Chapter 2
Indirect Economic Impacts of Dams

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2.1 Introduction

Dam projects generate a vast array of economic impacts—both in the region where they are located, and at inter-regional, national and even global levels. These impacts are generally evaluated in terms of additional output of agricultural commodities, hydropower, navigation, fishing, tourism, recreation, prevention of droughts and reduction in flood damages, and are referred to as direct impacts. The direct impacts, in turn, generate a number of indirect and induced impacts as a result of:

- Inter-industry linkage impacts, including both backward and forward linkages, which lead to increase in the demand for and outputs of other sectors.
- Consumption-induced impacts arising as a result of increase in incomes and wages generated by the direct outputs of the dam.

To illustrate, hydropower produced from a multipurpose dam provides electricity for households in urban and rural areas and for increased output of industrial products (e.g. fertilisers, chemicals, machinery). Changes in the output of these industrial

This chapter is based on a larger study on the subject sponsored by the World Bank and carried out by a number of researchers. For details see Ramesh Bhatia, Rita Cestti, Monica Scatasta and R.P.S. Malik (eds), Indirect Economic Impacts of Dams: Case Studies from India, Egypt and Brazil, Academic Foundation, New Delhi and World Bank, 2008.

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Table 2.1 Values of variables required for the estimation of a project multiplier

Definition of project multiplier =	Regional value added with project minus regional value added without project / Value added of agriculture and electricity with project minus value added of agriculture and electricity without project

commodities require increased inputs from other sectors such as steel, energy and chemicals, among others. Similarly, water released from a multipurpose dam provides irrigation that helps increase output of agricultural commodities. Increases in the output of these commodities require inputs from other sectors such as energy, seeds and fertilisers. Further, increased output of some agricultural commodities encourages the establishment of food processing and other industrial units. Thus, increased outputs of both electricity and irrigation from a dam result in significant backward linkages (i.e. demand for higher input supplies) as well as forward linkages (i.e. providing inputs for further processing).

Increased outputs of industrial and agricultural commodities generate additional employment, wages and incomes for households. Higher incomes result in higher consumption of goods and services which, in turn, encourage production of various agricultural and industrial commodities. Further, changes in output generated by the project may affect prices of direct project outputs, inputs, substitutes, complements and factors of production. Changes in wages and prices have both income and substitution effects on the expenditure and saving decisions of different owners of factors, which further impacts the demand for outputs within the region and throughout the economy. Induced impacts reflect the feedbacks associated with these incomes and expenditure effects, and also include any impacts of changes in government revenues and expenditures that result from the project.

The magnitude of indirect impacts of a dam via the inter-industry linkages and consumption-induced impacts depend on the strength of linkages amongst various sectors within the given economy. Multiplier analysis provides an approach for quantifying the magnitude of inter-industry linkages and consumption-induced effects in relation to purely direct impacts. As shown in Table 2.1, in order to estimate a project multiplier value for a dam (say the Bhakra Dam), for the numerator we need to estimate the regional value added (for the region where it is located, in this case Punjab, a state in India) under the 'with project' situation as well as under the 'without project' situation. For the denominator, we need to estimate the value added from the sectors that are directly affected by the major outputs of the dam (namely, agricultural output, hydroelectricity, water supply, etc.). A multiplier value of 1.90, for instance, indicates that for every dollar of value added generated directly by the project at maturity, another 90 cents are generated in the form of indirect or downstream effects.

Practitioners and policy analysts, though conscious of these indirect impacts of dams, have for a long time felt the need for their proper appraisal and quantification. The World Commission on Dams (WCD) Report and numerous other studies have discussed the importance and difficulties of evaluating indirect impacts of dams.

According to the WCD Final Report, 'a simple accounting for the direct benefits provided by large dams—the provision of irrigation water, electricity, municipal and industrial water supply, and flood control—often fails to capture the full set of social benefits associated with these services. It also misses a set of ancillary benefits and indirect economic (or multiplier) benefits of dam projects' (WCD 2000). As noted by the Operations Evaluation Department of the World Bank, 'dams providing water for irrigation also produce, in general, substantial benefits stemming from linkages between irrigation and other sectors of production. Unfortunately, there are no estimates available on the indirect benefits of the projects reviewed in the OED report' (World Bank 1996).

The present chapter attempts to move one step forward in bridging this information gap and addressing the felt need of improving our understanding of the impacts of dams. The chapter puts forward a methodological framework for estimation of multipliers and illustrates this framework by providing quantitative estimates of the indirect economic impacts and multipliers in respect of three large dams located in different parts of the World: Bhakra Dam (India), High Aswan Dam (Egypt), and Sobradinho Dam and the set of cascading reservoirs (Brazil). The salient features of the dams selected for these case studies are presented in Table 2.2.

