | 3,183 *** | 6,590 ** | 5,481 ** | 2,280 ** | 1,824 ** |
| Middle East and North Africa | 6,311 ** | 5,251 * | 8,780 * | 7,542 ns | 4,582 ns | 3,648 ns |
| South Asia | 1,847 *** | 1,514 *** | 3,393 *** | 2,866 *** | 1,008 *** | 781 *** |
| Southeast Asia | 4,386 ** | 3,561 ** | 9,709 ns | 7,957 ns | 1,840 *** | 1,459 *** |
| East Asia | 5,105 *** | 4,317 ** | 8,221 * | 6,900 ns | 1,990 ** | 1,735 ** |
| Latin America and the Caribbean | 4,006 *** | 3,193 *** | 4,903 *** | 3,806 ** | 3,432 ** | 2,800 * |

*Notes:* [a] The results of t-test for mean differences between SSA and other regions are shown after the unit costs. ***, **, and * indicate that the mean differences are statistically significant at the 1, 5, and 10 percent level, respectively.

[b] New construction projects, including 'new construction with land opening,' 'new construction from rainfed,' and 'new construction + rehabilitation.'

[c] Rehabilitation projects, including 'rehabilitation + new construction' and rehabilitation.

ns = not significant

The average unit total cost is US$5,000/ha for the entire sample projects and US$3,900/ha for the non-SSA samples.[19] The corresponding figure for the SSA sample is US$11,800/ha, definitely highest among all the regions. The differences in the unit total cost between SSA and other regions are all statistically significant at the 5 percent level or higher. The same applies to the unit hardware cost, except that the significance level for the mean difference between SSA and MENA is 10 percent, not 5 percent.

As observed in the previous section, the share of new construction projects in the total irrigation projects is higher in SSA relative to non-SSA. Since new construction projects, requiring more construction work, are usually more expensive than rehabilitation projects, the higher share of new construction projects in SSA might have made the unit costs for all the sample projects in SSA unduly high. Table 6 shows this is not the case. As expected, there are large differences in the unit costs of irrigation projects by project purpose. On average, the unit costs of new construction projects are about three times higher than the unit costs of rehabilitation projects.[20] For the same purpose of projects, however, the unit costs in SSA are all highest among the regions.

The average unit total cost for new construction projects is US$14,500/ha in SSA, while it is US$6,600/ha in non-SSA. For rehabilitation projects, the average unit total cost is US$8,200/ha in SSA and US$2,300/ha in non-SSA. The cost differences between SSA and non-SSA are all statistically significant at the 5 percent level. However, the comparison of the unit costs between SSA and individual regions

[19] All costs presented in this study are in 2000 prices unless otherwise indicated. As to the deflator used, see section: *The Data.*

[20] The mean differences in the unit costs between new construction and rehabilitation are highly significant statistically.

reveals that the cost difference is not statistically significant for some cases. For example, for the unit hardware cost for new construction, the cost difference is not statistically significant at the conventional significance levels for MENA, SEA and EA.[21] But, in none of the cases is the average unit costs lower in SSA than in non-SSA; even for the non-significant cases, the unit costs in SSA are substantially higher than those of non-SSA regions.

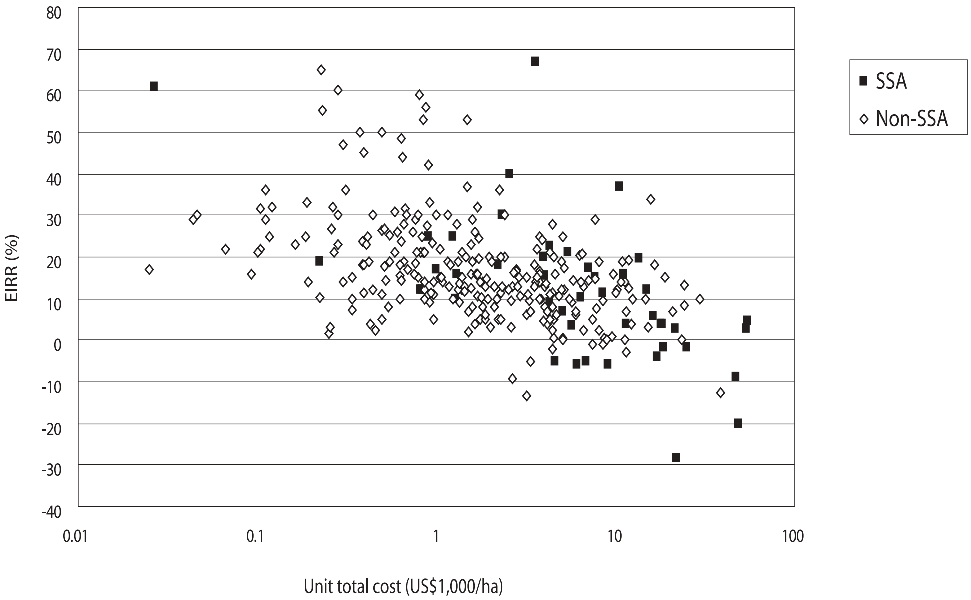
The comparison of simple regional averages of unit costs thus strongly supports the popular view that irrigation projects in SSA are more expensive compared with those in the other regions. The cost of irrigation projects in SSA is highest among the six developing regions under study.

## Unit Costs by Project Performance: Success versus Failure Projects

How firm is the statistical comparison with the simple regional averages for the entire study period? We try to challenge this on two fronts: first, unit costs by project performance, and second, changes over time in unit costs.

As expected, an inverse relationship is observed between the unit total cost and the performance of irrigation projects (figure 3): it is statistically highly significant, about a quarter of the variation in EIRR being explained by the variation of unit total cost.[22] We see that relatively more SSA projects have higher unit total cost and lower EIRR. However, there are SSA projects with high project performance.

FIGURE 3.
Unit total cost and EIRR of sample irrigation projects (N=314).




[21] There is a Malaysian new irrigation construction project that was a terrible failure case with an extremely high unit total cost. If this project is excluded, the average unit total cost for SEA becomes significantly lower than that for SSA.

[22] Simple regression applied to the data in figure 4 gives the following result:

$$EIRR = \underset{(3.49)^{***}}{52.3} - \underset{(0.453)^{***}}{4.78} \text{ Ln (Unit total cost)} \qquad R^2 = 0.263$$

These observations lead to the idea of grouping the sample projects according to the level of project performance. We group irrigation projects with EIRR of 10 percent or above and call them 'success' projects and those with EIRR of less than 10 percent as 'failure' projects. The EIRR of 10 percent is the threshold rate widely adopted among the international donor agencies when evaluating the outcomes of public investment projects, below which a development project is considered, if *ex-ante*, not worth implementing, and if *ex-post*, a failure (Belli et al. 1997: 146).

Table 7 compares the unit costs of irrigation projects by success and failure. A quite different picture emerges as to the cost comparison between SSA and non-SSA regions. Let us look at the 'success' projects first. For new construction projects, the average unit total cost is US$5,700 per ha in SSA and US$4,600 per ha in non-SSA. The difference between these two is not statistically significant. Comparing SSA with other regions, the unit total costs in SA and SEA are significantly lower, but those in EA and LAC are not significantly different. The cost difference between SSA and MENA is significant, but the unit total cost in MENA is indeed higher than in SSA. In the case of unit hardware cost, except MENA for which the cost is significantly higher than in SSA, no significant cost difference is observed across regions.

For successful rehabilitation projects, the cost difference between SSA and the other regions is less pronounced. The average unit total cost for SSA is US$3,500 per ha, which is significantly

TABLE 7.
Average unit costs of irrigation projects by region, by purpose of project and by 'success' and 'failure' case.[a]

| Region | New construction | | Rehabilitation | |
|---|---|---|---|---|
| | Unit total cost | Unit hardware cost | Unit total cost | Unit hardware cost |
| 'Success' projects[b] | 4,785 | 3,748 | 1,969 | 1,488 |
| **Sub-Saharan Africa** | **5,726** | **3,552** | **3,488** | **2,303** |
| Non-SSA | 4,603 ns | 3,786 ns | 1,833 * | 1,415 ns |
| Middle East and North Africa | 8,464 * | 7,044 ** | 3,193 ns | 2,383 ns |
| South Asia | 2,526 ** | 2,141 * | 898 ** | 674 ** |
| Southeast Asia | 3,861 * | 3,146 ns | 965 ** | 711 ** |
| East Asia | 4,101 ns | 3,294 ns | 1,990 ns | 1,735 ns |
| Latin America and the Caribbean | 3,663 ns | 2,841 ns | 3,730 ns | 3,004 ns |
| 'Failure' projects[c] | 14,174 | 11,318 | 6,054 | 4,454 |
| **Sub-Saharan Africa** | **23,184** | **17,395** | **16,366** | **9,784** |
| Non-SSA | 10,624 ** | 8,924 ** | 3,991 ** | 3,388 ** |
| Middle East and North Africa | 10,125 ** | 9,657 ns | 13,612 ns | 11,868 ns |
| South Asia | 5,048 *** | 4,249 *** | 1,706 ** | 1,458 ** |
| Southeast Asia | 15,556 ns | 12,768 ns | 3,333 ** | 2,735 ** |
| East Asia | 22,639 ns | 19,520 ns | | |
| Latin America and the Caribbean | 7,632 *** | 5,928 ** | 2,488 ** | 2,156 ** |

*Notes:* [a] The results of t-test for mean differences between SSA and other regions are shown after the unit costs. ***, **, and * indicate that the mean differences are statistically significant at the 1, 5, and 10 percent level, respectively.

[b] Projects with EIRR of 10 percent or higher

[c] Projects with EIRR less than 10 percent

ns = not significant

higher than the overall non-SSA average of US$1,800 per ha, but is not significantly different from the cost in MENA, EA and LAC. In the case of unit hardware cost, the difference between SSA and non-SSA regions as a group becomes insignificant, implying that if the software components are excluded in the cost accounting, the cost of rehabilitation projects in SSA is comparable to that in non-SSA.

In contrast, not only are the unit total costs of 'failure' projects in SSA very high, but they are also significantly higher than in non-SSA regions as a group. The average unit total cost of failed new construction projects in SSA is US$23,200 per ha, four times higher than the unit total cost of successful projects in SSA and more than twice the average of failed projects in non-SSA. With such a high unit cost, it is virtually impossible for a new construction project to be successful. The consequence of failure for the unit cost in SSA is even more serious for rehabilitation projects. The average unit total cost for failed rehabilitation projects in SSA is US$16,400 per ha, which is nearly five times as high as the unit cost for successful projects in SSA. There is no chance at all for such a high-cost rehabilitation project to be economically viable.

It must be emphasized that relatively costly failure projects are not unique to SSA: the degree of failure in EA and SEA for new construction projects and MENA for rehabilitation projects seems to be as serious as in SSA. The unit hardware cost of failed new construction projects in EA is, on average, higher than that in SSA, though the difference is not significant. The same is the case for failed rehabilitation projects in MENA.

In figure 3, it is conspicuous that many of the failure cases with high unit total cost are SSA projects. Compared with the other regions, the probability of irrigation project failure is indeed higher in SSA (table 8). The percentage of

TABLE 8.
Number and share of 'success' projects by region and type of project.[a]

| | New construction | | Rehabilitation | | Total | |
|---|---|---|---|---|---|---|
| | No. | (%) | No. | (%) | No. | (%) |
| 'Success' projects | | | | | | |
| Sub-Saharan Africa | 13 | (50) | 12 | (63) | 25 | (56) |
| Non-SSA | | | | | | |
| Middle East and North Africa | 17 | (81) | 26 | (87) | 43 | (84) |
| South Asia | 21 | (66) | 51 | (86) | 72 | (79) |
| Southeast Asia | 11 | (50) | 29 | (63) | 40 | (59) |
| East Asia | 7 | (78) | 9 | (100) | 16 | (89) |
| Latin America and the Caribbean | 11 | (69) | 19 | (76) | 30 | (73) |
| Total | 80 | (63) | 146 | (78) | 226 | (72) |
| All Projects | | | | | | |
| Sub-Saharan Africa | 26 | (100) | 19 | (100) | 45 | (100) |
| Non-SSA | | | | | | |
| Middle East and North Africa | 21 | (100) | 30 | (100) | 51 | (100) |
| South Asia | 32 | (100) | 59 | (100) | 91 | (100) |
| Southeast Asia | 22 | (100) | 46 | (100) | 68 | (100) |
| East Asia | 9 | (100) | 9 | (100) | 18 | (100) |
| Latin America and the Caribbean | 16 | (100) | 25 | (100) | 41 | (100) |
| Total | 126 | (100) | 188 | (100) | 314 | (100) |

*Notes:* [a] 'Success' projects are those with EIRR of 10 percent or higher.

'success' projects in SSA is 56 percent, which is the lowest among the regions. This rate is also quite low in SEA, while in all other regions, the probability of success has been higher at more than 70 percent. Looking at new construction projects, the probability of 'success' projects in SSA and SEA is as low as 50 percent: Implementing new construction projects in these two regions is like a gamble with an equal chance of succeeding and failing. It is interesting to observe that rehabilitation projects perform better than new construction projects. The probability of 'success' for rehabilitation projects in SSA (and also in SEA) is 63 percent. This is lowest among the regions, but is far better than 50 percent for new construction projects.

Observations of the 'success' and 'failure' projects reveal that costly failure irrigation projects are largely contributing to the significantly higher average unit costs in SSA compared with the non-SSA regions. As far as 'success' projects are concerned, irrigation projects in SSA are not significantly more expensive than in other regions. Compared to the low cost regions of SA and SEA, the cost of irrigation projects in SSA is still higher. This is particularly so for rehabilitation projects. However, the cost level in SSA is comparable with that in MENA, EA and LAC. These observations imply that addressing the high unit cost of irrigation development in SSA relative to other regions involves addressing the causes of failures in irrigation projects and the higher probability of failures in SSA.

## Changes in Unit Costs over Time

As observed earlier, the performance of irrigation projects has been improving over time (figure 2). Many factors that may affect project performance have also shown consistent trends over time. Coupled with figure 3 that reveals the negative relation between EIRR and the unit total cost of irrigation projects, the improvement in project performance leads us to a conjecture that the unit cost of irrigation projects has been declining. Such a trend, if it exists, might have changed the relative position of SSA among the developing regions in terms of the cost of irrigation projects.

Such conjectures are indeed supported by our data. The top panel of figure 4 plots all the sample irrigation projects according to their unit total cost and the year the project started. The variation in the unit cost across projects is very large. However, fitting a linear trend line gives a highly significant negative trend. During the study period, the cost of irrigation projects has been declining steadily as a trend.

As observed earlier, rehabilitation has become the dominant purpose of irrigation projects, overshadowing new construction projects. For all regions, a large increase in the number of irrigation projects from the 1970s to the 1980s was mostly brought about by the increase in rehabilitation projects (table 9). In the 1990s when the number of irrigation projects decreased drastically, the dominance of rehabilitation projects became more distinct. The unit cost of rehabilitation projects being generally cheaper than that of new construction projects, the decline in the unit total cost for all projects might have been due to this shift over time in irrigation projects from new construction to rehabilitation. The middle and bottom panels of figure 4 reveal that this is the case, but only partly. The middle panel shows there is no time trend in the unit total cost of new construction projects. The trend line is horizontal, showing neither positive nor negative trend. In contrast, the bottom panel discloses a significantly negative time trend for the unit total cost of rehabilitation projects.[23] The declining trend in the

[23] Three trend equations in figure 5 are shown below:

| | | | | | | |
|---|---|---|---|---|---|---|
| All projects | Ln (Cost) | = | 75.7<br>(22.5)*** | - | 0.0343 Year<br>(0.0114)*** | $R^2$ = 0.0284 |
| New construction projects | Ln (Cost) | = | 11.5<br>(27.6) | - | 0.0016 Year<br>(0.0139) | $R^2$ = 0.0001 |
| Rehabilitation projects | Ln (Cost) | = | 78.0<br>(28.9)*** | - | 0.0358 Year<br>(0.0146)** | $R^2$ = 0.0313 |

where Cost = unit total cost, Year = year project started, and figures in parenthesis are standard errors. *** and ** stand for the significance level of 1 and 5 percent, respectively.

FIGURE 4.
Unit total cost of irrigation projects and its time trend.

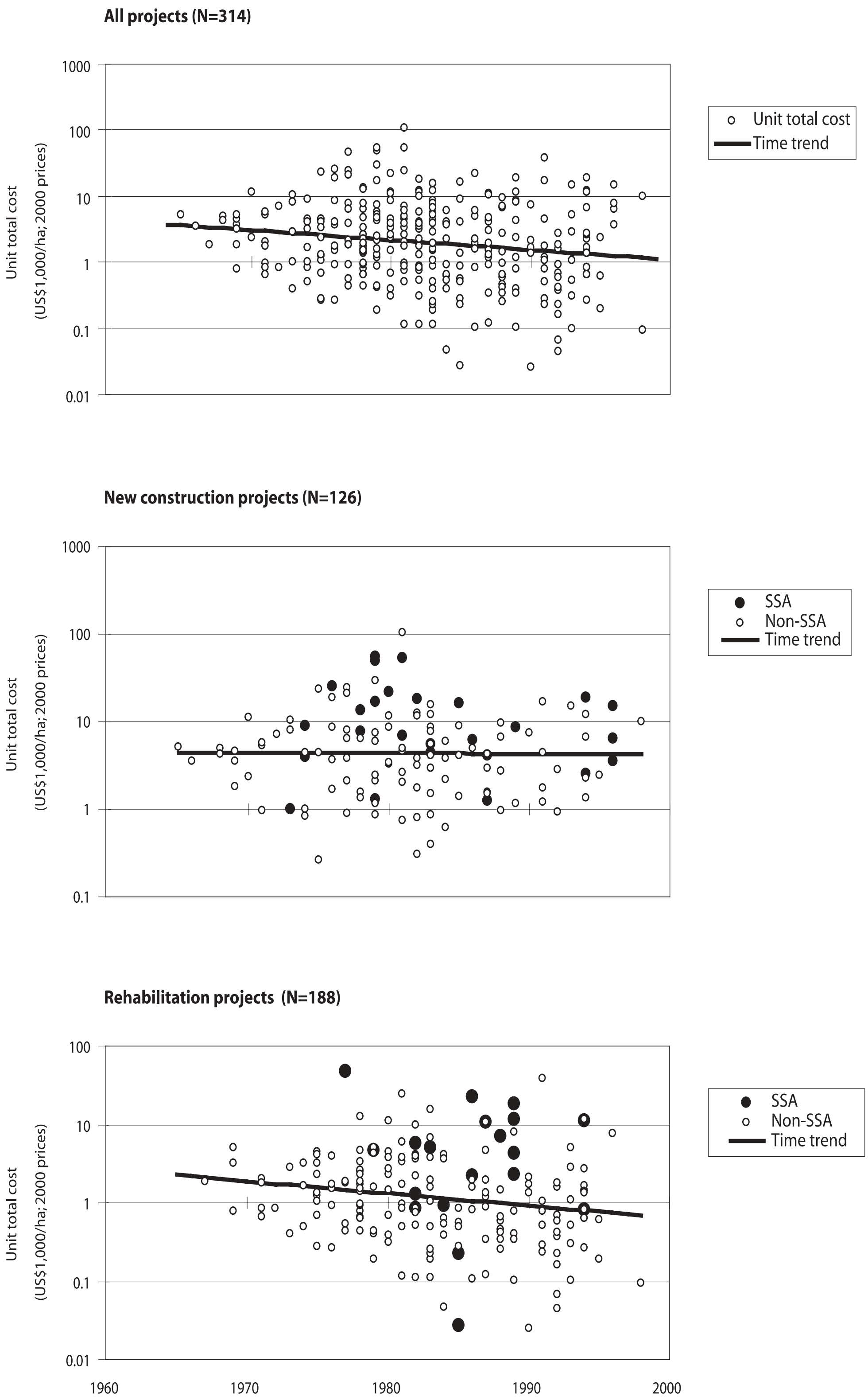


TABLE 9.
Changes in the unit total cost of irrigation projects, SSA and non-SSA regions, by time period.

| | 1960s | 1970s SSA vs non-SSA[1] | 1980s SSA vs non-SSA[1] | 1990s SSA vs non-SSA[1] | Time trend[2] |
|---|---|---|---|---|---|
| SSA | | | | | |
| Number of observations | | | | | |
| All projects | | 12 | 26 | 7 | |
| New construction projects | | 10 | 11 | 5 | |
| Rehabilitation projects | | 2 | 15 | 2 | |
| Unit total cost (US$/ha in 2000 prices) | | | | | |
| All projects | | 19,543 *** | 9,213 ** | 8,313 ** | ns |
| New construction projects | | 18,270 ** | 13,360 ns | 9,233 ns | ns |
| Rehabilitation projects | | 25,908 ns | 6,172 ** | 6,012 ns | ns |
| Non-SSA | | | | | |
| Number of observations | | | | | |
| All projects | 11 | 87 | 116 | 55 | |
| New construction projects | 7 | 35 | 44 | 14 | |
| Rehabilitation projects | 4 | 52 | 72 | 41 | |
| Unit total cost (US$/ha in 2000 prices) | | | | | |
| All projects | 3,527 | 3,979 | 4,142 | 3,253 | -*** |
| New construction projects | 3,976 | 6,960 | 6,882 | 6,054 | ns |
| Rehabilitation projects | 2,742 | 1,972 | 2,467 | 2,297 | -*** |
| All regions | | | | | |
| Number of observations | | | | | |
| All projects | 11 | 99 | 142 | 62 | |
| New construction projects | 7 | 45 | 55 | 19 | |
| Rehabilitation projects | 4 | 54 | 87 | 43 | |
| Unit total cost (US$/ha in 2000 prices) | | | | | |
| All projects | 3,527 | 5,865 | 5,070 | 3,825 | -*** |
| New construction projects | 3,976 | 9,473 | 8,178 | 6,890 | ns |
| Rehabilitation projects | 2,742 | 2,858 | 3,106 | 2,470 | -** |

*Notes:* [1] t-test for mean differences between SSA and non-SSA for corresponding items. ***, **, and * indicate that the mean differences are statistically significant at the 1, 5, and 10 percent level, respectively.

[2] t-test for the time trend in a trend regression: Ln (unit total cost) = a + b (time). ***, **, and * indicate that the mean differences are statistically significant at the 1, 5, and 10 level, respectively.

+ (-) sign indicates the time trend is increasing (decreasing)

ns = not significant

top panel has thus resulted partly from the shift in irrigation projects from more expensive new construction projects to cheaper rehabilitation projects, and partly from the declining time trend in the unit cost of rehabilitation projects.

These two panels also show that most SSA projects lie above the trend line for both new construction and rehabilitation projects. This means that the unit costs of these SSA projects are higher than the all-region average. It is difficult to detect any improvement from the two panels. Even in recent decades, the unit cost of SSA projects appears to be higher than the all-region averages for both purposes of irrigation projects. Such observations seem to support the popular view that the cost of irrigation projects in SSA is more expensive than in other regions. However, there are signs of improvements in the relative position of SSA irrigation projects.

The average unit total cost of rehabilitation projects for all regions increased slightly from US$2,900/ha in the 1970s to US$3,100/ha in the 1980s and then declined to US$2,500/ha in the 1990s (table 9). Between the 1970s and the 1990s, the average unit total cost of new construction projects continued to decline from

US$9,500/ha to US$6,900/ha, but the time trend is not statistically significant because of the large variation in the unit cost. Non-SSA regions as a whole (i.e., excluding SSA) show exactly the same trend patterns as for all regions (including SSA), except for two points; first, the unit total cost for non-SSA is consistently lower than in all regions together for both purposes of projects and for all corresponding periods,[24] and second, the negative time trend for rehabilitation projects in non-SSA is significant at the 1 percent level, instead of the 5 percent level for all regions.

In SSA, for new construction as well as rehabilitation projects, the average unit cost declined drastically from the 1970s to the 1990s (table 9). The time trend is, however, not statistically significant for either, because of the small size of the SSA sample with a large variation. Yet it is remarkable that between the 1970s and the 1990s, the average unit total cost for all projects in SSA shrunk by more than half, from US$19,500/ha to US$8,300/ha. For rehabilitation projects, the unit total cost declined drastically from US$25,900/ha (more expensive than new construction projects!) in the 1970s to US$6,200/ha in the 1980s, and further to US$6,000/ha in the 1990s.

As a result, for new construction projects, the ratio of SSA unit cost to non-SSA unit cost declined from 2.6 in the 1970s to 1.9 in the 1980s and further to 1.5 in the 1990s. In the case of rehabilitation projects, this ratio declined dramatically from as high as 13.1 in the 1970s to 2.5 in the 1980s, though in the 1990s it remained at almost the same level as in the 1980s. In the 1970s, the difference in the unit cost of new construction projects between SSA and non-SSA is statistically significant. In the 1980s, the unit cost of rehabilitation projects in SSA is significantly higher than that in non-SSA. By the 1990s, however, the difference between SSA and non-SSA is not statistically significant for either project purpose. For all projects, the average unit cost in SSA is significantly higher than that in non-SSA from the 1970s through to the 1990s. However, this is because the share of new construction projects increased substantially from the 1980s to the 1990s in SSA, whereas the opposite was the case in non-SSA.

Our data thus indicate that substantial improvements in the cost of irrigation projects in SSA over the last three decades have changed the relative status of SSA vis-à-vis other developing regions. The positive gap in the unit cost between SSA and non-SSA, which used to be enormous, has been sharply reduced. For the most recent decade, the null hypothesis of no gap between SSA and non-SSA cannot be rejected for both new construction and rehabilitation projects, though the small size of the SSA sample makes the statistical test less reliable, particularly for rehabilitation projects.

The statement above, based on the changes in the unit cost of irrigation projects over time, may be reinforced by examining changes in the performance of these projects over time. We have already observed that the performance for all projects has been improving (figure 2). Table 10 examines the changes in project performance over time by project purpose. For all regions, the time trend for both new construction and rehabilitation projects is positive and statistically significant. For non-SSA regions, the improvement over time of project performance is statistically significant for rehabilitation projects. The average EIRR has been improved for new construction projects too, though its time trend is not statistically significant.

For SSA, the performance of new construction projects has shown significant improvement over time. The improvement in EIRR is particularly distinct between the 1980s and the 1990s: it increased from 7.8 percent in the 1980s to 25.5 percent in the 1990s. The level of project performance in SSA was significantly lower than in non-SSA in the 1970s and 1980s. However, the difference in EIRR between SSA

[24] Except for the 1960s, for which the sample projects are the same for non-SSA and for all regions. It should be noted that not only is the number of sample projects in the 1960s small, but also all of them started in the latter half of the 1960s.

TABLE 10.
EIRR of irrigation projects, SSA and non-SSA regions, by time period.

| | 1960s | 1970s | 1980s | 1990s | |
|---|---|---|---|---|---|
| | | SSA vs non-SSA[1] | SSA vs non-SSA[1] | SSA vs non-SSA[1] | Time trend[2] |
| SSA | | | | | |
| All projects | | 3.9 *** | 12.6 ns | 22.2 ns | + ** |
| New construction projects | | 6.1 ** | 7.8 * | 25.5 ns | + ** |
| Rehabilitation projects | | -6.9 *** | 16.2 ns | 14.0 ** | ns |
| Non-SSA | | | | | |
| All projects | 12.8 | 15.7 | 15.9 | 20.9 | + ** |
| New construction projects | 12.8 | 14.8 | 13.0 | 17.3 | ns |
| Rehabilitation projects | 12.6 | 16.4 | 17.6 | 22.2 | + * |
| All regions | | | | | |
| All projects | 12.8 | 14.3 | 15.3 | 21.1 | + *** |
| New construction projects | 12.8 | 12.9 | 11.9 | 19.4 | + * |
| Rehabilitation projects | 12.6 | 15.5 | 17.4 | 21.8 | + * |

*Notes:* [1] t-test for mean differences between SSA and non-SSA for corresponding items. ***, **, and * indicate that the mean differences are statistically significant at the 1, 5, and 10 percent level, respectively.

[2] t-test for the time trend in a trend regression: Ln (unit total cost) = a + b (time). ***, **, and * indicate that the mean differences are statistically significant at the 1, 5, and 10 percent level, respectively.

+ (-) sign indicates the time trend is increasing (decreasing)

ns = not significant

and non-SSA is insignificant in the 1990s when on average the level of EIRR in SSA became higher than in non-SSA. Such results reinforce the statement that in the 1990s the unit cost of new construction projects in SSA is comparable to that in non-SSA.

In the case of rehabilitation projects in SSA, the time trend is not statistically significant. However, the improvement in EIRR between the 1970s and the 1980s was substantial; it increased from -6.9 percent in the 1970s to 16.2 percent in the 1980s. Consequently, the difference in EIRR between SSA and non-SSA, which had been significant in the 1970s, became non-significant in the 1980s. From the 1980s to the 1990s, the average EIRR in SSA declined slightly to 14 percent in the 1990s, while it increased substantially from 17.6 percent in the 1980s to 22.2 percent in the 1990s in non-SSA. As a result, the difference between the two regions became significant again in the 1990s. Coupled with the observation (in table 9) that for rehabilitation projects, the ratio of SSA unit cost to non-SSA unit cost is around 2.5, this observation suggests that for rehabilitation projects in SSA there is still room for improvement.

How are the findings in this subsection related to the findings in the previous subsection, i.e., the incidence of success and failure of projects? Table 11 gives an answer to this question: the probability of success has improved over time. The improvement is observed in both SSA and non-SSA, but it is particularly distinct in SSA. In the 1970s, nearly 60 percent of irrigation projects implemented in SSA failed. In the 1990s, the success probability in SSA increased to nearly 90 percent. The improvement occurred in non-SSA too, but the degree of improvement has been much higher in SSA. Such an increase in success probability of irrigation projects has been behind the decline in, and the convergence towards the non-SSA level of, the unit cost in SSA.

As observed in table 9, the unit cost of irrigation projects in SSA during the 1970s was extremely expensive for both new construction and rehabilitation projects. This was mainly due to the fact that many irrigation projects at the dawn of irrigation development in SSA turned out

TABLE 11.
Number of success and failure projects in SSA and non-SSA regions by time period.[a]

| | 1960s | 1970s | 1980s | 1990s |
|---|---|---|---|---|
| SSA | | | | |
| Number of observations | | | | |
| All projects | | 12 | 26 | **7** |
| | | (100) | (100) | (100) |
| Success projects | | 5 | 14 | 6 |
| | | (42) | (54) | (86) |
| New construction | | 5 | 4 | 4 |
| Rehabilitation | | | 10 | 2 |
| Failure projects | | 7 | 12 | 1 |
| | | (58) | (46) | (14) |
| New construction | | 5 | 7 | 1 |
| Rehabilitation | | 2 | 5 | |
| Non-SSA | | | | |
| Number of observations | | | | |
| All projects | 11 | 87 | 116 | 55 |
| | (100) | (100) | (100) | (100) |
| Success projects | 8 | 63 | 80 | 50 |
| | (73) | (72) | (69) | (91) |
| New construction | 6 | 25 | 24 | 12 |
| Rehabilitation | 2 | 38 | 56 | 38 |
| Failure projects | 3 | 24 | 36 | 5 |
| | (27) | (28) | (31) | (9) |
| New construction | 1 | 10 | 20 | 2 |
| Rehabilitation | 2 | 14 | 16 | 3 |

*Notes* : [a] Figures in parenthesis are percentages.

to be serious failures. It should be remarked that most of the expensive projects in SSA which resulted in miserable failures, were implemented from the mid 1970s to the early 1980s when a "privileged" status was accorded to irrigation investment in SSA (Zalla 1987). It is said that at the World Bank this was a time of aggressive agricultural and irrigation expansion, during which attempts to meet lending targets resulted in the downgrading of technical and economic screening of projects (Jones 1995). Typical examples of serious failure with prohibitively high unit costs are, among others, the Bura Irrigation Settlement Project in Kenya (new construction project) and the Lake Chad Polders Project in Chad (rehabilitation project).[25]

It may be conjectured that these costly failure projects in the early stage of irrigation development in SSA are so impressive among the people concerned that the popular belief that irrigation projects in SSA are more expensive than in other regions has become pervasive and persistent, even to the level of preventing them from seeing the recent improvements in the cost of irrigation projects in this region.

## Characteristics of 'Success' and 'Failure' Projects

An examination of the profiles of success and failure projects suggests some key factors that

[25] These projects ended up with unit costs that are more than twice the estimates at appraisal, largely because of reductions in actual against planned irrigated area (large sizing error).

TABLE 12.
Comparison of project characteristics between success and failure projects, SSA and non-SSA regions.[a]

| | SSA | | Non-SSA | |
|---|---|---|---|---|
| | Success | Failure | Success | Failure |
| EIRR (%) | 23 | -2 *** | 21 | 4 *** |
| Project size ('000 ha) | 48 | 5 ** | 240 | 61 *** |
| Average size of system ('000 ha) | 13 | 3 * | 52 | 19 *** |
| Year project started | 1986 | 1982 ** | 1983 | 1981 *** |
| Bank input for appraisal (staff weeks) | 96 | 85 | 106 | 108 |
| Bank input for supervision (staff weeks) | 123 | 71 ** | 118 | 120 |
| Time overrun (years) | 1.8 | 2.0 | 1.6 | 1.9 |
| Cost overrun (%) | 11 | 5 | 7 | 5 |
| Sizing error (%) | 12 | 34 *** | -5 | 1 |
| Number of project components | 6.1 | 5.5 | 6.8 | 7.3 |
| Share of government funds (%) | 23 | 26 | 47 | 49 |
| Share of software components (%) | 35 | 31 | 22 | 18 *** |
| Annual rainfall (mm) | 797 | 620 * | 1133 | 1378 ** |
| PPP ratio | 0.45 | 0.47 | 0.42 | 0.42 |
| GDP per capita (US$ in 2000 prices) | 392 | 361 | 1105 | 1225 |
| Irrigation (%) | 92 | 85 | 87 | 97 ** |
| Irrigation and power project (%) | 0 | 5 | 5 | 0 ** |
| Multi-sector project (%) | 8 | 10 | 8 | 3 |
| New construction project (%) | 52 | 65 | 33 | 49 ** |
| Rehabilitation projects (%) | 48 | 35 | 67 | 51 ** |
| River-diversion system (%) | 44 | 40 | 33 | 46 * |
| River-dam-reservoir system (%) | 16 | 0 * | 25 | 26 |
| Tank system (%) | 4 | 0 | 2 | 0 |
| River-lift system (%) | 12 | 55 *** | 7 | 12 |
| Groundwater-lift system (%) | 16 | 0 * | 21 | 7 *** |
| Drainage/flood control system (%) | 8 | 5 | 11 | 6 |
| O&M by government agency alone (%) | 56 | 60 | 47 | 59 * |
| O&M by government with farmers (%) | 40 | 35 | 37 | 34 |
| Farmer-managed system (%) | 4 | 5 | 15 | 7 * |
| System with conjunctive use (%) | 4 | 5 | 43 | 18 *** |
| Farmers' contribution to fund (%) | 28 | 5 ** | 20 | 3 *** |
| System for rice (%) | 56 | 75 | 48 | 59 |
| System for cereals (%) | 4 | 15 | 32 | 25 |
| System for sugar/cotton (%) | 28 | 5 ** | 5 | 10 |
| System for tree crops (%) | 0 | 0 | 6 | 3 |
| System for vegetables (%) | 12 | 5 | 6 | 3 |
| System for fodder (%) | 0 | 0 | 2 | 0 |

*Notes:* [a] Whether the differences in mean or ratio between the success and failure cases are statistically significant is tested by t-test for mean difference (continuous variables) and Z-test for ratio difference (binary variables), and the results are marked with asterisks; ***, **, and * indicate that the difference is statistically significant at the 1, 5, and 10 percent level, respectively.

have influenced the performance of irrigation projects. Table 12 compares project characteristics between success and failure projects for variables available in our database and for the SSA and non-SSA regions.

Except EIRR, the performance indicator itself, these variables can be grouped into five in terms of their impact on success and failure. The first group includes variables for which a significant difference is observed between success and failure projects consistently in both non-SSA and SSA. Variables in the second and third groups have a significant impact on success and failure only in either non-SSA or SSA, respectively. Variables that have a significant impact on success and failure in both regions with the opposite direction belong to the fourth group. The fifth group consists of variables for which no significant impact is observed in both SSA and non-SSA.

Of the variables included in the first group, project size appears to be the most important key variable that is consistently larger in success projects compared with failure ones. In terms of simple correlation coefficients between the EIRR of irrigation projects and the variables listed in table 12, this variable has the highest coefficient, 0.41. Among the variables, project size also records the highest simple correlation coefficient of -0.77 with the unit total cost of irrigation projects (figure 5).[26] Another interesting variable in the first group is the year the project started, which indicates that success projects tend to be found in more recent years. This is another expression of what we have observed, i.e., the improvement in project performance over time. It is also interesting to observe that the percentage of projects for which the farmers contributed to project investment cost is consistently higher in success projects than in failure ones. As to the type of irrigation systems, groundwater-lift systems have a higher probability to succeed.