2.2 Analytical Framework for the Estimation of Multipliers

A number of analytical tools for estimating multiplier effects have been suggested in the literature (Bell et al. 1982; Hazell and Ramasamy 1991; Haggblade et al. 1991; Hoffman et al. 1996; Aylward et al. 2000). These tools, which are essentially in the nature of multi-sector models, include: (i) input–output (I/O) models, (ii) social accounting matrices (SAM)-based models and (iii) computable general equilibrium (CGE) models. We briefly describe the three analytical tools below.

2.2.1 Input–Output (I/O) Models[1]

The core around which all economy-wide, multi-sector models are built is the input–output model pioneered by Leontief (1953, 1970). Input–output analysis is a way to trace the flow of production among the sectors in the economy, through the final

[1] Semi-input-output (S-I/O) models represent a variant of I/O models whereby a distinction is made between tradable and non-tradable goods. The former are assumed to have an exogenously set domestic level of output, so that any change in demand will be reflected in a change in exported quantities. In terms of domestic production, therefore, the whole brunt of demand shocks is borne by non-tradable goods. The implication of this distinction is that induced, consumption-based impacts will reverberate throughout the economy only via adjustments in non-tradable goods and their inter-industry linkages. This characterisation is important, in that it refines the representation of the specific regional structure of production, reducing the risk of overestimating induced impacts that are not felt by regional sectors.

Table 2.2 Salient features of selected dams

Dam and location		Height of dam/type of dam/size of reservoir	Area irrigated/production of foodgrain per year	Installed capacity (MW)/annual generation (kWh)	Urban water use and development	Persons benefited	Persons resettled
Bhakra Dam (B), Pong Dam (P) and Nangal Dam (N)[a]	India	225 m/concrete and earth-filled/18 BCM	10.3 million ha/27 million tons grain	2,800 MW/14 billion kWh	Water for cities in two states and Delhi	34 million	32,000 (B); 100,000 (P)
Aswan High Dam	Egypt	111 m/rock-filled/164 BCM	2.65 million ha/production of foodgrain per year is not available	2,100 MW/8–10 billion kWh	Aswan city: Value of production quadrupled	40 million	100,000
Sobradinho Dam (S) and Cascade of Reservoirs (C)[b]	Brazil	41 m × 8.5 km 4,214 km^2 (area)/34.1 BCM	São Francisco Basin: 400,000 ha (120,000 ha are public but private is growing faster); high-value crops/production of foodgrain per year is not available	1,050 MW (S) 9,800 MW (C)/annual generation (kWh) is not available	Water for cities and towns in numerous Brazilian states	40 million (with hydropower) 5.5 jobs/ha (incl. induced urban empl.)	120,000 (C)

BCM billion cubic metres

[a]Bhakra Dam system includes Bhakra Dam, Pong Dam and Nangal Dam

[b]The set of cascading reservoirs include ltaparcia (Luis Gonzaga) Dam, the Paulo Afonso I-IV Complex, Moxoto (Apollonio Sales) Dam and Xingo Dam. The latter is not part of this analysis since it became operational in 1995

domestic or export demand. The essence of I/O analysis is that it captures the interrelatedness of production arising through the flow of intermediate goods among sectors. The fundamental input–output problem is that of a planner who wants to determine the appropriate adjustments in economic quantities throughout the economy in order to achieve a specific final output (Hewings 1985; Dervis et al. 1982).

I/O models are based on an accounting framework that records all inter-industry flows at the chosen level of disaggregation, final demand (household, government, investment and export), factor remuneration and total imports. Columns in an I/O table record payments from the column sector to other industries, factors and imports. Their totals represent total gross inputs for a sector. Rows represent all receipts for a row sector from the columns (other industries and final demand categories), with their totals representing total gross output. Inter-industry linkages are based on a fixed coefficient Leontief matrix, which eliminates any substitution possibilities for producers. Similarly, factor wages are fixed value-added proportions of total gross output.

These models evaluate indirect and induced economic impacts by computing multipliers embodying the impact of a unitary change in one sector's output—due to an exogenous change in final demand—onto the output of other sectors, income and employment. The existence of a multiplier depends on drawing unused or underused resources into more productive economic activities (Haggblade et al. 1991), so that the presence of such underutilised resources in the region of interest is crucial for the existence of multiplier impacts as estimated by this class of models. Leontief or output multipliers only reflect the degree to which industrial sectors are linked with each other and the strength of such linkages, but tell us nothing about the larger or smaller impact on a regional or national economy of increased demand for the output of any of those sectors. The main limitation of this model is that it assumes linearity in production and cost-determined prices independent of demand.