Of the variables in the second group, some are related to the software or institutional aspects of irrigation projects. Typical of these is the share of software components, which has a positive impact on the probability of success. Similarly, the degree of farmers' participation in system O&M after project completion seems to have a positive impact on project performance, as indicated by the negative impact of O&M by government agency alone and by the positive impact for farmer-managed systems. The probability of success is also higher for irrigation and power projects than for projects solely for irrigation; for rehabilitation projects than for new construction projects; and for systems with conjunctive water use than otherwise.

Four variables in the third group may point to some unique aspects of irrigation projects in SSA. Compared to failure projects, success projects in SSA absorb more bank staff inputs to supervise the project implementation. The degree of sizing error is particularly large in failure projects in SSA. There is no case for failure of river-dam-reservoir systems with a large water storage capacity, while the probability of failure is very high for river (or pond or lake) - lift systems. Annual rainfall is the only variable in the fourth group; in SSA, success projects tend to be found in areas with relatively more rainfall, whereas the opposite is the case in non-SSA. This may suggest that the impact of rainfall on project performance differs between rain-short regions and rain-abundant regions.

There are some characteristics specific to SSA, as the variables in the third and fourth groups indicate. However, the majority of variables having a significant impact on success and failure of projects seem to be common in SSA and non-SSA. A general observation in this comparison of project characteristics between success and failure projects is that the structure determining project performance is largely the

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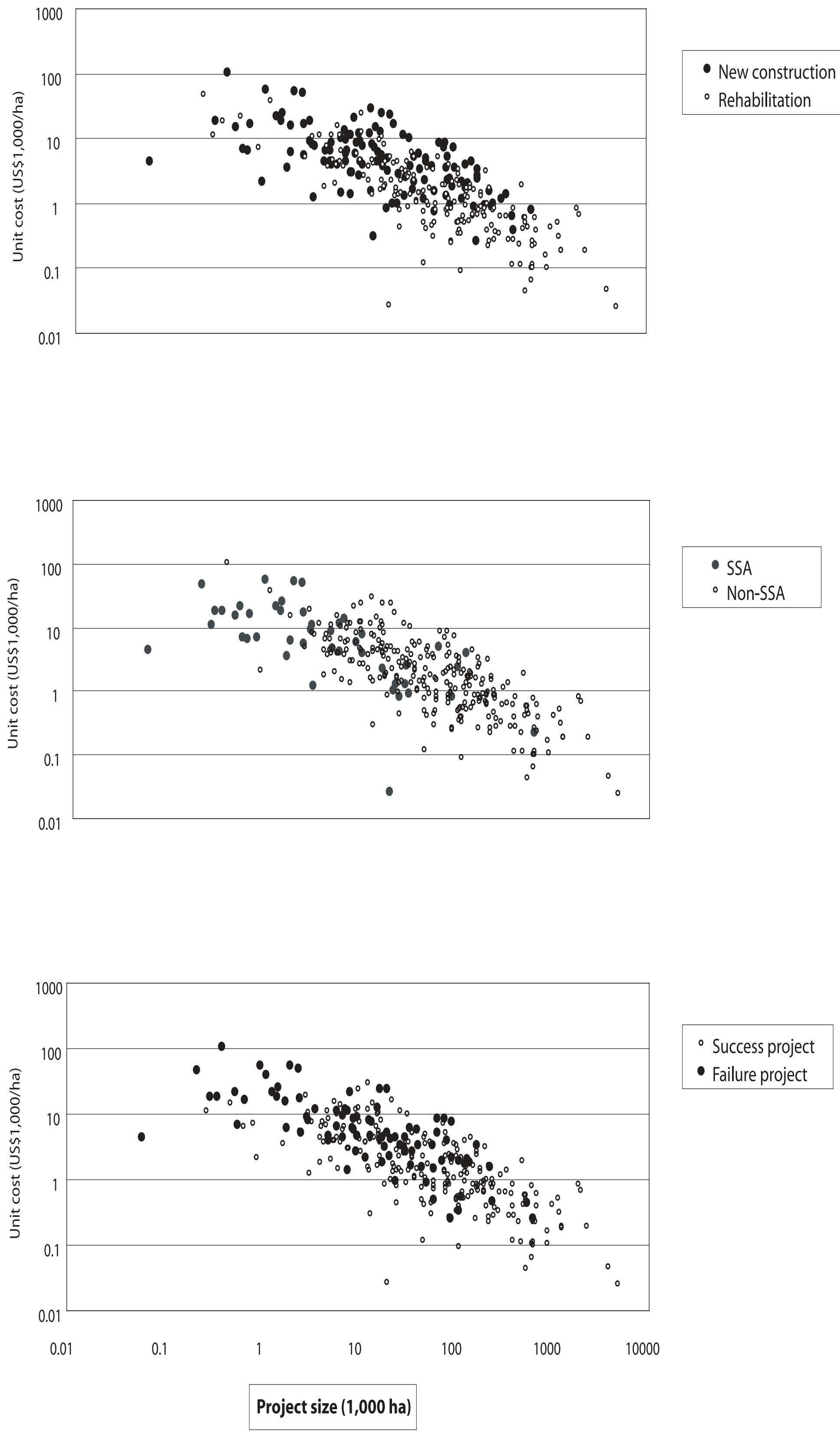
[26] A log-linear line fitted to the data give the following results:

$$\text{Ln (Unit total cost)} = \underset{(0.113)^{***}}{9.68} - \underset{(0.0274)^{***}}{0.574}\ \text{Ln (Project size)} \qquad R^2 = 0.585$$

FIGURE 5.
Project size and unit total cost of sample irrigation projects (N=314).



same between SSA and non-SSA. Another point worth noting is that many variables that favor project success are those that have a positive time trend in table 5 and *vice versa*. Examples are project size, share of software components, farmer-managed systems and farmers' contribution to fund, all of which favor project success and at the same time show a positive time trend. An example of the opposite case is new construction projects that work against project success and have changed over time with a negative trend.

Whether all the above variables are indeed crucial determinants of the cost and performance of irrigation projects is examined more systematically in the following sections.

## Determinants of Cost and Performance of Irrigation Projects

We have observed that the popular view that irrigation projects in SSA are more expensive than in other regions is not groundless, if all sample projects implemented during the last four decades are compared by means of simple regional averages. However, a careful scrutiny of the sample projects by dividing them into success and failure cases has revealed that it is failure projects that make the cost of irrigation projects in SSA substantially higher than in other regions, and that no significant cost difference is observed between SSA and non-SSA as far as success projects are concerned. Furthermore, the examination of changes in irrigation projects over time has made it clear that as the probability for irrigation projects to fail has declined, the unit cost (performance) of irrigation projects has also decreased (improved), resulting in a less pronounced cost (performance) difference between SSA and non-SSA. In this section, by applying regression analysis to our database, we examine the factors that determine the variations in the unit costs and the performance of irrigation projects, and confirm whether projects in SSA are indeed more expensive than in other regions.

We have estimated four regression equations using the total project cost, the total hardware cost, the project size and the EIRR as the dependent variable, and then derived the elasticity of the unit total cost, the unit hardware cost and EIRR with respect to the explanatory variables.[27]

### Factors Determining Unit Costs and Performance of Irrigation Projects

The results of regression analysis are summarized in table 13 in terms of elasticity.[28] Note that elasticities are reported only for the variables that give statistically significant (at the 10 percent level or higher) coefficients in the regression analysis. Let us examine the factors that affect the unit costs and the performance of irrigation projects.

[27] The details of the regression analysis are presented in Appendix B.

[28] Elasticity in table 13 shows the ratio of the incremental percentage change in the dependent variable with respect to an incremental percentage change in an explanatory variable. For example, a 10 percent increase in the project size brings about a 6.79 percent decrease in the total unit cost, while all other variables are held constant.

TABLE 13.
Derived elasticities of unit total cost, unit hardware cost, project size, and EIRR.[a]

| Explanatory variable | Dependent variable | | | |
|---|---|---|---|---|
| | Unit total cost (1) | Unit hardware cost (2) | Project size (3) | EIRR (4) |
| Transformed[b] | | | | |
| Project size | -0.679 | -0.726 | | 0.319 |
| Average size of systems | | -0.447 | 0.478 | -0.043 |
| Year project started | | | 1.016 | |
| Bank input for supervision | 0.118 | 0.096 | | -0.147 |
| Number of project components | | | -0.282 | -0.270 |
| Share of government funds | -0.193 | -0.195 | 0.382 | |
| Share of software components | | -0.188 | | |
| Annual rainfall | | | -0.272 | 0.160 |
| GDP per capita | 0.251 | 0.205 | | -0.407 |
| PPP ratio | 0.099 | 0.104 | | |
| Not transformed[c] | | | | |
| Cost overrun | 0.006 | 0.006 | 0.025 | |
| Sizing error | | 0.002 | -0.001 | |
| Farmers' contribution | | | | 0.185 |
| Conjunctive use of water | | | 0.698 | 0.181 |
| Multi-sector project | -0.507 | -0.575 | -0.663 | |
| New construction with land opening | 0.806 | 0.808 | -0.829 | |
| New construction from rainfed | 0.730 | 0.710 | -0.693 | -0.220 |
| New + rehabilitation | 0.610 | 0.597 | -0.646 | |
| Rehabilitation + new | 0.306 | 0.328 | | |
| River-dam-reservoir | 0.235 | 0.226 | | |
| Tank | | | -1.037 | |
| Drainage/flood control | -0.364 | -0.372 | | |
| Government with farmers group | | | | 0.255 |
| Farmer-managed system | -0.377 | -0.441 | 0.630 | 0.328 |
| Tree crops | | | -1.064 | 0.383 |
| Vegetables | -0.375 | -0.408 | -0.935 | 0.472 |
| Fodder | -0.591 | | | 1.247 |
| AfDB | | | -0.830 | |
| IFAD | | | | -0.863 |
| East Asia | 0.339 | 0.408 | | 0.516 |
| Latin America and the Caribbean | | | | 0.421 |
| Middle East and North Africa | | | -1.271 | 0.411 |
| Sub-Saharan Africa | | | -1.680 | 0.575 |

*Notes:* [a] Derived from the regression equations in Appendix 1, Table A5. For continuous variables, elasticities are estimated at their means, and for binary variables, setting the variable unity. Elasticities are shown only for the variables that give significant coefficients in regression estimation. For details of estimation, see the Appendix 2 of this paper.

[b] The variables transformed in the regression estimation. For details, see the Appendix 2.

[c] The variables not transformed in the regression estimation. For details, see the Appendix 2.

**Project Size:** Among the factors analyzed, the project size, as measured by the total irrigated area benefited by a project, is shown to be the most important factor influencing the unit costs (regressions (1) and (2)).[29] The project size elasticity of unit total cost is estimated to be – 0.7: the larger the project size, the lower the unit cost of irrigation projects. It should be noted that, in terms of magnitude, the project-size elasticity for both unit total cost and unit hardware cost is largest among the continuous variables included in the analysis.

Such a significant scale economy of the project size could be attributed primarily to engineering economies of scale in formulating and implementing irrigation projects. 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, a scale economy 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 scale economy that dominates in irrigation projects suggests the very high importance of these scarce inputs.

This significant cost-reducing effect of project size holds firm across purpose (new construction or rehabilitation), location, and performance (success or failure). Having a substantial project area to be developed could mean a greater opportunity to take advantage of this economy of scale.

The EIRR regression reveals that the project size is also the most important factor determining the performance of irrigation projects (regression (4)). The larger the total project area, the higher the probability of project success or the larger the expected economic returns. This result confirms the earlier findings of Jones (1995: 70-72) that "big projects just do better than small projects." Since the unit project cost is a critical determinant of the EIRR of a project, it is expected that the project size has a significant impact on project performance through reducing the unit project cost. Some reports have argued that the performance of both large and small irrigation projects has been poor while success cases were observed for both types of projects; therefore the scale of operation appears less important in determining the success of the project than how it is managed (e.g., Rosegrant and Perez 1995; Brown and Nooter 1992; Adams 1990). How projects are managed must be important, but our analysis indicates that, as far as the scale of irrigation projects is concerned, it is definitely the case that "big is beautiful."

**Average Size of Systems within Irrigation Projects:** Though only in the total hardware cost regression (regression (2)), the impact of this variable on the unit hardware cost is negative: the larger the average size of systems, the lower the unit hardware cost. This variable is strongly associated with project size (regression (3)). Such results suggest that the negative relationship between this variable and the unit hardware cost is due mostly to the fact that the average size of systems is larger in larger-sized projects. That is, the lower unit hardware cost is associated with the economies of scale.

However, in spite of the hardware-cost-reducing impact, the average size of irrigation systems has a significant performance-reducing impact (regression (4)). This result implies that the smaller the size of irrigation systems within a project, the better the expected project performance. One possible explanation for this seemingly contradictory result is the management advantage in smaller systems

[29] The test values for the project size in the original regression are extremely large (see Appendix A, table A5), indicating the high degree of importance the project size has.

compared to larger ones. With potentially fewer farmers to coordinate within each system compared with large systems, smaller systems would be relatively easier to manage. The better economic performance is attributed to better management (ADB-PEO 1995). This finding suggests that irrigation projects should be carefully designed so as to maximize the complementary factors making small systems more effective. This result is not inconsistent with the finding on project size pointing to the economies of scale in larger projects. However, it suggests that at the system or scheme level, management factors appear to be more important than scale. Box 1 features a large irrigation project in SSA with small systems.[30]

**Year Project Started:** As observed earlier, the unit total cost of irrigation projects shows a declining time trend and their performance an increasing time trend (figures 2 and 4). Contrary

**Box 1. Nigerian National Fadama Development Project: An Example of a Large Investment Project Building Small-Scale Irrigation Schemes**

Supported by a World Bank loan of US$67.5 million (out of a total cost of US$104 million), this project was intended to assist in the construction of about 50,000 tubewells in wetland areas with high groundwater tables (*fadama*) including the provision of low-cost petrol pumps, construct other supporting infrastructure to improve marketing of produce, organize farmers for irrigation management and better access to marketing services, improve drilling and other technologies, and carry out a number of environmental and other studies. The project therefore represents a relatively large investment project intended to irrigate 50,000 ha through small-scale technologies and small-scale irrigation systems; and because the investment included other support structures such as roads and storage facilities, it also represents a multi-purpose project in which irrigation was a central component.

The Implementation Completion Report (World Bank 2000) concludes that in spite of a number of management problems, the project “substantially achieved its objectives” on most dimensions and “established the viability of a full cost recovery Fadama Development Program in Nigeria” (page ii). Impact studies revealed that in some states farmers’ returns per ha increased by 65 to 500 percent depending on the crop grown, new technologies and crop varieties were adopted, and most families had improved their incomes and used their profits to purchase capital goods, improve their homes, and send their children to school. The re-estimated economic rate of return of 40 percent exceeded the appraisal estimate of 24 percent.

IWMI sponsored a study on the impacts of the project on poverty (summarized in van Koppen et al. 2005: 46-52). This study confirmed the overall positive impacts of the project, though they were less dramatic than reported by the World Bank. Not surprisingly, the World Bank and others have continued to support the Nigerian Government in implementing further fadama development projects.

References: van Koppen et al. 2005; World Bank 2000.

[30] If we take projects in the whole 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). If we lower the cut-off for project size to 10,000 ha, the National Fadama Development Project in Nigeria would qualify as a “large project (with a total irrigated area of about 30,000 ha) with small systems.” Other examples in South Asia and Latin America using this definition 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.

to these observations, the impact of the year the project started is not significant in either the cost regression or the EIRR regression. Once the impacts of other factors are accounted for, time does not have any significant impact on project performance or unit costs, unit total cost and unit hardware cost. This means that the observed time trends have been brought about not by time *per se* but by other factors. Instead, this variable has a positive elasticity in the project-size regression. So, increases in project size over time, among others, may have contributed to lowering unit project costs and improving project performance.

**Bank Input for Supervision:** This variable, which is defined as the number of weeks spent by the staff members of donor agencies for project monitoring and supervision, gives a positive impact on the unit costs and a negative impact on the project performance: the larger the bank input for supervision, the higher the unit costs and the lower the project performance. It should be noted that this variable may suffer from the simultaneity problem; the causality between this variable and the performance (or the level of the unit costs) of a project goes either way.[31] The bank 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 donor agency spends more staff time on the project. The data reveal that the former is actually the case.

**Number of Project Components:** We expect that the number of project components captures the degree of project complexity. This variable has no significant impact on the unit costs, but it has a negative impact on EIRR. The project size regression shows that this variable is associated with lower project size. These findings seem to suggest that irrigation projects must be formulated in such a way that scarce resources related to the project management are not dissipated by too much project complexity.

**Share of Government Funds:** The contribution of government funds to the total investment is shown to have a negative impact on the unit costs: the higher the share of government funds in the total investment, the lower the unit project costs.[32] This result is of interest, since it is related to a heated controversy. There have been many arguments revolving around the roles and impacts of government funds in development projects funded by foreign donors.

Roughly speaking, two schools of thought can be distinguished: one school may be called the 'inefficient-government hypothesis,' and the other school the 'efficient-government hypothesis.' Proponents of the inefficient-government hypothesis insist that the governments of developing countries are less efficient in using their own resources due to lack of transparency and accountability, graft, corruption, etc. (David 2000; Muthee and Ndiritu 2003). Also, the lack of counterpart funds has been cited in many project reports as a major bottleneck in implementation. In contrast, proponents of the efficient-government hypothesis point out that governments in developing countries, though having many problems, have an incentive to use their own funds more carefully than ODA funds. The higher government contribution in project funding leads governments to higher efficiency in the use of public funds through the sense of greater ownership and commitment (Bruns 1997; Jones 1995).[33]

[31] It should be noted that the exclusion of this variable alters little the results of the regression analyses in this section. This suggests that the bias due to the simultaneity, if any, is not large.

[32] The inclusion of this variable in the regression also creates the problem that a variable appears on both sides of a regression equation, as the case of the unit costs and the project size. We include this variable in the analysis, because it is of interest. In doing so, we examined carefully whether or not its inclusion results in changes in the regression results, and find the results are altered little.

[33] Based on this hypothesis, international donor agencies have recently been promoting the policy of increasing counterpart funding, purportedly to share the financial "burden" and improve project performance and sustainability (Bruns 1997; Jones 1995).

The results of the cost regression seem to provide empirical support to the efficient-government hypothesis. However, it must be noticed that this variable has no significant impact on project performance, as if to counterbalance the two schools.[34]

**Share of Software Components in Total Project Investment:** The software components in irrigation projects include such components as engineering management, technical assistance, agriculture support, institution building, training of the agency staff and beneficiary farmers. An important trend in the history of irrigation projects in developing countries since their 'big-bang' in the early 1970s has been an increasing recognition of the importance of the software components as opposed to the hardware, or engineering components, for the success and sustainability of the projects. We have observed a positive trend over time of the share of the investment in software components in the total investment (table 5).

It is interesting to see that this variable has a negative impact on the unit hardware cost. Such a result provides empirical support to counteract the claim that investments in such non-essential, non-engineering components as beneficiary participation and technical assistance necessarily increase the unit cost of projects. More investments in software components can mean improvements in project management/ implementation, and better management of irrigation systems constructed/ rehabilitated in the post-project phases, through improved skills and capacities of the implementing agency staff and farmer-beneficiaries. It should be noted, however, that the empirical support our study provides in this respect is partial. This variable shows no significant impact on the EIRR regression: our data neither negate nor establish the positive link between the software components and the project performance.

**Annual Rainfall:** We take annual rainfall in the area where an irrigation project is situated as a proxy measure of water availability for the project. This variable has no significant impact on project costs. However, it does have an impact on performance: the more the annual rainfall, the higher the project performance. Such a result may suggest that there exists a causal link between the amount of rainfall and the project performance via more water availability and easier access to water sources. In this respect, it is interesting to observe that the annual rainfall has a negative association with the project-size regression. This means that irrigation projects in areas with higher annual rainfall tend to be smaller in project size, with relatively less need to install large facilities to collect and store water.

**Macroeconomic Factors:** Real GDP (Gross Domestic Product) per capita, is another factor which increases the unit costs. The result indicates that wealthier countries tend to have more expensive irrigation projects. The same variable, consistently, gives a negative impact on the project performance: the project performance tends to be lower in higher-income countries. It should be noted that the elasticities are relatively large. In particular, the elasticity of EIRR for GDP is the largest among the continuous variables used in the analysis.[35]

A few reasons for such results can easily be suggested. First, we note that as economies develop, wages tend to be higher. Labor being a substantial cost component of irrigation projects, especially for those with heavy physical construction, higher wages mean higher project costs. Higher wages in high-income countries should induce labor-saving construction technology to substitute labor for capital, but such substitution is insufficient to cancel out the increase in wage rate.[36] Second, another possible reason is that wealthier countries tend to have

[34] To be confident in this respect, a better understanding is necessary of the process by which government funds are committed for and spent in irrigation projects.

[35] The stability of the estimated results for this variable across different regression models is second highest, only after the project size.

[36] As any observer of irrigation projects would agree, the degree of difference in construction technology adopted in irrigation projects between high- and low-income countries is far less than the degree of difference in the wage rate between these two groups of countries.

more expensive irrigation projects because they can afford them. As economies develop, the agriculture sector's contribution to the economy declines. This process usually accompanies an increasing income as well as productivity disparity between the agriculture and non-agriculture sectors, the former being left behind. Such a situation, almost without exception, makes agricultural protectionism politically attractive: farmers in high-income countries have more influence in getting their governments to respond to their demands for government support and subsidies. The implementation of apparently high-cost, low-performance projects is justified on the ground of protecting 'disadvantaged' farmers rather than on economic merits or objectives of increasing food production and facilitating growth in agriculture.

PPP (purchasing power parity) ratio, defined in this study as the ratio of the PPP conversion factor to the official exchange rate, shows a positive impact on the unit costs. An increase in this variable for a country means that the local currency of the country becomes cheaper relative to the US dollar.[37] With a cheaper local currency, imported goods become more expensive. Since irrigation projects rely on many imported goods, a higher PPP ratio results in higher unit costs. The results of our estimation reveal that this causal chain is at work. In spite of this cost-increasing impact, however, no significant impact on the project performance is observed for PPP ratio.

**Planning, Design and Implementation of Projects:** Time overrun, cost overrun and sizing error can be used as measures of poor project planning, inadequate project design, and deficient project implementation, all of which are likely to increase the unit costs. Among these factors, cost overrun reveals a positive impact in the cost regressions.[38] Sizing error also shows a positive impact on the total hardware cost. However, the impact of these factors on the unit costs is not so large, which might be a reason why the EIRR regression finds these factors giving no significant impact on the project performance.

To know the nature of cost overrun and sizing error, it may be of interest to note that these factors are significantly correlated with project size. It is understandable that cost overrun is positively correlated with project size. Intriguing is that smaller project size is associated with larger sizing error. This seems to suggest that smaller projects are not necessarily better planned than larger projects.[39]

**Farmers' Contribution to Project Funds:** Whether or not farmer-beneficiaries contribute to project funds does not affect the unit costs, but it does affect project performance. As indicated by its positive time trend (table 5), 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 greater sense of ownership among the beneficiaries of irrigation systems constructed/rehabilitated by the project, and thereby to result in more sustainable projects, while reducing the financial burden of the implementing agencies. The evaluations of this policy have shown that farmer contribution leads to more successful participatory processes and greater successes of

[37] This PPP ratio is written as PPP ratio = (PPP conversion factor/official exchange rate), where the numerator and the denominator are both in terms of local currency unit per US dollar.

[38] In the literature, various reasons for cost overruns are enumerated: (a) changes in design and scope, (b) fluctuations in prices and supplies, (c) misallocation of materials, labor and equipment, (d) construction delays, (e) delays in payments by implementing agencies to contractors, and (f) unforeseen repairs and remedial works (Frimpong and Oluwoye 2003; Flyvbjerg et al. 2002; Nijkamp and Ubbels 1999; Adams 1997; Dlakwa and Culpin 1990; Arditi et al. 1985). Basic factors underlying these reasons are poor planning, inadequate design, and deficient implementation of projects.

[39] One potential complication which can increase sizing error is when the technical design of a project is done as a part of implementation rather than project preparation. If detailed designs are done in the preparation stage, it is likely that the appraisal command area will be more accurate and there will be less discrepancy between planned and actual area. There have been projects which do the detailed design only at implementation stage as a strategy to fast-track project approvals. There are cases in recent projects in which detailed design is deliberately done as a part of implementation as a strategy to increase beneficiary participation and 'buy-in, ' i.e., commitment. An example of such a project is the Southern Philippines Irrigation Sector Project funded by the Asian Development Bank.

irrigation projects (Bruns 1997). The result in this study confirms these earlier findings, and supports a policy that encourages farmers to contribute to the project cost, on the grounds that it serves as an incentive to using the investment funds more effectively for farmers' needs and priorities.

**Conjunctive Water Use:** *Ceteris paribus*, conjunctive use of surface water and groundwater certainly provides better water availability to farmers. A typical case of conjunctive 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. As shown in table 3, such projects account for over one-third of the entire sample. The result of our analysis shows that, though having no significant impact on unit costs, conjunctive water use improves the project performance significantly.

**Type and Purpose of Project and Type of System:** Among different types of irrigation project, multi-sector projects (MSPs), such as integrated rural development projects, have significantly lower unit costs than 'irrigation' projects. Irrigation development implemented as a component of MSPs is smaller in size, as shown by the project size regression. It appears that the diseconomy associated with small project size is overcome in the case of MSPs by their larger project size, not in terms of irrigated area but in terms of total investment including many other sector components, which would command significant economies of scale. As is well known, there are many factors that make it difficult for this type of projects to succeed (e.g., ADB-PEO 1995). The fact that the lower unit costs due to MSPs does not result in significantly higher project performance may be because of these difficulties inherent in MSPs.

It is certainly the case that unit costs are higher for irrigation projects with heavier construction components. Among the purposes of irrigation projects, the requirement for construction work would decrease from the heaviest new construction projects with land opening to the lightest rehabilitation projects in the order listed in table 1. The result of the regression analysis shows that the unit costs decrease exactly according to this order. It is also shown that new construction projects are smaller in project size than rehabilitation projects and that the performance of new construction projects converting rainfed fields into irrigated ones is lower than rehabilitation projects.

Among the types of irrigation systems involved in projects, irrigation systems with dams and large storage capacities have significantly higher unit total costs while drainage/flood control systems have significantly lower unit costs than simple river-diversion systems. Given the heavier construction requirements for a dam and a reservoir, the higher unit costs for river-dam-reservoir systems are expected. Flood control systems, such as recession irrigation systems, and drainage systems such as polders, require far less complicated structures, and therefore their unit costs are lower.

**Mode of O&M and Farmers' Participation:** As shown earlier (table 5), steady shifts in the mode of O&M in irrigation systems have been observed from 'government agency alone' to 'government with farmers' and 'farmer-managed system.' Indeed, the participation of farmers in irrigation projects and system management through establishing water users' associations (WUAs), or participatory irrigation management (PIM) has been central to the efforts made in the irrigation sector to improve project performance and the sustainability of irrigation systems in the last three decades.

The project cost regressions show that projects with farmer-managed systems have significantly lower unit costs than projects with government agency-managed systems. It is said that the mode of O&M is a good proxy for project design and selection of technologies for irrigation systems. Deeper involvement of farmers in projects makes it possible for projects to adopt tailor-made, appropriate technology fitted to farmers' real needs, which 'rationalizes' the project costs (Bruns 1997). It should be noted that projects intended for farmer-managed systems are not necessarily small-sized projects. On the contrary, the project size regression reveals that projects with farmer-managed systems are positively associated with the project size.

Our analysis also reveals that compared to systems managed by government agency alone, systems managed jointly by government agency and farmers' organizations, and farmer-managed systems, perform significantly better. It is interesting to notice that the EIRR elasticity is larger for farmer-managed systems than for systems managed jointly by government agency and farmers' organizations. There have been mixed results from experiences with PIM and irrigation management transfer (IMT) in SSA as well as in other regions (Penning de Vries et al. 2005; Shah et al. 2002; Abernethy and Sally 2000; Jones 1995). Our findings in this respect provide general support for the new paradigm of PIM. In particular, with farmer-managed systems costing less and performing better, there are good reasons to promote investments in this type of systems.

**Type of Crops Irrigated:** For the major irrigated crops, vegetable and fodder systems are cheaper to construct than rice systems. Their project performance is also consistently better than rice systems. Tree crop systems, though no unit cost-reducing impact is found, also perform better than rice systems. These results are consistent with an earlier observation by Jones (1995) that unit costs for rice systems are higher than for other systems. This difference arises because they require very different infrastructure. The water requirement of other crops, which need intermittent irrigation with such devices as sprinkler and drip irrigation, is much less than that of rice, which usually needs continuous irrigation with canals, ditches and water gates. The less physical infrastructure-demanding nature of these systems may be reflected in the fact that projects to construct/rehabilitate them are significantly smaller in project size.

In addition to the lower unit costs, better price prospects for fruits, vegetables, and livestock products that use fodder contribute to higher project performance of these systems as compared to rice systems. 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, resulting in the historic low profitability of rice production during the last two decades in developing countries. In contrast, price prospects are much better for fruits, vegetables and livestock products, the demand for which increases as the economy develops. Systems that irrigate such high-value crops enjoy higher project performance for higher profitability of crops irrigated. Though the number of projects of this type is still small, there is growing evidence of successful experiences for these systems in many regions including SSA.[40]

**Regional Effects:** The most important result of the cost regression is that the coefficient of SSA dummy is not statistically different from zero. This means that, once the factors that have been observed as having significant impacts on the unit costs are accounted for, no significant difference in the unit costs is found between SSA and South Asia, which is on average cheapest among the regions.[41] Our regression analysis thus rejects the popularly-held view that irrigation projects in SSA are inherently more expensive.

[40] Many observers report success in irrigation projects growing high-value crops in SSA and elsewhere (Diao et al. 2003; Dijkstra 2001; Minot and Ngigi 2003; Blank et al. 2002; Penning de Vries et al. 2005; Sally and Abernethy 2002; Tiffen 2003).

[41] South Asia is used as the base region in the regression analyses. The cost regressions show that, even after accounting for other factors, the cost of irrigation development in East Asia (EA) is significantly more expensive compared to SA. This suggests that the higher unit costs in EA have to be explained by some region-specific factors not included in our regression analysis. Except for EA, the difference in the unit costs between SA and all other regions, including SSA, is not statistically significant.

Similarly, the EIRR regression shows that all the regional dummies have a significant, positive coefficient, except for SEA. *Ceteris paribus*, the project performance in all other regions except SEA is better than in SA. It is noteworthy that the coefficient of the SSA dummy is largest in magnitude. Our regression analysis again rejects the popularly-held view that irrigation projects in SSA have less potential to perform better than those in other developing regions. If irrigation projects in SSA perform poorly, there are good reasons for this. Once the factors causing poor performance are overcome, the performance in SSA could even be better than in other regions.

## Cost and Performance of Irrigation Projects in SSA and Non-SSA

The comparison between SSA and non-SSA in terms of the simple average of unit costs (table 6) and of EIRR (table 4) is consistent with the popularly-held views that irrigation projects in SSA are more expensive and perform less satisfactorily. But contrary to the popular view, our regression analysis confirms that projects in SSA are not inherently more expensive and they actually perform better than those in other regions.

Looking at tables 3, 4 and 13, we can infer that projects in SSA are more expensive because the project size, the average size of system, the share of government funds and the share of farmer-managed systems are smaller, and sizing error and the share of new construction projects are larger, than in non-SSA. Likewise, projects in SSA appear to perform more poorly because the project size and the annual rainfall are smaller and projects with conjunctive use of water and with farmer-managed systems are fewer in number than in non-SSA. In particular, the extremely small size of irrigation projects has made project costs in SSA higher and the project performance poorer as compared to other regions. As indicated in table 7, the unit cost of SSA projects is high because the probability of failure is high in SSA. The smaller the project size, the higher the probability of project failure. *To a large extent, the small size of SSA projects is a major cause of higher cost and poorer performance, indirectly as well as directly.*

Table 9 tells us that the difference in the unit total cost of irrigation projects between SSA and non-SSA has been reduced over time and becomes insignificant in recent decades. This table also shows that, on average, the unit total cost decreased drastically over time. Similarly, table 10 reveals that the difference in EIRR between SSA and non-SSA has been reduced and becomes insignificant in recent decades, and that the improvement over time in EIRR in SSA has been statistically significant. Can our regression analysis identify what factors have brought about such trends?

Examination of time trends in table 5 in comparison with table 13 verifies that, in SSA, the decreasing trend of cost overrun and sizing error has contributed to reducing unit costs. Underlying these trends are improvements over time in the design, planning and implementation of irrigation projects. Similarly, decreases in the number of project components, representing simpler and more specified irrigation projects in recent years, have contributed to improving EIRR. There has been a tendency in SSA that irrigation projects implemented in recent years are situated in areas with more rainfall than those in earlier years, which has contributed to lowering the unit costs. Decreases in PPP would also have worked in favor of lowering unit costs, while increases in the number of systems with conjunctive water use may have improved project performance.

More impressive is the trend in software-related factors. The emphasis on software aspects of projects and participatory approaches to irrigation management in recent years has been equally apparent in both SSA and elsewhere. All the software-related factors, i.e., the share of software components in total investment cost, the share of systems with O&M by government agency with farmers (WUA), the share of farmer-managed systems and farmers' contribution to project funds, are increasing over time in non-SSA. All of these factors are shown to be increasing over time in SSA as well, except for the share of farmer-managed systems.

Increases in all of these variables have contributed to reducing the project cost and enhancing the project performance.

Most of the factors that have contributed to reducing unit costs and/or to improving project performance in SSA are common in non-SSA. In addition to the common factors, non-SSA has some more factors that have worked for betterment of irrigation projects over time. The most important of these is project size, which shows a highly significant positive time trend for non-SSA, but not for SSA. Since the degree of impact of project size on EIRR as well as on unit costs is large, this trend has contributed substantially to reducing unit costs and improving EIRR in non-SSA.

For non-SSA, furthermore, significant increases in the share of multi-sector projects (MSPs) and the share of tree crop (fruit) systems, and significant decreases in the share of new construction projects and river-dam-reservoir systems has contributed to lowering the unit costs and improving project performance. No time trend is observed for these variables in SSA. Noteworthy for SSA are considerable increases in the latest decade of the share of vegetable systems. Since the elasticity of this variable is relatively large for both the unit costs and EIRR, the increase in vegetable systems has had substantial impacts in lowering the unit costs and improving project performance in SSA.[42]

Altogether, the factors that have brought about the reduction of costs and performance improvements of irrigation projects are more clearly identified in non-SSA than in SSA. In reality, however, the difference in unit costs and project performance between SSA and non-SSA has narrowed. This suggests that the degree and speed of improvements in irrigation projects in SSA have been deeper and faster than in non-SSA.

# Summary of Findings and Recommendations

## Summary of Findings

Using a database consisting of 314 irrigation projects implemented in developing countries all over the world over the last four decades, we have examined the cost of irrigation projects with special reference to the popular view that irrigation projects in SSA are more expensive than those in other developing regions. The findings of our study are summarized as follows:

1. The popular view that irrigation projects in SSA are more expensive than those in other developing regions is not groundless. In terms of simple averages for the entire sample of projects implemented in developing countries during 1965 to 2000, the average unit total cost for new construction projects is US$14,500/ha in SSA and US$6,600/ha in non-SSA. For rehabilitation projects, the average unit total cost is US$8,200/ha in SSA and US$2,300/ha in non-SSA. The cost differences between SSA and non-SSA are all statistically significant.
2. However, the cost difference between SSA and non-SSA disappears, if the entire sample of projects is divided into 'success' and

[42] For SSA, there are two variables, the trend of which has been against reducing the unit costs of irrigation projects: the share of government funds and the share of drainage/flood control systems. However, the negative impacts of these variables have been overwhelmed by the positive impacts of the variables mentioned in the text.

‘failure’ projects by using the EIRR at project completion of 10 percent as the breakeven rate. The average unit hardware cost for ‘successful’ new construction projects is US$3,600/ha in SSA and US$3,800/ha in non-SSA, and that for ‘successful’ rehabilitation projects is US$2,300/ha in SSA and US$1,400/ha in non-SSA. The cost differences between SSA and non-SSA are all statistically insignificant. Observations of success and failure projects thus reveal that the high probability of project failure in SSA is largely contributing to the higher average unit costs in SSA compared with non-SSA. As far as success projects are concerned, irrigation projects in SSA are no more expensive than in other regions.

3. More importantly, the cost and performance of irrigation projects have improved over time in both non-SSA and SSA. The unit total cost of irrigation projects has been decreasing and the performance of these projects measured by the EIRR has been increasing. Such improvements in irrigation projects have accompanied a reduction in the probability of project failure. The degree and speed of improvements have been deeper and faster in SSA than in non-SSA, so that the difference in unit cost and project performance between SSA and non-SSA, which used to be significant in earlier decades, has been reduced to the extent that there is no significant difference in the latest decade.

4. Regression analyses to identify factors that affect the cost of irrigation projects confirm that the difference in the unit costs between SSA and all other regions is not statistically significant, once these factors are accounted for. *The popularly-held view that irrigation projects in SSA are inherently more expensive is thus statistically rejected*. Similarly, regression analyses to identify factors that affect the performance of irrigation projects confirm that *ceteris paribus,* project performance in SSA is highest among all the regions. *The popularly-held view that irrigation projects in SSA have less potential to perform well compared to those in other developing regions is also statistically rejected*.