2.2.2 Social Accounting Matrices (SAM) Models

More recently, I/O linear models have been applied to databases that extend the I/O table to include the distribution of income among 'institutions' (i.e. household categories, firms, government), to better represent their expenditure, and to distinguish between production activities and produced commodities. A SAM is an economy-wide data framework that represents the circular flow of income and expenditure in the economy of a nation or region. Again, each cell represents a payment from a column account to a recipient row account. A distinction between SAM-based multiplier analysis and I/O models is that SAM explicitly traces the distribution of factor incomes to institutions. Thus, such models are able to account for the way in which initial asset distribution and factor endowments interact with the structure of production in determining final outcomes, particularly for welfare analysis. This capacity is also enhanced by the fact that SAMs generally comprise numerous household groups.

Each cell of the SAM can be seen as a 'block' representing sets of transactions. As row and column totals must be equal, expressions linking row and column elements with their totals can be used to form a system of linear equations that embodies market, behavioural and system relationships. The first has to do with the accounts relative to goods and factor markets. Behavioural relationships regard the budget constraints of the economic agent or the institution represented in the SAM. Finally, system relationships regard the capital and rest of the world accounts, where macroeconomic (internal and external) balances are represented. This system can then be used to estimate project multipliers.

2.2.3 Computable General Equilibrium (CGE) Models

As policy makers' capacity to directly control quantity variables—as is implicitly assumed by linear I/O and SAM-based linear models—declines, and the use of market incentives to affect them becomes more important, it is crucial to understand how markets respond to different sets of policy interventions. CGE models are well suited to this purpose, providing a framework where endogenous prices and quantities interact to simulate the workings of decentralised markets and autonomous economic decision-makers. Following the pioneering efforts of researchers (Adelman and Robinson 1978; Taylor et al. 1980), standard CGE models have been extensively used to study policy impacts on income distribution, growth and structural change in developing economies. A CGE model is a system of simultaneous nonlinear equations that provide a complete and consistent picture of the 'circular flow' in an economy, capturing all market-based interactions among economic agents.

Four features distinguish CGE models from Leontief's input–output modelling tradition: (i) price endogeneity, as opposed to quantity adjustments, to reach an equilibrium, (ii) price-responsive input and output substitutability—perfect or imperfect—through the use of non-linear supply and demand equations (Robinson 1989), (iii) the abandonment of the perfect dichotomy between traded and non-traded goods from traditional I/O models and (iv) factor supply constraints, which generate output supply constraints.

2.3 Choosing the Right Analytical Tool and the Analytical Models Used in the Case Studies

From the point of view of the analysis of indirect and induced impacts of dam projects, the choice of analytical tool should not always favour the most sophisticated tool, but rather be driven by the assumptions regarding the mechanisms through which impacts are transmitted in the specific region of interest—particularly factor mobility. When prices are assumed fixed, as in I/O or SAM-based multiplier analysis, all adjustments occur through quantity changes. In the absence of supply constraints, adjustments occur via impacts on labour or capital employment and

Table 2.3 Case studies and methodologies for the estimation of multiplier effects and income distribution impacts of dams

Case study	Methodology	Outputs
Bhakra Dam, India	Social accounting matrix (SAM)-based multiplier model and linear programming model	Value-added multipliers and income distribution and poverty reduction impacts
High Aswan Dam, Egypt	Computable general equilibrium (CGE) model coupled with mathematical programming model for the water sector	Value-added multipliers and income distribution
Sobradinho Dam and Reservoirs, Brazil	Semi-input/output model for multiplier analysis only	Value-added multipliers

inter-regional factor migration. The presence of idle labour or capacity in the system—either locally or in other regions, if the model is inter-regional—is thus crucial for the existence of quantity-driven multiplier impacts as estimated by these models.

On the other hand, a variable-price model, such as a standard CGE,[2] implies the presence of supply constraints, so that for at least one factor the aggregate levels of factor employment are fixed. In this case, a change in sectoral demand results in relative price changes, determining substitution effects among inputs and among outputs, with factor reallocation across sectors in the regional economy. If available, a CGE could also be used to compute SAM-based, fixed-price multipliers analysis, making it possible to highlight the differential impacts that can be seen when considering changes in relative prices, factor mobility and wage differentiation.

Often the selection of a suitable analytical tool for multiplier analysis of a dam critically depends on the availability of I/O tables or SAM databases and models for a region. For estimation of the indirect and induced impacts, for multipliers and income distributional analysis, we have used different analytical techniques in the three case studies (Table 2.3).