5. The regression analyses reveal the size of projects in terms of the total irrigated area benefited to be the most strategic factor that reduces the cost, and increases the performance, of irrigation projects. The existence of such indivisible factors as capable design engineers and project managers creates a significant scale economy in irrigation projects. A general rule in irrigation projects (but not necessarily irrigation systems) is *big is beautiful*. On average, the project size in non-SSA regions has become larger since the 1960s, which has been an important factor in reducing project cost and increasing project performance over time. In this respect, irrigation projects in SSA are seriously handicapped: the size of SSA projects has been considerably smaller than in non-SSA, and moreover, there has been no increasing trend in size.

6. Although the average size of irrigation systems within a project has a unit-hardware-cost-reducing impact, it also has a performance-reducing impact. This implies that the smaller the size of irrigation systems within a project, the better the expected economic returns. These results on the impact of the sizes of project and irrigation system provide justification for developing many ‘small’ schemes within large projects since these options have reinforcing effects on both unit costs and project performance. *Big projects are better, but big projects supporting small-scale irrigation systems may be best.*

7. Factors related to the effectiveness and efficiency of project design and implementation form a group of factors that have significant impacts on the cost of irrigation projects. Cost overrun, used as a measure of design feasibility and

implementation efficiency, is shown to increase the unit cost of irrigation projects. Reductions over time in cost overrun have helped to reduce the cost of irrigation projects in SSA and non-SSA alike. Also, sizing error, defined as the gap between planned and realized irrigated areas, has a unit-hardware-cost-increasing effect. Significant improvements in this factor over time have contributed to reducing the unit costs in SSA.

8. Another important set of factors having significant impacts on performance as well as cost of irrigation projects is what may be called ‘institution/software related factors’. Typical of these factors is the mode of O&M of irrigation systems after the project. Projects with irrigation systems managed by farmers themselves record better results in terms of project performance and unit costs. Projects with O&M systems shared by the government irrigation agency and farmer-beneficiaries through WUAs, also perform better than those where O&M is done by the government agency alone. Similarly, the higher share of software components in the total investment reduces the unit hardware cost of irrigation projects. Furthermore, projects with farmers’ contribution to the project funding perform better than otherwise.

9. Starting from the campaign to promote irrigation fee payment in the 1970s, the institutional/software aspects of irrigation projects have attracted increasing attention in the irrigation sector of developing countries. The participatory approach has been gaining momentum gradually in the irrigation sector, as in other fields of development. As a result, factors related to these aspects have all shown positive trends over time in both non-SSA and SSA, and have contributed considerably to the reduction in unit costs and the increase in performance of irrigation projects. Altogether, our study provides *prima facie* evidence that the new approach to irrigation projects emphasizing the importance of institutional/software aspects, is indeed a legitimate approach.

10. An increase in the share of government funds in the total project investment has a negative impact on the unit project costs, giving empirical support for the efficient-government hypothesis. This states that higher government contribution in project funding leads the government to higher efficiency in the use of public funds through the sense of greater ownership and commitment.

11. A salient difference in irrigation projects between SSA and non-SSA is that the share of new construction projects is significantly higher in SSA than in non-SSA due to the relatively recent history of irrigation development in SSA. *Ceteris paribus*, this makes the cost of irrigation projects in SSA higher than in other regions. Moreover, the share of new construction projects has been decreasing significantly over time in non-SSA, while there is no such trend in SSA. This difference may have worked to increase the unit costs in SSA relative to those in other regions.

12. For type of irrigation systems, the unit costs are significantly higher for river-diversion systems with major storage capacity, and significantly lower for drainage/flood control systems, as compared to simple river-diversion systems. In non-SSA, the share of irrigation projects for river-diversion systems with major storage capacity has been declining over time, contributing to the reduction in unit costs, while in SSA the share of drainage/flood control systems has been declining, contributing to the increase in unit costs.

13. The unit costs of irrigation components implemented as a part of multi-sector projects, such as integrated rural development projects, are lower than in ordinary irrigation projects. In non-SSA, the relative share of this type of irrigation project increased in the 1990s, as the

number of ordinary irrigation projects shrank. This change is a factor that has contributed to the decline over time in the unit costs outside SSA.

14. Irrigation projects that adopt conjunctive use of surface water and groundwater perform better than otherwise. The number of projects with conjunctive use has a positive time trend both in SSA and non-SSA. As such, increases in the conjunctive use of water should have contributed to the improvements in the project performance over time.

15. The cost and performance of irrigation projects differ according to the crops grown. Systems designed for staple cereals, especially rice, tend to have higher unit costs and lower performance than systems designed for such crops as fruit trees, vegetables and fodder. On one hand, demand for irrigation infrastructure, such as dams, reservoirs, sluices, and canals, is heavier for traditional staple crops than systems for non-cereal modern crops, which require much lighter infrastructure. Further, the price of cereals has been declining sharply since the mid-1980s, resulting in worsening profitability relative to crops such as fruits and vegetables, the demand for which increases as the economy develops. Tree crop systems in non-SSA and vegetable systems in SSA have been increasing significantly, contributing to lowering the unit costs or enhancing the project performance, or both, over time.

16. Among the macroeconomic factors examined, real GDP per capita is a significant factor which increases unit costs and reduces project performance. Wealthier countries tend to have more expensive irrigation projects, since they can afford to do so. The PPP also tends to increase the unit costs, through increasing the prices of imported commodities. For the sample irrigation projects in SSA as well as in non-SSA, there has been no significant time trend in the real GDP per capita, indicating that there has been no bias in implementing irrigation projects either in higher income or lower income countries. In contrast, the PPP ratio has a significant negative time trend indicating a shift towards currency undervaluation in all regions. With a positive elasticity, the downward trend in the PPP ratio over time is consistent with the observed downward movement in unit costs over time.

17. Finally, we note the lack of research in SSA on the poverty impacts of irrigation investments. This is in contrast with Asia, where there is a growing literature (e.g., Hussain 2005). Nor are there sufficient data available as a basis for such research in SSA. In fact, this study wanted to capture some aspects of poverty impacts but could not due to insufficient data from project documents. Given the importance of achieving the MDGs in Africa, and the unsupported assumptions often made about the poverty outcomes of irrigation investments, it is critical to fill this gap with a large-scale research program combining qualitative and quantitative approaches. This research needs to include newer types of projects promoting individualized micro-agricultural water management technologies as well as more conventional irrigation projects.

## Recommendations

Our recommendations, addressed to governments and investors in sub-Saharan Africa, emerge very clearly from the findings of this study, as follows:

1. Under the right conditions, irrigation investments in SSA can provide good returns and therefore have significant impacts on poverty reduction and agricultural growth. As a part of a larger package of investments in support of CAADP, irrigation investments make sense in many instances.

2. Governments and investors should seek to develop relatively large investment projects, and avoid small projects, as there are significant economies of scale in irrigation projects. This is not a problem for large countries. To be more effective in assisting smaller countries, regional projects (which may include large countries as well) may offer a way to achieve important economies of scale and synergies among countries as well.

3. In general, governments and donors should focus on developing small-scale irrigation systems as they offer significant performance advantages over large-scale systems. Given that Africa has few large flat irrigable areas, this recommendation may be especially relevant in SSA. Therefore, large investment projects supporting many small-scale irrigation systems are likely to lead to the best results.

4. Both the software and hardware components of irrigation projects are critical. However, underinvesting in software can lead to significantly higher costs and lower performance. We recommend investing in good planning, design, project management, and supervision, combined with effective training, capacity building and institutional development among future users and managers.

5. We recommend maximizing farmers' effective involvement in all stages of irrigation system development and management, from the beginning. Maximizing farmers' contributions to the development of their systems (consistent with their capacity) combined with farmers taking significant management responsibility for the completed scheme usually results in lower costs and higher performance.

6. We recommend that irrigation be included as a component in multi-sector projects. Clearly, such MSPs must be carefully designed to avoid being overly complex, as this does reduce performance. There is a need to balance the advantages of the economy of scale and the disadvantages of potential complexity in MSPs. But it is very likely that there is a synergy among investments in irrigation and other infrastructure (e.g., roads, communications) that results in higher performance, and it is that synergy that governments and investors should capture.

7. Where conditions are favorable, irrigation systems should be designed to take advantage of the performance-enhancing effects of conjunctive use of surface water and groundwater. This recommendation reinforces the importance of providing a reliable water supply for successful irrigation.

8. We recommend paying careful attention to the issue of types of crops to be grown. Irrigation systems used only for staple crops are often more expensive and have lower performance; a partial exception is rice schemes in some cases. Irrigation systems designed for high-value cash crops are cheaper and show higher returns. This will only be the case where there is access to good markets—another argument for MSPs.

9. Finally, we recommend that donors and governments, under the auspices of NEPAD, sponsor a systematic research program to identify how to optimize the poverty-reduction impacts of irrigation investments in sub-Saharan Africa.

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# Appendix A

**List of sample projects and their characteristics by region.**

TABLE A1.
List of sample projects.

| Project name | Donor | Region | Country | Year project started | Total project area under new construction (ha) | Total project area under rehabilitation (ha) | Total irrigation cost in 2000 prices (million US$) |
|---|---|---|---|---|---|---|---|
| Khairpur Tile Drainage and Irrigated Farming Development Project (Khairpur II) | WB | SA | Pakistan | 1977 | | 17,800 | 32.1 |
| Salinity Control and Reclamation Project IV | WB | SA | Pakistan | 1979 | | 509,490 | 208.0 |
| Salinity Control and Reclamation Project | WB | SA | Pakistan | 1982 | | 50,018 | 177.6 |
| On-Farm Water Management Project | WB | SA | Pakistan | 1982 | | 639,394 | 71.4 |
| Irrigation Systems Rehabilitation project | WB | SA | Pakistan | 1984 | | 3,823,732 | 177.6 |
| Baluchistan Minor Irrigation and Agricultural Development Project | WB | SA | Pakistan | 1984 | 8,798 | | 52.6 |
| Fourth Drainage Project | WB | SA | Pakistan | 1984 | | 119,381 | 75.6 |
| Command Water Management Project | WB | SA | Pakistan | 1985 | | 357,331 | 100.3 |
| Left Bank Outfall Drain Stage I project | WB | SA | Pakistan | 1986 | | 490,065 | 940.8 |
| On-Farm Water Management Project II | WB | SA | Pakistan | 1986 | | 893,726 | 93.4 |
| SCARP Transition Pilot Project | WB | SA | Pakistan | 1987 | | 46,336 | 5.6 |
| Second Irrigation Systems Rehabilitation | WB | SA | Pakistan | 1990 | | 4,810,000 | 120.5 |
| On-Farm Water Management Project III | WB | SA | Pakistan | 1992 | | 885,827 | 144.9 |
| Second SCARP Transition Project | WB | SA | Pakistan | 1992 | | 540,978 | 23.9 |
| Fordwah Eastern Sadiqia (South) Irrigation and Drainage Project | WB | SA | Pakistan | 1993 | | 105,000 | 54.4 |
| Balochistan Community Irrigation and Agriculture Project | WB | SA | Pakistan | 1996 | 1,425 | 2,902 | 33.2 |
| Birganj Irrigation Project - Narayani Zone | WB | SA | Nepal | 1974 | 18,710 | | 15.8 |
| Bhairawa-Lumbini Groundwater Project | WB | SA | Nepal | 1977 | 5,760 | | 22.2 |
| SUNSARI MORANG Irrigation and Drainage Project | WB | SA | Nepal | 1979 | | 9,750 | 44.6 |
| Narayani Zone Irrigation and Development - Stage II Project | WB | SA | Nepal | 1978 | 12,700 | | 20.0 |
| Mahakali Irrigation Project | WB | SA | Nepal | 1981 | 2,100 | 2,700 | 21.7 |
| Babai Irrigation Engineering Project | WB | SA | Nepal | 1982 | 13,500 | | 4.1 |
| Bhairawa Lumbini Groundwater Management | WB | SA | Nepal | 1983 | 7,778 | | 22.7 |
| Narayani III Irrigation Project | WB | SA | Nepal | 1988 | 24,500 | | 23.8 |

(Continued)

TABLE A1. (Continued)

List of sample projects.

| Project name | Donor | Region | Country | Year project started | Total project area under new construction (ha) | Total project area under rehabilitation (ha) | Total irrigation cost in 2000 prices (million US$) |
|---|---|---|---|---|---|---|---|
| Khairpur Tile Drain | | | | | | | |
| Sunsari Morang Irrigation II Project | WB | SA | Nepal | 1988 | | 26,450 | 37.9 |
| Mahakali Irrigation II Project | WB | SA | Nepal | 1989 | 9,900 | 100,000 | 43.6 |
| Sunsari Morang Headworks Project | WB | SA | Nepal | 1993 | | 57,900 | 17.5 |
| Bhairawa-Lumbini Groundwater Irrigation III Project | WB | SA | Nepal | 1991 | 40,245 | 5,760 | 55.1 |
| Kadana Irrigation Project | WB | SA | India | 1971 | 80,540 | | 421.1 |
| Pochampad Irrigation Project | WB | SA | India | 1972 | 75,000 | | 530.5 |
| Chambal Command Area Development Project (Rajasthan) | WB | SA | India | 1975 | | 197,000 | 136.7 |
| Chambal Command Area Development Project (Madhya Pradesh) | WB | SA | India | 1976 | | 222,635 | 59.8 |
| Rajasthan Canal Command Area Development Project | WB | SA | India | 1974 | 136,000 | 108,000 | 243.7 |
| Godavari Barrage Project | WB | SA | India | 1975 | | 400,000 | 112.4 |
| West Bengal Agricultural Development Project | WB | SA | India | 1977 | 86,100 | | 77.7 |
| Andhra Pradesh Irrigation and CAD composite Project | WB | SA | India | 1978 | | 560,764 | 240.0 |
| Periyar Vaigai Irrigation Project | WB | SA | India | 1978 | 17,100 | 63,200 | 62.2 |
| First Maharashtra Composite Irrigation Project | WB | SA | India | 1979 | 87,000 | 30,000 | 246.4 |
| Karnataka Irrigation Project | WB | SA | India | 1980 | 97,330 | 69,900 | 553.4 |
| Orissa Irrigation | WB | SA | India | 1979 | 60,000 | 57,000 | 136.9 |
| Gujarat Medium Irrigation Project | WB | SA | India | 1979 | 134,400 | 33,600 | 406.2 |
| Punjab Irrigation Project | WB | SA | India | 1980 | | 1,200,000 | 371.7 |
| Haryana Irrigation Project | WB | SA | India | 1979 | | 1,270,000 | 237.5 |
| Uttar Pradesh Public Tubewells Project | WB | SA | India | 1981 | 60,225 | | 44.4 |
| Gujarat Irrigation II Project | WB | SA | India | 1981 | 41,766 | 93,173 | 271.6 |
| Maharashtra Irrigation II Project | WB | SA | India | 1980 | 66,800 | | 582.3 |
| Karnataka Tanks Irrigation Project | WB | SA | India | 1983 | 16,800 | | 69.8 |
| Mahanadi Barrages Project | WB | SA | India | 1982 | | 167,000 | 143.1 |
| Madhya Pradesh Medium Irrigation Project | WB | SA | India | 1982 | 127,617 | | 222.7 |

(Continued)

TABLE A1. (Continued)
List of sample projects.

| Project name | Donor | Region | Country | Year project started | Total project area under new construction (ha) | Total project area under rehabilitation (ha) | Total irrigation cost in 2000 prices (million US$) |
|---|---|---|---|---|---|---|---|
| Kallada Irrigation and Tree crop Development Project | WB | SA | India | 1983 | 12,600 | | 149.7 |
| Madhya Pradesh Major Irrigation Project | WB | SA | India | 1982 | 360,000 | 269,000 | 495.3 |
| Haryana Irrigation II Project | WB | SA | India | 1983 | | 1,270,000 | 242.6 |
| Second Uttar Pradesh Public Tubewells Project | WB | SA | India | 1984 | 385,000 | | 241.2 |
| Chambal(Madhya Pradesh) Irrigation II project | WB | SA | India | 1983 | | 221,000 | 49.4 |
| Maharashtra Water Utilization Project | WB | SA | India | 1984 | | 115,203 | 61.8 |
| Upper Ganga Irrigation Modernization Project | WB | SA | India | 1984 | | 701,000 | 275.1 |
| Periyar Vaigai Irrigation II Project | WB | SA | India | 1985 | 7,500 | 73,600 | 69.5 |
| Gujarat Medium Irrigation II Project | WB | SA | India | 1985 | 279,696 | 60,804 | 471.3 |
| West Bengal Minor Irrigation Project | WB | SA | India | 1987 | 59,500 | | 93.0 |
| National Water Management Project | WB | SA | India | 1988 | | 640,000 | 164.3 |
| Bihar Public Tubewell Project | WB | SA | India | 1988 | | 240,320 | 110.4 |
| Maharashtra Composite Irrigation III Project | WB | SA | India | 1987 | 227,800 | | 344.4 |
| Upper Krishna Irrigation Project (phase II) | WB | SA | India | 1990 | 93,513 | | 694.0 |
| Haryana Water Resources Consolidation Project | WB | SA | India | 1995 | | 2,300,000 | 442.8 |
| Punjab Irrigation and Drainage Project | WB | SA | India | 1990 | 15,000 | 115,719 | 221.5 |
| Chandpur II Irrigation Project | WB | SA | Bangladesh | 1973 | | 31,971 | 91.6 |
| Northwest Tubewell Project | WB | SA | Bangladesh | 1971 | 85,795 | | 81.4 |
| Barisal Irrigation Project | WB | SA | Bangladesh | 1974 | | 103,197 | 51.7 |
| Karnafuli Irrigation Irrigation Project | WB | SA | Bangladesh | 1977 | | 18,333 | 34.3 |
| First Rural Development Project | WB | SA | Bangladesh | 1977 | 10,028 | 15,314 | 11.2 |
| Muhuri Irrigation Project | WB | SA | Bangladesh | 1978 | | 31,200 | 79.2 |
| Shallow Tubewell Project | WB | SA | Bangladesh | 1979 | | 56,657 | 25.1 |
| Drainage and Flood Control Project | WB | SA | Bangladesh | 1980 | 2,833 | 105,625 | 42.3 |
| Small Scale Drainage and Flood Control Project | WB | SA | Bangladesh | 1981 | | 392,000 | 45.6 |
| Low Lift Pump Project | WB | SA | Bangladesh | 1981 | 11,837 | 33,691 | 22.8 |

(Continued)

TABLE A1. (Continued)
List of sample projects.

| Project name | Donor | Region | Country | Year project started | Total project area under new construction (ha) | Total project area under rehabilitation (ha) | Total irrigation cost in 2000 prices (million US$) |
|---|---|---|---|---|---|---|---|
| Drainage and Flood Control II Project | WB | SA | Bangladesh | 1983 | | 59,750 | 29.6 |
| Deep Tubewell II Project | WB | SA | Bangladesh | 1983 | | 97,127 | 102.7 |
| Bangladesh BWDB Small Schemes Project | WB | SA | Bangladesh | 1985 | | 107,789 | 59.3 |
| BWDB Systems Rehabilitation Project | WB | SA | Bangladesh | 1991 | | 253,168 | 72.0 |
| Shallow Tubewell and Low Lift Pump Irrigation Project | WB | SA | Bangladesh | 1992 | | 460,000 | 105.2 |
| Fourth Flood Control and Damage Project | WB | SA | Bangladesh | 1988 | | 48,300 | 20.1 |
| Second Small Scale Flood Control, Drainage and Irrigation Project | WB | SA | Bangladesh | 1989 | 52,812 | 229,842 | 95.9 |
| Sri Lanka Lift Irrigation Project | WB | SA | Sri Lanka | 1969 | 152 | 2,420 | 13.1 |
| Drainage and Reclamation Project | WB | SA | Sri Lanka | 1971 | 1,435 | 3,904 | 10.9 |
| Mahaweli Ganga Development Project Stage I | WB | SA | Sri Lanka | 1971 | 1,983 | 51,275 | 93.5 |
| Tank Irrigation Modernization Project | WB | SA | Sri Lanka | 1978 | 394 | 12,748 | 18.5 |
| Mahaweli Ganga Development Project II | WB | SA | Sri Lanka | 1979 | 13,760 | | 102.4 |
| Village Irrigation Rehabilitation Project | WB | SA | Sri Lanka | 1982 | | 45,555 | 34.3 |
| Mahaweli Ganga Development Project III | WB | SA | Sri Lanka | 1982 | 16,136 | | 198.1 |
| Major Irrigation Rehabilitation Project | WB | SA | Sri Lanka | 1986 | 3,225 | 20,592 | 37.7 |
| National Irrigation Rehabilitation Project | WB | SA | Sri Lanka | 1993 | | 38,380 | 41.7 |
| North China Plains Agricultural Project | WB | EA | China | 1983 | 78,900 | 74,200 | 133.0 |
| Pishihang-Chaohu Area Development | WB | EA | China | 1985 | | 540,000 | 270.4 |
| Northern Irrigation Project - Hetao | WB | EA | China | 1989 | 61,200 | 185,000 | 190.0 |
| Shaanxi Agricultural Development Project | WB | EA | China | 1991 | 117,694 | 12,200 | 224.8 |
| Tarim Basin | WB | EA | China | 1992 | 80,000 | 120,000 | 184.5 |
| HeBei Agricultural Development Project | WB | EA | China | 1991 | 169,478 | 498,276 | 154.8 |
| HeNan Agricultural Development Project | WB | EA | China | 1992 | 96,673 | 160,023 | 95.9 |
| SiChuan Agricultural Development Project | WB | EA | China | 1992 | 20,090 | 135,200 | 249.3 |
| Xiaolangdi Multipurpose | WB | EA | China | 1994 | | 1,860,000 | 1,535.6 |
| Irrigated Agriculture Intensification Project | WB | EA | China | 1991 | 534,400 | 632,500 | 597.0 |
| Songliao Plain Agricultural Development Project | WB | EA | China | 1994 | 35,290 | 11,700 | 106.9 |
| Second Red Soil Area Development Project | WB | EA | China | 1994 | 52,507 | 25,737 | 103.8 |
| Yangtze Basin Water Resources Project | WB | EA | China | 1995 | 24,968 | 660,232 | 415.6 |

(Continued)

TABLE A1. (Continued)
List of sample projects.

| Project name | Donor | Region | Country | Year project started | Total project area under new construction (ha) | Total project area under rehabilitation (ha) | Total irrigation cost in 2000 prices (million US$) |
|---|---|---|---|---|---|---|---|
| Pyongtaek-Kumgang Irrigation Project | WB | EA | Korea | 1970 | 27,730 | | 315.7 |
| Yong San Gang Irrigation Project Stage I | WB | EA | Korea | 1973 | 32,300 | | 329.4 |
| Yong San Gang Irrigation Project Stage II | WB | EA | Korea | 1977 | 16,678 | | 402.8 |
| Miho Watershed Area Development Project | WB | EA | Korea | 1977 | 8,186 | 227 | 177.7 |
| Ogseo Area Development Project Stage I | WB | EA | Korea | 1978 | 1,866 | 8,195 | 125.6 |
| Upper Pampanga River Irrigation Project | WB | SEA | Philippines | 1969 | 32,400 | 46,000 | 281.2 |
| Aurora Penaranda Irrigation Project | WB | SEA | Philippines | 1975 | 1,500 | 16,500 | 79.8 |
| Tarlac Irrigation Systems Improvement Project | WB | SEA | Philippines | 1975 | 4,154 | 22,235 | 61.2 |
| Jalaur Multipurpose Irrigation Project | WB | SEA | Philippines | 1978 | 2,900 | 20,444 | 40.7 |
| Magat River Multipurpose Project | WB | SEA | Philippines | 1976 | 37,650 | 40,350 | 669.9 |
| Chico River Irrigation project | WB | SEA | Philippines | 1977 | 5,500 | 7,500 | 102.7 |
| National Irrigation Systems Improvement Project I | WB | SEA | Philippines | 1978 | 900 | 26,100 | 91.2 |
| National Irrigation Systems Improvement Project II | WB | SEA | Philippines | 1978 | 8,000 | 52,000 | 90.4 |
| Medium Scale Irrigation Project | WB | SEA | Philippines | 1982 | 19,160 | | 61.6 |
| Communal Irrigation Development Project I | WB | SEA | Philippines | 1983 | 19,936 | 25,662 | 72.2 |
| Irrigation Operation Support Project | WB | SEA | Philippines | 1989 | | 621,000 | 64.5 |
| Communal Irrigation Development Project II | WB | SEA | Philippines | 1991 | 15,535 | 34,127 | 52.7 |
| Irrigation Operation Support Project II | WB | SEA | Philippines | 1993 | | 646,000 | 64.8 |
| Muda Irrigation Project | WB | SEA | Malaysia | 1966 | 98,000 | | 345.6 |
| Kemubu Irrigation Project | WB | SEA | Malaysia | 1968 | 19,000 | | 92.2 |
| Western Johore Agricultural Development Project | WB | SEA | Malaysia | 1975 | | 135,000 | 166.7 |
| North Kelantan Rural Development Project | WB | SEA | Malaysia | 1978 | 1,309 | 12,000 | 62.0 |
| National Small-Scale Irrigation Project | WB | SEA | Malaysia | 1978 | | 36,000 | 94.0 |
| Northwest Selangor Integrated Rural Development Project | WB | SEA | Malaysia | 1979 | | 20,300 | 103.7 |
| Krian-Sungei Manik Irrigation Project | WB | SEA | Malaysia | 1980 | | 30,560 | 136.8 |
| Muda Irrigation Project II | WB | SEA | Malaysia | 1979 | | 24,200 | 104.1 |

(Continued)

TABLE A1. (Continued)
List of sample projects.

| Project name | Donor | Region | Country | Year project started | Total project area under new construction (ha) | Total project area under rehabilitation (ha) | Total irrigation cost in 2000 prices (million US$) |
|---|---|---|---|---|---|---|---|
| Rompin Endau Area Development Project | WB | SEA | Malaysia | 1981 | 400 | | 42.1 |
| Trans Perak Area Development Project | WB | SEA | Malaysia | 1983 | 12,571 | 4,035 | 92.6 |
| Kedah Valley Ag development Project | WB | SEA | Malaysia | 1983 | | 6,112 | 40.4 |
| Western Johore Agricultural Development Project II | WB | SEA | Malaysia | 1987 | | 85,000 | 100.6 |
| Sirikit Dam Project | WB | SEA | Thailand | 1969 | 92,500 | | 168.0 |
| Chao Phya Irrigation Improvement Project I | WB | SEA | Thailand | 1974 | | 15,900 | 26.1 |
| Northeast Irrigation Improvement Project | WB | SEA | Thailand | 1975 | | 38,700 | 40.6 |
| Phitsanulok Irrigation Project | WB | SEA | Thailand | 1976 | | 83,250 | 332.9 |
| Chao Phya Irrigation Improvement Project II | WB | SEA | Thailand | 1978 | | 201,066 | 126.9 |
| Irrigation Project XI | WB | SEA | Thailand | 1981 | | 58,064 | 194.9 |
| Irrigation Project XII | WB | SEA | Thailand | 1982 | | 22,000 | 91.2 |
| Dau Tieng Irrigation Project | WB | SEA | Vietnam | 1980 | 42,000 | | 140.8 |
| Laos Agricultural Rehabilitation and Development Project | WB | SEA | Laos | 1978 | 6,770 | 980 | 10.5 |
| Burma Irrigation Project I | WB | SEA | Burma | 1975 | 154,472 | 9,308 | 42.5 |
| Lower Burma Paddyland Development Project | WB | SEA | Burma | 1978 | 26,022 | 54,575 | 53.0 |
| Lower Burma Paddyland Development II | WB | SEA | Burma | 1981 | 20,235 | 41,056 | 59.0 |
| Kinda (Nyaunggyat) Dam Multipurpose Project | WB | SEA | Burma | 1982 | 20,235 | 35,613 | 210.8 |
| Groundwater Irrigation Project I | WB | SEA | Burma | 1985 | 4,947 | | 19.9 |
| Tank Irrigation Project | WB | SEA | Burma | 1983 | 1,421 | 400 | 28.0 |
| Ye-U Irrigation Rehabilitation and Modernization Project | WB | SEA | Burma | 1988 | | 111,000 | 37.5 |
| Irrigation and Rehabilitation Project I | WB | SEA | Indonesia | 1969 | 21,200 | 153,500 | 137.6 |
| Irrigation and Rehabilitation Project II | WB | SEA | Indonesia | 1971 | 14,000 | 186,000 | 168.9 |
| Irrigation and Rehabilitation Project III | WB | SEA | Indonesia | 1971 | 70,159 | 131,741 | 131.3 |
| Irrigation and Rehabilitation Project IV | WB | SEA | Indonesia | 1973 | 28,580 | 183,420 | 83.8 |
| Jatiluhur Irrigation Extension Project | WB | SEA | Indonesia | 1975 | 24,500 | 24,000 | 216.0 |
| Irrigation Project VI | WB | SEA | Indonesia | 1976 | 24,911 | 159,856 | 275.6 |

(Continued)

TABLE A1. (Continued)
List of sample projects.

| Project name | Donor | Region | Country | Year project started | Total project area under new construction (ha) | Total project area under rehabilitation (ha) | Total irrigation cost in 2000 prices (million US$) |
|---|---|---|---|---|---|---|---|
| Irrigation Project VIII | WB | SEA | Indonesia | 1978 | 35,100 | 90,000 | 116.9 |
| Irrigation Project IX | WB | SEA | Indonesia | 1978 | 3,268 | 33,200 | 83.1 |
| Irrigation Project XI | WB | SEA | Indonesia | 1979 | 6,960 | | 40.8 |
| Irrigation Project VII | WB | SEA | Indonesia | 1977 | 5,420 | 134,000 | 76.1 |
| Irrigation Project X | WB | SEA | Indonesia | 1978 | 18,300 | 92,000 | 207.9 |
| Irrigation Project XIV | WB | SEA | Indonesia | 1981 | 7,400 | 242,871 | 214.8 |
| Irrigation Project XV | WB | SEA | Indonesia | 1980 | 10,000 | 11,000 | 48.6 |
| Irrigation Project XII | WB | SEA | Indonesia | 1980 | | 170,742 | 116.2 |
| Irrigation (East Java Province) Project XVII | WB | SEA | Indonesia | 1983 | 10,070 | 62,989 | 142.8 |
| Irrigation Project XVI | WB | SEA | Indonesia | 1983 | 6,567 | 2,403 | 76.2 |
| Swamp Reclamation Project II | WB | SEA | Indonesia | 1985 | 9,870 | | 89.1 |
| Provincial Irrigation Project II | WB | SEA | Indonesia | 1984 | 33,551 | | 127.1 |
| Kedung Ombo Multipurpose Dam and Irrigation Project | WB | SEA | Indonesia | 1986 | 23,408 | 25,700 | 244.9 |
| West Tarum Canal Improvement Project | WB | SEA | Indonesia | 1986 | | 60,797 | 49.3 |
| Central and West Java Provincial Irrigation Project | WB | SEA | Indonesia | 1987 | 66,300 | 115,000 | 237.5 |
| Irrigation Subsector Project (O&M) II | WB | SEA | Indonesia | 1992 | 21,254 | 978,321 | 423.6 |
| Irrigation Subsector Loan Project | WB | SEA | Indonesia | 1988 | 4,118 | 536,848 | 318.3 |
| Integrated Swamps Development Project | WB | SEA | Indonesia | 1994 | 12,500 | 32,000 | 63.8 |
| Java Irrigation Improvement and Water Resources Management Project | WB | SEA | Indonesia | 1994 | 6,244 | 285,377 | 184.1 |
| Provincial Irrigated Agriculture Development Project | WB | SEA | Indonesia | 1994 | 93,600 | 106,900 | 128.7 |
| Groundwater Development Project | WB | SEA | Indonesia | 1991 | 7,000 | | 31.3 |
| Lower Sao Francisco Polders Project | WB | LAC | Brazil | 1977 | 36,400 | | 76.9 |
| Lower Sao Francisco Irrigation Project | WB | LAC | Brazil | 1980 | 7,339 | | 84.4 |
| Irrigation Subsector Project | WB | LAC | Brazil | 1989 | 298,774 | | 349.4 |
| Upper and Middle Sao Francisco Irrigation Project | WB | LAC | Brazil | 1987 | 2,119 | 14,437 | 177.3 |
| Jaiba Irrigation Project | WB | LAC | Brazil | 1989 | | 17,446 | 141.4 |
| Itaparica Resettlement and Irrigation Project | WB | LAC | Brazil | 1988 | 168,950 | | 453.6 |
| Northeast Irrigation Project I | WB | LAC | Brazil | 1991 | 22,266 | | 372.2 |

(Continued)

TABLE A1. (Continued)
List of sample projects.

| Project name | Donor | Region | Country | Year project started | Total project area under new construction (ha) | Total project area under rehabilitation (ha) | Total irrigation cost in 2000 prices (million US$) |
|---|---|---|---|---|---|---|---|
| Irrigation Development Project | WB | LAC | Chile | 1994 | 10,023 | 138,500 | 94.4 |
| Atlantico Irrigation Project | WB | LAC | Colombia | 1969 | 9,900 | | 44.8 |
| Cordoba Agricultural Development Project II | WB | LAC | Colombia | 1976 | | 51,100 | 46.7 |
| Irrigation Rehabilitation Project I | WB | LAC | Colombia | 1983 | | 5,700 | 89.8 |
| Upper Magdalena Pilot Watershed Management Project | WB | LAC | Colombia | 1983 | 6,260 | | 9.3 |
| Irrigation Rehabilitation Project II | WB | LAC | Colombia | 1987 | | 76,300 | 150.6 |
| Small-Scale Irrigation Project | WB | LAC | Colombia | 1992 | 17,093 | 8,100 | 70.1 |
| Yaque del Norte Irrigation Project | WB | LAC | Dominican Republic | 1974 | | 29,730 | 95.8 |
| Nizao Irrigation Project | WB | LAC | Dominican Republic | 1980 | | 12,000 | 45.2 |
| Milagro Irrigation Project | WB | LAC | Ecuador | 1973 | 1,837 | 1,250 | 25.1 |
| Tungurahua Rural Development Project | WB | LAC | Ecuador | 1981 | 7,800 | 1,800 | 25.2 |
| Lower Guayas Flood Control Project | WB | LAC | Ecuador | 1991 | | 170,000 | 130.8 |
| Irrigation Technical Assistance | WB | LAC | Ecuador | 1994 | | 88,000 | 23.4 |
| Tapakuma Irrigation Project | WB | LAC | Guyana | 1975 | | 16,900 | 67.9 |
| Black Bush Irrigation Project | WB | LAC | Guyana | 1980 | | 30,364 | 80.7 |
| El Nino Emergency Assistance Project | WB | LAC | Guyana | 1998 | | 111,336 | 10.3 |
| Rehabilitation and Expansion of the Region Lagunera and San Juan Del Rio Irrigation Districts | WB | LAC | Mexico | 1967 | 35,900 | 104,000 | 262.5 |
| Rio Colorado Irrigation Project | WB | LAC | Mexico | 1969 | | 207,000 | 663.7 |
| Rio Sinaloa Irrigation Project | WB | LAC | Mexico | 1975 | | 105,000 | 342.0 |
| Punuco First-Stage Project | WB | LAC | Mexico | 1974 | 144,000 | | 644.7 |
| Bajo Rio Bravo and Bajo Rio San Juan Rehabilitation Project | WB | LAC | Mexico | 1979 | | 130,846 | 206.0 |
| Small-Scale Agricultural Infrastructure Project | WB | LAC | Mexico | 1979 | 238,000 | | 205.4 |
| Rio Fuerte/Rio Sinaloa Irrigation Project | WB | LAC | Mexico | 1981 | 61,300 | 79,779 | 241.2 |
| Apatzingan Irrigation Project | WB | LAC | Mexico | 1982 | | 15,842 | 155.6 |
| Ocoroni Irrigation Project | WB | LAC | Mexico | 1982 | 7,773 | | 88.5 |

(Continued)

TABLE A1. (Continued)
List of sample projects.