2.4 Summary Results of Case Studies

2.4.1 Multiplier Effects of the Bhakra Dam, India

The Bhakra Dam in the northern part of India has contributed significantly to the increases in the output of agricultural commodities and electricity over the last 45 years or so. Additional gross irrigated area has been of the order of about 7 million ha. Total foodgrain production in the Bhakra command area during the year 1996–1997 was of the order of 27 million tons—an additional output of 24.6 million tons compared to the food output in the early 1960s. The hydropower stations installed in

[2] A Social accounting matrix can feed into a standard CGE model.

the Bhakra system have a combined generating capacity of 2880 MW, which currently generate about 14,000 million units (kWh) of electricity in a year. These increases have inevitably generated downstream growth in many other sectors of the regional economy as well as in other parts of the country.

Substantial marketed surplus of foodgrains in the states of Punjab and Haryana have provided foodgrains for urban poor all over India at relatively low food prices through 'fair price shops'. Such surplus foodgrains have been used for 'food for work' programmes in many states thus helping the rural poor, especially during drought conditions, and generating multiplier effects. Hundreds of thousands of migratory workers from underdeveloped areas of Bihar and Uttar Pradesh have sent large amounts of remittances creating further multiplier effects in those regions.

The case study employs a SAM-based analytical framework to estimate regional value-added multipliers arising from inter-industry linkages of production and consumption-induced effects. The SAM-based model has been used to estimate the outcomes of 'with project' and 'without project' scenarios. Simulation results obtained for 'without project' situations are compared with the values of relevant variables as estimated in the SAM for 1979–1980 representing the 'with project' situation. The analysis has been done for a year (1979–1980) for which adequate data were available from a detailed study (Bhalla et al. 1990) of the input–output structure of the Punjab economy.

The aspects of the dam that have been analysed include: changes in area irrigated, changes in supplies of electric power and changes in yields and production technology (primarily in fertiliser use) that would have been likely in its absence. Relevant variables comprise all the elements of the regional SAM, assuming fixed prices. The effects are divided into direct and indirect. The indicators capturing the effects include production, trade, as well as disaggregated household incomes and their distribution.

The multiplier has been estimated under two alternative scenarios about the groundwater availability in the absence of dam. Table 2.4 presents a summary of the estimates of regional value added under 'with' and 'without project' scenarios and of how these have been used to estimate multiplier value under the two assumptions.

As shown in Table 2.4, the multiplier values under the two scenarios work out to 1.90 and 1.78. Thus, for every rupee (Rs) of additional value added directly by the project in agricultural and electricity sectors, another Rs 0.90 (in the first scenario) and Rs 0.78 (in the second scenario) were generated in the form of downstream or indirect effects.

The income distribution impacts of the Bhakra Dam have been analysed by comparing the differences in aggregate income levels of various household categories under 'with' and 'without project' scenarios and by assessing direct and indirect components of income differences under the two situations. Figures 2.1 and 2.2 summarise the results obtained.

The results obtained signify the following:

- The dam provides income gains to all categories of households, including urban households, and that percent increase in income of agricultural labour households is higher than that of landed households. This poorest group (agricultural labour) registered a 65% increase in income as compared to a rural average

Table 2.4 Estimated values for multiplier effects of the Bhakra Dam, India

Definition of multiplier	$\dfrac{\text{Regional value-added with project minus Regional-value added without project}}{\text{Value-added of agriculture and electricity with project minus Value-added of agriculture and electricity without project}}$
Value under assumption I (million Indian Rupees)	$\dfrac{42,379-32,878}{15,343-10,343}=1.90$
Value under assumption II (million Indian Rupees)	$\dfrac{42,379-30,729}{15,343-8,807}=1.78$

Note: Assumption I: Assuming that under 'without project' situation, groundwater use will be at 50% of the use in 1979–1980 (under 'with project' situation) and additional thermal power equal to 50% of hydro output will be available
Assumption II: Assuming that under 'without project' situation, groundwater use will be at 50% of the use in 1979–1980 (under 'with project' situation) and no additional power will be available from thermal sources

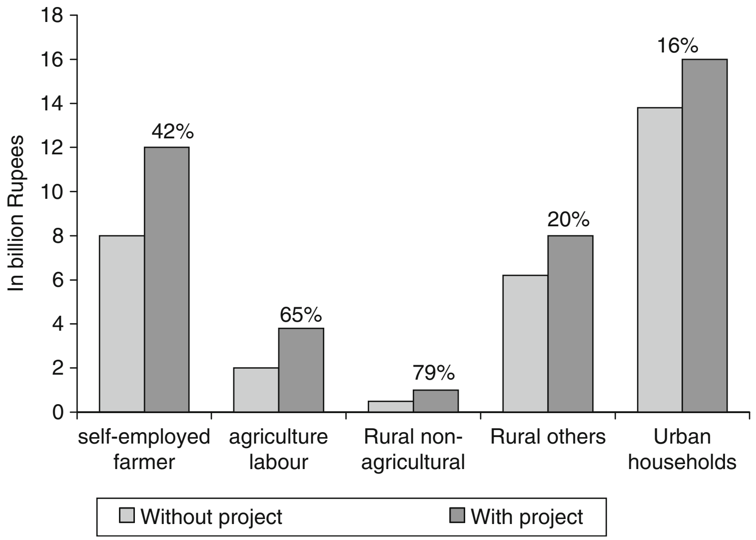

Fig. 2.1 Income of different types of households with and without Bhakra Dam, India. (The percentage figures indicate increase in income under the 'with project' scenario)

increase of 38% (under the 'with project' scenario as compared to the hypothetical 'without project' scenario).

- The gains from dams for different categories of households emanate from different sources. While landed households, agricultural labour and rural non-

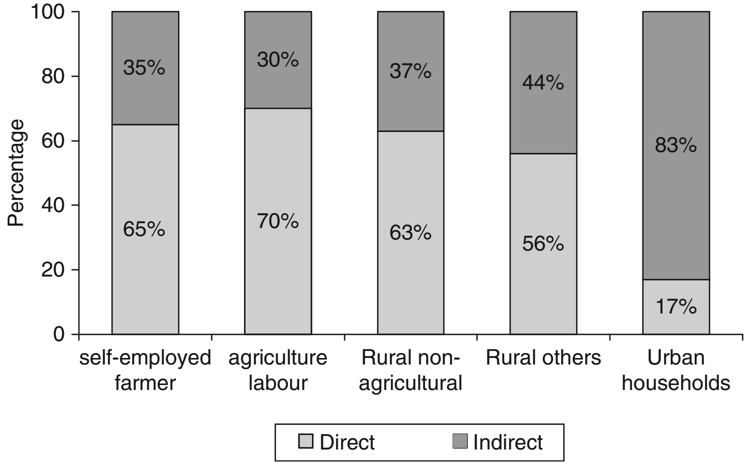

Fig. 2.2 Income gains to households by sectors affected directly and indirectly by the Bhakra Dam, India

agricultural labour households derive larger gains from the sectors directly affected by the project, rural other households and urban households derive larger gains from indirectly impacted sectors.

2.4.2 Multiplier Effects of the High Aswan Dam, Egypt

The economic benefits of providing highly reliable and non-flooding water supply to Egypt through the High Aswan Dam have been as follows: (i) It has saved Egypt from devastating floods resulting in lost summer harvests, damage to infrastructure and potential loss of life. (ii) Dam water has been used to reclaim 1.3 million new *feddans*.[3] (iii) Perennial irrigation of one million *feddans* has replaced basin irrigation. (iv) Rice and sugar cane production has increased considerably. (v) It has enabled the average generation of 8 billion kWh used in industry and the electrification of all towns and villages in Egypt. (vi) It has facilitated navigation up and down the Nile all the year round. Table 2.5 shows the actual crop areas in 1995, 25 years after the High Aswan Dam, compared with pre-dam areas. It shows major increases in areas of wheat, maize, rice and sugar cane cultivation, and a major decrease in the area for cotton.

This case study assesses the impact of the High Aswan Dam in Egypt from an economy-wide perspective. The primary analytical tool used is a CGE model. The study also shows that SAM multiplier analysis—characterised by the assumption that the prices of commodities, factors and foreign exchange are fixed—is a special case of CGE analysis. The model is built around a 1996–1997 SAM for Egypt

[3] A feddan is equal to 1.038 acres.

Table 2.5 Cropped area, before and after High Aswan Dam, Egypt

Crop	1970	1995
Wheat	1387	1829
Maize	1727	1906
Millet	469	346
Rice	799	1276
Cotton	1751	884
Sugar cane	122	274

complemented by a wide range of additional information. The analysis consists of a set of comparative-static simulations under alternative assumptions about the workings of the economy. The simulations are used to assess how Egypt's economy would have performed in 1996–1997 without the dam and how the economy, with and without the dam, would have been affected by year-to-year variations in Nile flows.

The scenarios without the dam consider the impact of changes in the supplies of irrigated land and water, changes in the supplies of electric power, changes in yields and production technology (primarily changes in fertiliser use) and real costs associated with the investment relative to other investments (in flood control and hydropower) that would have been likely in its absence. The 'without dam' scenarios also consider the implications of the fact that the performance of Egypt's economy in each year would have depended on Nile flow levels. Monte Carlo simulations have been used to assess the impacts of their stochastic nature in the absence of the dam. The CGE model is calibrated to account for water requirements for specific crops. In addition, the model explicitly models water balances across seasons.

Three simulations have been considered. In simulation 1 (SIM 1), all factor prices adjust to clear factor markets, assuming exogenously specified aggregate employment of labour and capital. In SIM 2, the labour wage is fixed and labour supply adjusts freely to clear the labour market—there is no aggregate employment constraint. In SIM 3, both the wage and the return to capital are fixed, assuming unlimited supplies of labour and capital are available at the fixed wages.