| Project name | Donor | Region | Country | Year project started | Total project area under new construction (ha) | Total project area under rehabilitation (ha) | Total irrigation cost in 2000 prices (million US$) |
|---|---|---|---|---|---|---|---|
| Bajo Rio Bravo/Rio San Juan Rehabilitation Project II | WB | LAC | Mexico | 1983 | | 89,500 | 22.4 |
| San Fernando Rainfed Agricultural Development Project | WB | LAC | Mexico | 1983 | 396,696 | | 154.9 |
| Rainfed Areas Development Project | WB | LAC | Mexico | 1995 | 86,478 | | 207.7 |
| Irrigation and Drainage Sector Project | WB | LAC | Mexico | 1992 | 148,500 | 1,811,729 | 1,325.4 |
| On-Farm and Minor Irrigation Networks Improvement Project | WB | LAC | Mexico | 1994 | | 225,691 | 378.9 |
| San Lorenzo Irrigation and Land Settlement Project | WB | LAC | Peru | 1965 | 36,600 | | 190.8 |
| Irrigation Rehabilitation Project | WB | LAC | Peru | 1980 | 12,976 | 27,659 | 59.7 |
| Lower Piura Irrigation Rehabilitation Project II | WB | LAC | Peru | 1981 | | 34,700 | 208.4 |
| Natural Resources Management and Irrigation Development Project | WB | LAC | Uruguay | 1994 | 7,555 | 25,400 | 45.8 |
| Bas Cheliff Irrigation Project | WB | MENA | Algeria | 1983 | | 4,500 | 17.0 |
| Cheliff Irrigation Project | WB | MENA | Algeria | 1988 | 6,400 | 636 | 67.3 |
| Sahara Regional Development Project | WB | MENA | Algeria | 1994 | | 3,677 | 42.7 |
| Nile Delta Drainage Project I | WB | MENA | Egypt | 1972 | | 397,812 | 330.8 |
| Upper Egypt Drainage Project I | WB | MENA | Egypt | 1975 | | 126,000 | 166.5 |
| Upper Egypt Drainage Project II | WB | MENA | Egypt | 1978 | | 210,000 | 204.8 |
| Nile Delta Drainage Project II | WB | MENA | Egypt | 1978 | | 334,110 | 211.6 |
| New Land Development Project | WB | MENA | Egypt | 1981 | | 10,080 | 245.8 |
| Irrigation Pumping Stations Rehabilitation Project | WB | MENA | Egypt | 1983 | | 476,280 | 53.2 |
| Drainage Project V | WB | MENA | Egypt | 1987 | | 186,000 | 166.5 |
| Channel Maintenance Project | WB | MENA | Egypt | 1990 | | 92,417 | 194.4 |
| National Drainage Project | WB | MENA | Egypt | 1992 | 248,010 | 277,473 | 309.6 |
| Pumping Stations Rehabilitation Project II | WB | MENA | Egypt | 1992 | | 617,400 | 40.8 |
| Matruh Resource Management Project | WB | MENA | Egypt | 1994 | 3,211 | 1,539 | 31.6 |
| Dez Irrigation Project | WB | MENA | Iran | 1970 | 81,000 | | 186.9 |
| Irrigation Improvement Project | WB | MENA | Iran | 1993 | | 105,600 | 296.4 |
| North East Ghor Irrigation and Rural Development Project | WB | MENA | Jordan | 1976 | 1,778 | 1,160 | 55.6 |

(Continued)

TABLE A1. (Continued)
List of sample projects.

| Project name | Donor | Region | Country | Year project started | Total project area under new construction (ha) | Total project area under rehabilitation (ha) | Total irrigation cost in 2000 prices (million US$) |
|---|---|---|---|---|---|---|---|
| Rharb Sebou Irrigation Project | WB | MENA | Morocco | 1971 | 35,700 | 5,000 | 233.5 |
| Sebou Development Project II | WB | MENA | Morocco | 1976 | 35,200 | | 58.2 |
| Souss Groundwater Project | WB | MENA | Morocco | 1977 | 6,123 | 1,110 | 46.2 |
| Doukkala Irrigation Project I | WB | MENA | Morocco | 1978 | 15,400 | | 96.9 |
| Doukkala Irrigation Project II | WB | MENA | Morocco | 1981 | 16,273 | | 81.6 |
| Small and Medium Scale Irrigation Project | WB | MENA | Morocco | 1984 | 443 | 12,983 | 55.0 |
| Large Scale Irrigation Improvement Project | WB | MENA | Morocco | 1988 | | 150,000 | 98.6 |
| Small and Medium Scale Irrigation Project II | WB | MENA | Morocco | 1990 | | 25,150 | 34.3 |
| Large Scale Irrigation Improvement Project II | WB | MENA | Morocco | 1993 | | 36,729 | 188.0 |
| Balikh Irrigation Project | WB | MENA | Syrian Arab Republic | 1975 | 20,200 | | 475.5 |
| Lower Euphrates Drainage Project | WB | MENA | Syrian Arab Republic | 1982 | | 124,000 | 64.4 |
| Irrigation Rehabilitation Project | WB | MENA | Tunisia | 1976 | | 17,784 | 30.5 |
| Sidi Salem Multipurpose Project | WB | MENA | Tunisia | 1979 | 6,516 | 6,303 | 381.0 |
| Southern Irrigation Project | WB | MENA | Tunisia | 1980 | 1,844 | 3,040 | 53.9 |
| Medjerda/Nebhana Irrigation Development Project | WB | MENA | Tunisia | 1983 | 2,311 | 1,000 | 25.7 |
| Central Tunisia Irrigation Project | WB | MENA | Tunisia | 1984 | 1,255 | 5,410 | 24.5 |
| Irrigation Management Improvement Project | WB | MENA | Tunisia | 1987 | | 105,000 | 35.8 |
| Gabes Irrigation Project | WB | MENA | Tunisia | 1987 | 200 | 4,910 | 23.5 |
| Agricultural Sector Investment Loan | WB | MENA | Tunisia | 1994 | 4,883 | 4,809 | 116.3 |
| Agricultural Sector Investment Loan II | WB | MENA | Tunisia | 1998 | 3,460 | 2,691 | 62.0 |
| Tihama Development Project | WB | MENA | Yemen | 1976 | 17,000 | | 61.9 |
| Tihama Development Project II | WB | MENA | Yemen | 1981 | | 12,000 | 45.3 |
| Tihama Development Project IV | WB | MENA | Yemen | 1982 | | 12,000 | 26.5 |
| Tihama V Regional Agricultural Development Project | WB | MENA | Yemen | 1988 | 4,200 | | 27.6 |
| Land and Water Conservation Project | WB | MENA | Yemen | 1994 | | 10,600 | 28.5 |
| Wadi Beihan Agriculture Development Project | WB | MENA | Yemen | 1982 | | 5,596 | 21.7 |
| Wadi Hadramawt Agricultural Project | WB | MENA | Yemen | 1992 | 1,450 | 2,700 | 7.5 |

(Continued)

TABLE A1. (Continued)
List of sample projects.

| Project name | Donor | Region | Country | Year project started | Total project area under new construction (ha) | Total project area under rehabilitation (ha) | Total irrigation cost in 2000 prices (million US$) |
|---|---|---|---|---|---|---|---|
| Moyen Cheliff Irrigation Project | AfDB | MENA | Algeria | 1991 | 290 | 840 | 43.5 |
| Upper Doukala Irrigation Project | AfDB | MENA | Morocco | 1993 | 14,400 | | 212.9 |
| Barbara Dam | AfDB | MENA | Tunisia | 1994 | 2,200 | 77,000 | 107.2 |
| Ghezala Mateur Agro-Industrial Complex Development Project | AfDB | MENA | Tunisia | 1984 | 907 | | 2.0 |
| Integrated Rural Development in Disadvantaged Areas: Phase One | AfDB | MENA | Tunisia | 1987 | 14,755 | | 63.7 |
| Ras Djebel-Galaat Irrigation Development Project | AfDB/ Bilateral | MENA | Tunisia | 1987 | 8,105 | | 23.9 |
| Development of 4 Irrigation Sectors in the Medjerda Valley | AfDB | MENA | Tunisia | 1968 | 4,125 | | 17.8 |
| Niena Dionkele Rice Development Project | WB | SSA | Burkina Faso | 1981 | 585 | | 4.0 |
| Semry Rice Project II | WB | SSA | Cameroon | 1978 | 6,700 | | 90.8 |
| Sategui-Deressia Irrigation Project | WB | SSA | Chad | 1976 | 1,500 | | 37.7 |
| Lake Chad Polders Project | WB | SSA | Chad | 1977 | | 220 | 10.4 |
| Revised Amibara Irrigation Project | WB | SSA | Ethiopia | 1978 | 10,300 | | 79.0 |
| Bura Irrigation Settlement Project | WB | SSA | Kenya | 1979 | 2,478 | | 121.7 |
| Mangoky Agricultural Development Project | WB | SSA | Madagascar | 1979 | | 5,000 | 23.0 |
| Lac Alaotra Rice Intensification Project | WB | SSA | Madagascar | 1984 | | 31,115 | 28.2 |
| Irrigation Rehabilitation Project | WB | SSA | Madagascar | 1986 | | 16,750 | 37.2 |
| Irrigation Rehabilitation Project II | WB | SSA | Madagascar | 1994 | | 25,295 | 20.6 |
| Mopti Rice Project | WB | SSA | Mali | 1973 | 14,370 | 7,230 | 21.7 |
| Mopti Rice Project II | WB | SSA | Mali | 1979 | 8,700 | 19,840 | 37.5 |
| Office Du Niger Consolidation Report | WB | SSA | Mali | 1989 | 43,000 | 60,000 | 239.5 |
| Gorgol Noir Irrigation Project | WB | SSA | Mauritania | 1981 | 2,000 | | 108.3 |
| Small Scale Irrigation Project | WB | SSA | Mauritania | 1986 | 1,221 | 639 | 11.4 |
| Agricultural Management and Services Project | WB | SSA | Mauritus | 1994 | 70 | 210 | 3.1 |
| Irrigation Project | WB | SSA | Niger | 1980 | 1,304 | | 28.3 |
| Irrigation Rehabilitation Project | WB | SSA | Niger | 1987 | | 3,050 | 32.5 |
| Pilot Private Irrigation Project | WB | SSA | Niger | 1996 | 1,693 | | 6.1 |
| National Fadama Development Project | WB | SSA | Nigeria | 1994 | 30,000 | | 77.1 |

(Continued)

TABLE A1. (Continued)
List of sample projects.

| Project name | Donor | Region | Country | Year project started | Total project area under new construction (ha) | Total project area under rehabilitation (ha) | Total irrigation cost in 2000 prices (million US$) |
|---|---|---|---|---|---|---|---|
| River Polders Project | WB | SSA | Senegal | 1974 | 2,960 | | 26.9 |
| Debi Lampsar Irrigation Project | WB | SSA | Senegal | 1979 | 2,550 | | 43.6 |
| Fourth Irrigation Project | WB | SSA | Senegal | 1989 | | 6,037 | 69.0 |
| Rahad Irrigation Project | WB | SSA | Sudan | 1974 | 126,000 | | 498.5 |
| New Halfa Irrigation Rehabilitation Project | WB | SSA | Sudan | 1982 | | 88,200 | 73.3 |
| Blue Nile Pump Scheme Rehabilitation Project | WB | SSA | Sudan | 1982 | | 9,000 | 51.6 |
| White Nile Pump Scheme Rehabilitation Project | WB | SSA | Sudan | 1982 | | 23,118 | 29.8 |
| Gezira Rehabilitation Project | WB | SSA | Sudan | 1985 | | 630,000 | 141.7 |
| The Region du Lac Development Rehabilitation Programme | AfDB | SSA | Chad | 1989 | 735 | 5,320 | 26.0 |
| Amibara Irrigation Project | AfDB | SSA | Ethiopia | 1987 | 7,500 | 2,800 | 41.7 |
| Phuthiatsana Integrated Rural Development Project | AfDB | SSA | Lesotho | 1983 | 29 | 32 | 0.3 |
| Tsiribihina Irrigated Agricultural Development Project - Manambolo Phase I | AfDB | SSA | Madagascar | 1988 | | 830 | 5.9 |
| Emergency Irrigation Infrastructure Repairs Project | AfDB | SSA | Madagascar | 1985 | | 19,815 | 0.5 |
| Boche Plain Irrigation Project | AfDB | SSA | Mauritania | 1979 | 1,000 | | 54.8 |
| Kourani Baria Irrigation Development Project | AfDB | SSA | Niger | 1985 | 693 | | 11.3 |
| Kapunga Rice Irrigation Project | AfDB | SSA | Tanzania | 1989 | 4,350 | 600 | 42.5 |
| Rice Development Project | AfDB | SSA | The Gambia | 1989 | 0 | 355 | 6.5 |
| Jahali-Pacharr Smallholder Rice Project | AfDB/ Bilateral | SSA | The Gambia | 1982 | 1,474 | | 26.8 |
| Manantali Dam Project | AfDB/ Bilateral | SSA | Senegal/ Mauritania/Mali | 1983 | 65,283 | | 331.4 |
| Projet Sucrier D'analiva | AfDB | SSA | Madagascar | 1983 | 2,500 | | 13.6 |
| Tombali Rice Development Project | IFAD/ AfDB/WFP | SSA | Guinea-Bissau | 1986 | | 546 | 12.1 |
| Smallholder Food Security Project | IFAD/WB | SSA | Malawi | 1994 | 300 | | 5.6 |
| Mara Region Farmers Initiative Project | IFAD | SSA | Tanzania | 1996 | 488 | | 7.3 |
| Smalholder Irrigation & Water Use Programme | IFAD | SSA | Zambia | 1996 | 640 | 17 | 4.2 |
| Small-scale Irrigation & Soil Conservation Project | IFAD/WB | SSA | Ethiopia | 1987 | 2,928 | 215 | 3.9 |

TABLE A2.
Number of sample projects by type of project, by other category, and by region.

| | Sub-Saharan Africa | Middle East and North Africa | South Asia | Southeast Asia | East Asia | Latin America and the Caribbean | Total |
|---|---|---|---|---|---|---|---|
| Type of project | | | | | | | |
| Irrigation | 40 | 44 | 87 | 63 | 9 | 37 | 280 |
| Irrigation and power | 1 | 3 | 3 | 3 | 1 | 1 | 12 |
| Multi-sector projects with irrigation | 4 | 4 | 1 | 2 | 8 | 3 | 22 |
| Purpose of project | | | | | | | |
| New construction with land opening | 9 | 2 | 1 | 2 | 0 | 3 | 17 |
| New construction from rainfed area | 7 | 10 | 20 | 10 | 3 | 9 | 59 |
| New construction + rehabilitation | 10 | 9 | 11 | 10 | 6 | 4 | 50 |
| Rehabilitation + new construction | 4 | 7 | 12 | 30 | 7 | 9 | 69 |
| Rehabilitation | 15 | 23 | 47 | 16 | 2 | 16 | 119 |
| Type of irrigation systems involved in project | | | | | | | |
| River diversion | 19 | 9 | 32 | 40 | 4 | 12 | 116 |
| River-dam-reservoir | 4 | 16 | 16 | 17 | 9 | 11 | 73 |
| Tank | 1 | 0 | 6 | 1 | 0 | 0 | 8 |
| River-lift (or pond or lake) | 14 | 6 | 3 | 2 | 2 | 10 | 37 |
| Groundwater-lift | 4 | 19 | 18 | 3 | 3 | 4 | 51 |
| Drainage/flood control | 3 | 1 | 16 | 5 | 0 | 4 | 29 |
| Mode of O&M after project | | | | | | | |
| Government agency alone | 26 | 33 | 52 | 26 | 1 | 23 | 161 |
| Government agency with farmers | 17 | 14 | 29 | 37 | 7 | 11 | 115 |
| Farmer-managed | 2 | 4 | 10 | 5 | 10 | 7 | 38 |
| Major crop grown | | | | | | | |
| Paddy | 29 | 4 | 48 | 64 | 9 | 11 | 165 |
| Other cereal | 4 | 26 | 33 | 1 | 8 | 14 | 86 |
| Sugar/cotton | 8 | 4 | 5 | 0 | 1 | 7 | 25 |
| Tree crops | 0 | 7 | 2 | 3 | 0 | 3 | 15 |
| Vegetables | 4 | 8 | 3 | 0 | 0 | 4 | 19 |
| Fodder | 0 | 2 | 0 | 0 | 0 | 2 | 4 |
| Conjunctive use | 2 | 32 | 44 | 2 | 9 | 11 | 100 |
| Farmers' contribution | 8 | 9 | 18 | 1 | 10 | 5 | 51 |
| Donor | | | | | | | |
| WB | 28 | 44 | 91 | 68 | 18 | 41 | 290 |
| AfDB | 12 | 7 | 0 | 0 | 0 | 0 | 19 |
| IFAD | 5 | 0 | 0 | 0 | 0 | 0 | 5 |
| Total | 45 | 51 | 91 | 68 | 18 | 41 | 314 |

TABLE A3.
Properties of new construction projects by region (N=126).[a]

| | Sub-Saharan Africa | Middle East and North Africa | South Asia | South east Asia | East Asia | Latin America and the Caribbean |
|---|---|---|---|---|---|---|
| Project size (1,000 ha) | 10 | 16 | 108 | 39 | 77 | 94 |
| | (245) | (117) | (125) | (107) | (89) | (131) |
| Average size of systems (1,000 ha) | 6 | 7 | 37 | 22 | 29 | 33 |
| | (374) | (164) | (195) | (140) | (105) | (297) |
| Year project started | 1983.4 | 1982.0 | 1980.8 | 1979.0 | 1983.4 | 1981.3 |
| | (0.4) | (0.4) | (0.3) | (0.3) | (0.5) | (0.4) |
| Bank input for appraisal (staff weeks) | 79 | 45 | 115 | 105 | 68 | 129 |
| | (141) | (97) | (83) | (110) | (71) | (87) |
| Bank input for supervision (staff weeks) | 102 | 65 | 135 | 84 | 97 | 104 |
| | (122) | (99) | (86) | (77) | (64) | (80) |
| Time overrun (years)[b] | 2.0 | 1.6 | 1.4 | 2.4 | 1.9 | 2.2 |
| | (2.6) | (2.3) | (2.0) | (1.5) | (1.1) | (2.6) |
| Cost overrun (%)[b] | 16 | 0 | 16 | 2 | 39 | 9 |
| | (58) | (59) | (41) | (45) | (43) | (58) |
| Sizing error (%)[b] | 15 | 10 | 7 | 23 | 0 | -3 |
| | (26) | (24) | (42) | (29) | (21) | (61) |
| Number of project components | 6.0 | 7.0 | 7.8 | 6.4 | 7.3 | 6.2 |
| | (50) | (74) | (45) | (55) | (34) | (52) |
| Share of government funds (%) | 28 | 44 | 42 | 44 | 62 | 62 |
| | (94) | (47) | (54) | (41) | (18) | (25) |
| Share of software components (%) | 35 | 16 | 17 | 17 | 21 | 24 |
| | (62) | (103) | (99) | (65) | (71) | (50) |
| Annual rainfall (mm) | 698 | 382 | 1,169 | 2,037 | 905 | 1,035 |
| | (47) | (42) | (41) | (29) | (52) | (63) |
| GDP per capita (US$ in 2000 prices) | 317 | 1,379 | 266 | 879 | 1,952 | 3,024 |
| | (52) | (42) | (36) | (77) | (88) | (33) |
| PPP | 0.46 | 0.64 | 0.31 | 0.45 | 0.39 | 0.31 |
| | (32) | (72) | (18) | (40) | (44) | (74) |
| EIRR (%) | 11 | 14 | 14 | 10 | 23 | 16 |
| | (160) | (54) | (69) | (84) | (70) | (80) |

*Notes:* [a] New construction projects include 'new construction with land opening,' 'new construction from rainfed area,' and 'new construction+rehabilitation.' Figures inside parenthesis are the coefficients of variation (CV) as a percentage (%) except for the items footnoted with [b].