A CGE model with all factor prices fixed, and hence with no supply constraints, operates like a fixed-price, multiplier model. Because factor prices are fixed, output prices must also be fixed, given standard cost functions. Output is completely demand determined. In fact, this model is not completely demand driven because land and water are assumed to be in fixed supply. The result is a kind of 'constrained multiplier model', which will behave like a SAM multiplier model. In SIM 2, with only labour unconstrained, one would expect the multipliers to be smaller than in SIM 3, where both labour and capital are unconstrained. SIM 2 seems like a reasonable specification for a country in which there is excess labour. In SIM 1, all aggregate factor supplies are fixed, and the model will operate like a standard neoclassical CGE model.

The results of value-added multipliers under the three scenarios are presented in Table 2.6. The value-added multipliers range between 1.22 and 1.4 in the three simulations. The multiplier value of 1.4 implies that for every Egyptian pound (LE) of value added in directly impacted sectors, another 0.4 LE of value added is generated through inter-industry linkages and consumption-induced effects.

Table 2.6 Multiplier results for the High Aswan Dam (HAD)

	'With HAD' minus 'without HAD'		
	SIM 1	SIM 2	SIM 3
Value added of directly impacted sectors[a] (LE billion)	3.1	5.3	22
Total value added	3.8	6.5	30.9
Multiplier	3.8/3.1 = 1.23	6.5/5.3 = 1.22	30.9/22 = 1.40

[a]Directly impacted sectors—agriculture, hydropower, navigation and tourism

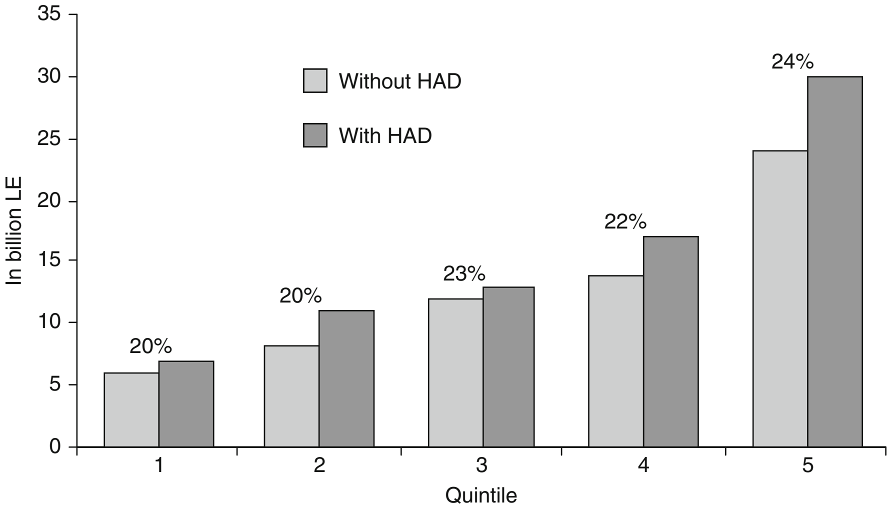

Fig. 2.3 Rural consumption by quintile, High Aswan Dam (HAD). (The percentage figures represent the percent difference between with and without HAD)

In order to trace the income distribution impacts of High Aswan Dam, we look at the consumption levels of different quintiles with and without the High Aswan Dam. Figure 2.3 shows consumption by quintile of the rural population with and without the dam, and Fig. 2.4 shows the corresponding quintile-wise consumption of the urban population. In the 'with project' situation, the lowest 20% (first quintile) of the rural population in Egypt accounted for 10.5% of the total rural income. The gain for this group is a 20% increase compared to a rural average increase of 22% (under the 'with project' scenario as compared to 'without project' scenario). Thus the gain for the poorest group is less than the rural average.

The above analysis thus suggests the following:

- The High Aswan Dam was, and is, a good investment, yielding significant annual net returns. The model analysis of net benefits is conservative, ignoring some benefits, which are significant but difficult to model (e.g. the elimination of major damages from periodic serious flooding).
- For agriculture, the existence of the dam allowed Egypt to pursue policies that distorted agricultural production, yielding a cropping pattern that favoured

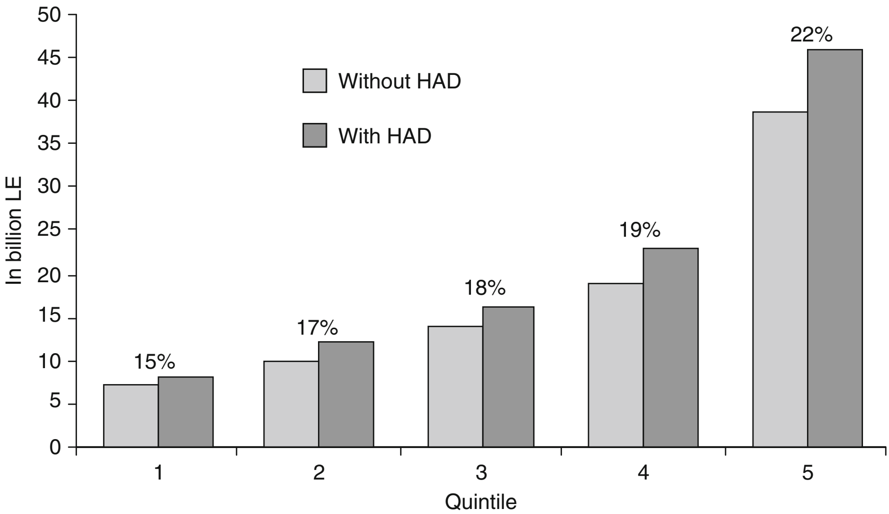

Fig. 2.4 Urban consumption by quintile, High Aswan Dam (HAD)

low-value crops that made inefficient use of both water and land. Reducing summer water and using the remaining water efficiently would yield increases in the value of agricultural production. With or without the dam, eliminating these distortions would greatly increase efficiency in the Egyptian agriculture.

Given the distortions in agricultural production, the largest gains from the dam arise from non-agricultural sources: hydropower, transportation and tourism.

2.4.3 Multiplier Effects of Sobradinho Dam and Cascade of Reservoirs in Brazil

This case study focuses on the complex of large dams and reservoirs built along the Sub-Médio São Francisco River, in one of the driest regions of Brazil's semi-arid north-east. The construction of the Sobradinho Dam in 1973–1979, was one of the most important factors in transforming the region's economy, society and landscape. The Sobradinho Lake has a surface area of over 4,000 km^2, stores 34,000 million cubic metres (MCM) and aliments a hydropower plant with a 1 GW capacity. The flow stabilisation that it provided enabled the construction of downstream reservoirs that form a hydropower complex with an installed capacity of almost 10 GW. These plants are operated by the São Francisco River Hydropower Company (CHESF), which serves over 40 million people in an area of about 1.2 million km^2—14.3% of Brazil's territory. The study characterises more precisely the benefits from hydropower generation by the selected dams, estimating the induced growth impacts generated by the creation of the north-north-east electric *pólo*.[4]

[4] It refers to regional development districts.

The dams also provided reliable water supply for investment in large irrigation projects and reduced risks for private irrigators. This has transformed agriculture production in the region (Nishizawa and Uitto 1995), with significant increases in planted area and output for high-value crops—especially permanent crops, such as mango and grapes—between 1975 and 1995. The Petrolina/Juazeiro district, located along the Sobradinho Reservoir, is now the major producer of table grapes in the country, accounting for 80% of Brazil's grape exports and 70% of mango exports, with its products headed primarily for Europe and the USA. In addition, integration between small, medium and large farmers has increased, generating both on-farm and off-farm employment (de Janvry and Sadoulet 2001) for both land-owning and landless rural populations. Recent analyses have shown that significant positive spillovers for smaller producers are taking place (Rodrigues 2001; Vergolino and Vergolino 1997). Agricultural growth has also spurred indirect and induced benefits through its linkages with the rest of the regional economy, benefiting populations in what is a largely urbanised area (around 60%).

The study uses an I/O model to estimate multipliers associated with the various products of the dams. The model is based on a 1992 I/O table for north-east Brazil, disaggregated at 31 productive sectors and 39 final products. It is important to note that prior to the construction of the Sobradinho Dam, the north-east economy of Brazil was characterised by the presence of considerable unused or underused resources. This is a crucial condition for the existence of quantity-driven multiplier impacts as estimated by fixed-price models (Haggblade et al. 1991).

The model analyses the impacts of eliminating one or more of the studied dams on the 1992 economy—a year of normal operation for them. The analysis does not attempt to produce a full counterfactual describing alternative development paths the region might have followed in the absence of these dams. The study simulates nine alternative 'without project' scenarios by combining three alternative scenarios each about hydropower availability and irrigation availability. The three alternative scenarios about power generation are as follows:

HLO: Sobradinho is not built, with no impacts on the output of the downstream stations existing in 1992 (i.e. they are not negatively affected by less reliable flows, nor do they increase their share in generation); no additional thermo or hydropower generation is installed; power generation declines by 14%.

HME: Sobradinho and Itaparica are not built, and we assume that this would force Paulo Afonso IV to operate at 50% of its 1992 capacity; we also assume that both small hydropower developments and thermal capacity would increase by a factor of 2.5; power generation declines by 43%.