[b] For these variables which take both positive and negative values, the standard deviation (SD) is shown instead of the CV.

N = number of observations

TABLE A4.
Properties of rehabilitation projects by region (N=188).[a]

| | Sub-Saharan Africa | Middle East and North Africa | South Asia | South east Asia | East Asia | Latin America and the Caribbean |
|---|---|---|---|---|---|---|
| Project size (1,000 ha) | 54 | 123 | 434 | 147 | 621 | 156 |
| | (255) | (140) | (196) | (133) | (94) | (245) |
| Average size of systems(1,000 ha) | 11 | 24 | 73 | 31 | 254 | 20 |
| | (196) | (211) | (272) | (161) | (238) | (189) |
| Year project started | 1985.8 | 1985.5 | 1983.2 | 1980.9 | 1989.7 | 1983.4 |
| | (0.2) | (0.3) | (0.3) | (0.3) | (0.3) | (0.4) |
| Bank input for appraisal (staff weeks) | 109 | 129 | 117 | 92 | 172 | 120 |
| | (96) | (71) | (59) | (78) | (76) | (57) |
| Bank input for supervision (staff weeks) | 99 | 90 | 168 | 103 | 163 | 123 |
| | (84) | (66) | (75) | (108) | (78) | (55) |
| Time overrun (years)[b] | 1.7 | 1.0 | 1.7 | 2.1 | 1.9 | 1.4 |
| | (2.1) | (2.2) | (2.3) | (1.5) | (1.7) | (2.0) |
| Cost overrun (%)[b] | -1 | -15 | 1 | 13 | 13 | 18 |
| | (69) | (34) | (31) | (48) | (15) | (59) |
| Sizing Error (%)[b] | 31 | 8 | -25 | -1 | -17 | -14 |
| | (33) | (31) | (109) | (25) | (52) | (99) |
| Number of project components | 5.6 | 7.8 | 7.1 | 6.4 | 6.2 | 6.4 |
| | (62) | (52) | (58) | (56) | (26) | (46) |
| Share of government funds (%) | 20 | 49 | 39 | 52 | 60 | 55 |
| | (72) | (34) | (45) | (32) | (19) | (34) |
| Share of software components (%) | 32 | 23 | 23 | 25 | 18 | 20 |
| | (44) | (88) | (60) | (50) | (65) | (78) |
| Annual rainfall (mm) | 747 | 220 | 1,244 | 2,110 | 812 | 886 |
| | (61) | (76) | (67) | (24) | (40) | (70) |
| GDP per capita (US$ in 2000 prices) | 462 | 1,112 | 342 | 1,118 | 1,021 | 2,742 |
| | (164) | (50) | (35) | (69) | (131) | (51) |
| PPP | 0.46 | 0.66 | 0.30 | 0.47 | 0.28 | 0.42 |
| | (34) | (74) | (21) | (33) | (44) | (57) |
| EIRR (%) | 14 | 17 | 20 | 16 | 30 | 15 |
| | (139) | (61) | (65) | (86) | (46) | (85) |

*Notes:* [a] Rehabilitation projects include solely 'rehabilitation' projects and 'rehabilitation + new construction' with the new irrigated area smaller than the rehabilitated area. Figures inside parenthesis are the coefficients of variation (CV) as a percentage (%) except for the items footnoted with [b].

[b] For these variables which take both positive and negative values, the standard deviation (SD) is used instead of the CV.

N = number of observations

TABLE A5.

Results of Box-Cox regression explaining the variation in total project cost, total hardware cost, project size, and EIRR of irrigation projects.[a]

| | Dependent variable | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Explanatory variables | Total project cost (1) | | Total hardware cost (2) | | Project size (3) | | EIRR (4) | |
| | Coef. | Test value | Coef. | Test value | Coef. | Test value | Coef. | Test value |
| Transformed | | | | | | | | |
| Project size | 1.634 *** | 110.1 | 1.346 *** | 93.64 | | | 5.113 *** | 35.97 |
| Average size of systems | 0.144 | 2.591 | 0.152 * | 3.067 | 0.152 *** | 53.10 | -0.696 ** | 3.784 |
| Year project started | 0.768 | 2.453 | 0.531 | 1.388 | 0.405 *** | 14.96 | -2.009 | 0.792 |
| Bank input for supervision | 0.600 *** | 8.082 | 0.474 *** | 6.656 | 0.035 | 1.941 | -2.361 ** | 4.276 |
| Number of project components | 0.195 | 0.360 | 0.282 | 0.852 | -0.155 * | 3.405 | -4.324 *** | 8.889 |
| Share of government funds | 0.960 *** | 9.370 | 0.919 *** | 10.50 | 0.116 ** | 4.589 | 0.680 | 0.192 |
| Share of software components | -0.259 | 2.335 | -0.927 *** | 29.67 | -0.058 | 2.252 | 0.656 | 0.831 |
| Annual rainfall | -0.091 | 0.196 | -0.043 | 0.065 | -0.030 * | 3.574 | 2.566 ** | 4.045 |
| GDP per capita | 1.279 *** | 20.45 | 1.007 *** | 20.16 | -0.018 | 1.241 | -6.530 *** | 10.20 |
| PPP | 0.505 ** | 3.940 | 0.511 * | 3.217 | -0.027 | 0.015 | -0.537 | 0.756 |
| Not transformed | | | | | | | | |
| Time overrun | 0.108 | 1.363 | 0.146 | 2.487 | 0.014 | 0.120 | -0.218 | 0.406 |
| Cost overrun | 2.231 *** | 32.17 | 2.140 *** | 29.87 | 0.350 ** | 4.297 | 0.237 | 0.028 |
| Sizing error | 0.004 | 2.215 | 0.005 * | 2.977 | -0.005 *** | 14.63 | 0.009 | 0.777 |
| Farmers' contribution | 0.077 | 0.025 | 0.173 | 0.129 | -0.288 | 1.856 | 2.968 * | 2.686 |
| Conjunctive use of water | -0.444 | 0.928 | -0.472 | 1.064 | 0.698 *** | 12.14 | 2.900 * | 2.811 |
| Irrigation and power | 1.112 | 1.680 | 1.156 | 1.834 | -0.350 | 0.867 | 1.776 | 0.307 |
| Multi-sector project | -2.819 *** | 12.75 | -3.058 *** | 15.12 | -0.663 ** | 3.761 | 2.428 | 0.699 |
| New construction with land opening | 3.880 *** | 20.85 | 3.753 *** | 19.64 | -0.829 ** | 5.255 | -0.994 | 0.102 |
| New construction from rainfed | 3.057 *** | 33.51 | 2.850 *** | 29.51 | -0.693 *** | 9.872 | -3.522 * | 3.261 |
| New + rehabilitation | 2.585 *** | 22.76 | 2.431 *** | 20.45 | -0.646 *** | 7.763 | -0.108 | 0.003 |
| Rehabilitation + new | 1.559 *** | 10.62 | 1.612 *** | 11.46 | 0.026 | 0.015 | -0.757 | 0.184 |
| River-dam-reservoir | 1.195 *** | 6.711 | 1.111 ** | 5.845 | 0.144 | 0.517 | 2.344 | 1.875 |
| Tank | -0.626 | 0.320 | -0.196 | 0.032 | -1.037 ** | 4.559 | 2.670 | 0.417 |
| River-lift | 0.464 | 0.586 | 0.569 | 0.884 | -0.328 | 1.564 | -2.702 | 1.437 |
| Groundwater-lift | -0.760 | 1.471 | -0.809 | 1.722 | 0.336 | 1.554 | 1.258 | 0.259 |
| Drainage/flood control | -1.855 *** | 8.118 | -1.831 *** | 7.923 | 0.101 | 0.123 | 0.254 | 0.011 |
| Government with farmers group | 0.157 | 0.156 | 0.089 | 0.050 | -0.074 | 0.174 | 4.081 *** | 7.523 |
| Farmer-managed system | -1.535 *** | 6.039 | -1.793 *** | 8.242 | 0.630 ** | 5.384 | 5.253 ** | 5.061 |
| Cereals | 0.292 | 0.346 | 0.306 | 0.382 | 0.253 | 1.331 | 1.019 | 0.306 |
| Sugar/cotton | 0.867 | 1.547 | 0.591 | 0.718 | 0.387 | 1.629 | -1.797 | 0.480 |
| Tree crops | 0.532 | 0.362 | 0.562 | 0.409 | -1.064 *** | 7.639 | 6.135 * | 3.480 |
| Vegetables | -2.201 *** | 7.114 | -2.283 *** | 7.751 | -0.935 *** | 6.874 | 7.572 *** | 6.120 |
| Fodder | -3.012 * | 3.102 | -2.579 | 2.312 | -0.311 | 0.182 | 19.988 *** | 9.603 |
| AfDB | 0.418 | 0.147 | 0.479 | 0.197 | -0.830 * | 3.450 | -4.051 | 0.980 |
| IFAD | 0.754 | 0.209 | 0.276 | 0.028 | -0.852 | 1.442 | -13.830 ** | 5.146 |
| East Asia | 1.726 * | 2.928 | 2.008 ** | 3.997 | -0.346 | 0.628 | 8.264 ** | 4.799 |
| Southeast Asia | -0.927 | 1.964 | -0.934 | 1.977 | 0.170 | 0.323 | 1.800 | 0.536 |
| Latin America and the Caribbean | -1.195 | 1.947 | -1.131 | 1.748 | -0.172 | 0.206 | 6.752 ** | 4.535 |

(Continued)

TABLE A5. (Continued)

Results of Box-Cox regression explaining the variation in total project cost, total hardware cost, project size, and EIRR of irrigation projects.[a]

| Explanatory variables | Dependent variable | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Total project cost (1) | | Total hardware cost (2) | | Project size (3) | | EIRR (4) | |
| | Coef. | Test value | Coef. | Test value | Coef. | Test value | Coef. | Test value |
| Middle East and North Africa | -0.431 | 0.320 | -0.532 | 0.488 | -1.271 *** | 13.86 | 6.595 ** | 5.541 |
| Sub-Saharan Africa | -0.114 | 0.021 | -0.396 | 0.254 | -1.680 *** | 22.81 | 9.222 *** | 10.16 |
| Constant | 4.047 | | 6.859 | | 2.748 | | 17.192 | |
| $\lambda$ | 0.015 | 0.340 | 0.050 | 1.030 | 0.314 *** | 4.410 | -0.088 | -1.350 |
| $\theta$ | 0.137 *** | 4.970 | 0.137 *** | 5.240 | 0.035 | 1.590 | | |
| $\sigma$ | 2.764 | | 2.749 | | 1.210 | | 10.314 | |
| Log likelihood | -3807.0 | | -3729.6 | | -1610.6 | | -1178.3 | |
| Number of samples | 314 | | 314 | | 314 | | 314 | |

*Notes:* [a] Test statistics for regression coefficient follow the $\chi^2$ 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 percent level, respectively.

Coef. = coefficient

# Appendix B.

## Regression Analysis for Identifying Determinants of Cost and Performance of Irrigation Projects

This appendix has been prepared to explain the regression analysis that we adopt to examine the factors that affect the cost and performance of irrigation projects. A natural way to find out such factors is to conduct a regression analysis in that the unit cost or EIRR (a measure of project performance) of irrigation projects is regressed onto various factors that may be related to the cost and performance. In what follows we explain the regression models to be used and present the estimation results.

## Regression Model

At the onset, it should be noted that the regression analysis adopted in this study is a means to identify the degree of partial correlation between the dependent variable (the unit cost / EIRR) and explanatory variables. The existence of correlation between two variables is nothing but a necessary condition to have a causal relation between them, but it is a popular way to examine a causal relation from one variable to the other by means of correlation between the two. In conducting such a correlation analysis, an undesirable situation is that some indispensable control variables are missing from the regression analysis. In order to avoid such a situation, we prepare as many variables as possible in our database.

In the case of the regression analysis to explain the variation of the unit cost of irrigation projects, we face another undesirable situation. We are interested in factors that affect the cost of developing/ rehabilitating a unit of irrigated area. We know, however, the project size is an important factor that has a significant impact on the unit cost (figure 5). The inclusion of project size as an explanatory variable in the regression to explain the variation of the unit cost creates an undesirable regression situation in that the same variable appears on both sides of a regression equation. The regression estimation under such a situation could lead to a false result. To avoid it, we estimate in two steps the elasticities of unit cost with respect to the factors that explain the variation in the unit cost across irrigation projects. The elasticity of unit cost with respect to a possible explanatory factor can be decomposed into two elasticities, the elasticity of total project cost with respect to the explanatory variable, and the elasticity of project size with respect to the explanatory variable:

$$\frac{d \log \left( Y / X_1 \right)}{d \log X_i} = \frac{d \log Y}{d \log X_i} - \frac{d \log X_1}{d \log X_i} = \frac{dY}{dX_i} \frac{X_i}{Y} - \frac{dX_1}{dX_i} \frac{X_i}{X_1} \qquad \text{(B1)}$$

where Y = total project cost, $X_1$ = project size, and $X_i$ = an explanatory variable. Thus, the elasticity of unit cost can be obtained as the difference between these elasticities. In the first step, we estimate two regression equations, one regressing Y onto all available explanatory variables and the other regressing $X_1$ onto all explanatory variables except $X_1$. In the second step, we estimate the elasticity of unit cost, substituting the appropriate partial derivatives obtained from the estimated regression equations into equation (B1).

As to the regression model to be adopted for the estimation of the two regression equations, little prior information is available. To let our data demonstrate best by itself, therefore, we adopt the Box-Cox model, the most flexible model among the linear regression models. A general Box-Cox model for the total project cost equation can be written as follows (Box and Cox 1964; Greene 2003: Ch.9):

$$Y_j^{(\theta_1)} = \alpha_0 + \sum_{K=1}^{K} \alpha_k X_{kj}^{(\lambda_1)} + \sum_{\ell=1}^{L} \beta_\ell Z_{\ell j} + \varepsilon_j \qquad \text{(B2)}$$

where Y is the dependent variable (total project cost) subject to a Box-Cox transformation with parameter $\theta_1$, i.e., $Y^{(\theta_1)} = (Y^{(\theta_1)} - 1)/\theta_1$, $X_k$ (k = 1, 2, …, K) are explanatory variables transformed by a Box-Cox transformation with parameter $\lambda_1$, i.e., $X_k^{(\lambda_1)} = (X_k^{(\lambda_1)} - 1)/\lambda_1$, $Z_\ell$ ($\ell$ = 1, 2, ..., L) are explanatory variables without transformation, and $\varepsilon \sim N(0, \sigma^2)$.[43]

As the dependent variable, we use the total project cost and the total hardware cost, alternatively. Of the variables listed in table 1, all those from project size down to donor are used as explanatory variables.[44] Among the explanatory variables, the variables that are continuous without non-positive value are selected for X's, i.e., explanatory variables subject to the Box-Cox transformation. The rest of the explanatory variables are Z's, which are grouped into two. The variables in the first group, from time overrun to sizing error, are continuous variables with non-positive values, for which we assume l = 1, i.e., the original linear form. The variables in the second group are binary dummy variables; 1 (one) if applicable and 0 (zero) if not. Of these, for category variables from type of project to donor, one variable each from each category must be omitted as the base when used in regression. The variables chosen for the base are irrigation, rehabilitation, river-diversion, government agency, paddy, South Asia, and WB, respectively.

The same mode is applied for the project size equation, except that $X_i$'s do not include the project size:

$$X_{1j}^{(\theta_2)} = \delta_0 + \sum_{K=2}^{K} \delta_k X_{kj}^{(\lambda_2)} + \sum_{\ell=1}^{L} \gamma_\ell Z_{\ell j} + \varepsilon_j \qquad \text{(B3)}$$

where $X_1^{(\theta_2)} = (X_1^{(\theta_2)} - 1)/\theta_2$, and $X_k^{(\lambda_2)} = (X_k^{(\lambda_2)} - 1)/\lambda_2$ .

With the Box-Cox equations above, the elasticity of the unit cost with respect to a transformed variable is given as follows:

$$\frac{\partial \left( Y/X_1 \right)}{\partial X_k} \frac{X_k}{\left( Y/X_1 \right)} = \alpha_k \left( \frac{X_k^{\lambda_1}}{Y^{\theta_1}} \right) - \delta_k \left( \frac{X_k^{\lambda_2}}{X_1^{\theta_2}} \right) \qquad \text{(B4)}$$

where $X_1$ is the project size and $X_i$ (k = 2, 3,… , K) is a transformed explanatory variable. Similarly, the elasticity for non-transformed variables is given as follows:

$$\frac{\partial \left( Y/X_1 \right)}{\partial Z_\ell} \frac{Z_\ell}{\left( Y/X_1 \right)} = \beta_\ell \left( \frac{Z_\ell}{Y^{\theta_1}} \right) - \gamma_\ell \left( \frac{Z_\ell}{X_1^{\theta_2}} \right) \qquad \text{(B5)}$$

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[43] An even more general Box-Cox model is to assume different values for λ for different independent variables subject to the transformation. A huge computational burden of such a model precludes us from adopting it.

[44] An exception is bank input for appraisal, which is not used in the regression analysis because many projects miss this information.

where $Z_\ell$ ($\ell$ = 1, 2, …, L) is a non-transformed explanatory variable. The elasticities may be evaluated at the mean for continuous variables and at unity for binary variables.

We are as interested in the factors that determine the performance of irrigation projects as the factors that affect the cost of these projects. For this purpose, we conduct a regression analysis in a similar manner as for the cost regression, using the EIRR at project completion or audit of each project as the dependent variable, with the same set of explanatory variables for the cost regression. Since EIRR takes a non-positive value, $\theta$, the Box-Cox parameter for the dependent variable, is assumed to be unity.

With little prior information on factors that affect project costs and performance, as explained earlier, we adopt it as a basic strategy in the regression estimation to use all the explanatory variables available in our database.[45]

## Results of Estimation

The results of Box-Cox estimations for the total project cost, the total hardware cost, the project size, and the EIRR using the entire sample of 314 irrigation projects are summarized in Appendix A, table A5. The estimated elasticities are presented in table 13 in the main text.

[45] For the purpose of our study, it is ideal if we can adopt regression analysis for the SSA sample as well as for the entire sample, so as to conduct a statistical test to check if SSA shares the same structure as to the cost and EIRR regressions with the entire sample. Unfortunately, the SSA sample (N=45) is too small to adopt our Box-Cox model, so that in this study we confine our regression analysis to the entire sample.

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