HHI: The extreme scenario assumes that Sobradinho and Itaparica dams are not built, that this prevents the operation of Paulo Afonso IV and that no additional small hydro or thermal capacity is added to the system; the worst-case scenario sees a 66% decline in power generation.

Regarding availability of irrigation in 'without project' cases, the following alternative scenarios were formulated:

Table 2.7 Value-added multipliers under supply-constrained combined scenarios

Scenario	HLO+ ALO	HLO+ AME	HLO+ AHI	HME+ ALO	HME+ AME	HME+ AHI	HHI+ ALO	HHI+ AME	HHI+ AHI
Multiplier	2.078	2.029	2.007	2.101	2.075	2.059	2.105	2.087	2.074

ALO: Only public irrigation projects in the Sub-Médio São Francisco—downstream of Sobradinho and upstream of Xingó—are not undertaken if the dams are not built, resulting in a 41,000 ha reduction in irrigated area.

AME: All irrigated land in the Sub-Médio São Francisco area (141,000 ha) becomes rain fed.

AHI: The extreme value adopted for a 'without project' case is a 75% decline in the basin's irrigated area (225,000 ha).

Combining these sets of assumptions, we obtain a grid of nine alternative combined 'without project' scenarios. The estimated multiplier values in the nine cases are given in Table 2.7.

The simulation results of a supply-constrained semi-I/O model for Brazil's northeast macro-region show that the large dams located in the Sub-Médio São Francisco have generated significant indirect and induced effects in the region. Value-added multiplier values are close to 2.0 in most scenarios. For every unit of value generated by the sectors directly affected by the dams, another unit could be generated as an indirect impact in the region. It may, however, be noted that under the unconstrained supply assumption, value-added multipliers are 10–18% larger. Under this assumption, the multipliers range between 2.28 and 2.4, which are comparable with other case studies in the present chapter.

Beyond the magnitude of these impacts, what matters is the information they provide regarding the structure of benefits that can be attributed to the dams. The results suggest that larger overall impacts might have been achieved if more attention had been given to multipurpose use of their water.

2.4.4 Value-Added Multipliers: A Comparison of the Case Studies

Although in all three case studies there is a common objective of estimating indirect economic impacts of dams, the results obtained are not strictly comparable due to differences in methodology, data sets used and underlying conditions prevailing in the three sites. We nevertheless present in Table 2.8 a summary comparison of the estimated values of value-added multipliers for the three case studies.

For the Bhakra Dam in India, estimates of multipliers range between 1.78 and 1.9 depending on assumptions about the impact of seepage from canals on the availability

Table 2.8 Value-added multipliers: comparative results of three case studies

Case study	Country	Methodology	Regional value added or income multiplier values under alternative assumptions
Bhakra Dam	Northern India	Social accounting matrix (SAM)-based model	1.78–1.9
High Aswan Dam	Egypt	Computable general equilibrium (CGE) model	1.22–1.40
Sobradinho Dam and the set of cascading reservoirs	Brazil	Semi-input/output model	2.28–2.40

of groundwater for irrigation and the availability of additional thermal power in the absence of the Bhakra Dam. In the case of the High Aswan Dam, the value-added multiplier values range between 1.22 and 1.4 in the three simulations. The multiplier values in the case study of Sobradinho Dam (and the set of cascading reservoirs) in Brazil range from 2.28 to 2.4 under the assumptions of unconstrained supply of labour and capital. The multiplier values for Brazil under supply-constrained scenarios for selected sectors, the value-added Type II multiplier values are close to 2.0 in most scenarios (Type II multipliers, in addition to the direct and indirect impacts, also include inducedimpacts).

2.5 Conclusions

The results on value-added project multipliers suggest that in addition to having direct impacts, large dams have significant indirect and induced impacts, which must be accounted for and taken into consideration in project evaluation. The income distribution impacts, in respect of two of the three dams which permitted such an analysis, also suggest that gains from the dams are shared by all sections of society, including people living in urban areas.

In both the High Aswan Dam and the Bhakra Dam, rural households gained more (in percentage terms) than urban households when income levels under ‘without’ and ‘with project’ scenarios are compared. In the case of High Aswan Dam, the income gains for the lowest income groups (poorest) in the ‘with project’ situation as compared to a ‘without project’ situation was 20%, in contrast to a rural average increase of 22%. Thus, the gains for the poorest group were slightly less than the rural average. In the Bhakra case study, however, rural agricultural labour households that account for 23% of the total rural population, gained a 65% increase in income as compared to a rural average increase of 38% (under the ‘with project’ scenario compared with a hypothetical situation where the project had not been undertaken). Thus, the estimated gain for the poorest group was much higher than that for the average, and was also higher than that for landed farmers. Such a result signifies an important implicit message: the dams act as a powerful vehicle for poverty alleviation.

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