Introduction

The growing demand for freshwater resources has increasingly focused the attention of governments, donors, and civil society on the importance of the cooperative management of international rivers for economic growth, environmental management, and geopolitical stability. Africa has many international rivers and extreme rainfall variability, which give rise to real challenges in managing water resources as well as real opportunities for mutual gain through the cooperative management of shared waters.

Cooperation in international rivers management is fundamentally a political activity. An economic perspective can, however, help clarify the economic, social, and environmental tradeoffs inherent in political decisions and provide an objective language and framework within which cooperative opportunities can be identified and explored. Economic tools can also be used to design alternative management schemes that may not be immediately apparent to political leaders and to analyze the incentives the various schemes offer to riparians.

This paper presents some fundamental economic concepts and ideas that can assist managers of international water resources, particularly those in Africa. Part I focuses on that continent's international shared waters and natural, cultural, and historical legacies. It provides a broad overview of numerous shared rivers and some basic insights into riparian dynamics and the feasibility of cooperative management.

Part II examines the economics of international rivers. First, it explores the broad links between water resources management and economic growth and poverty. Next it focuses on the concept of water as an economic good and the implications this has for management. Alternative constructs of the costs and values of water, from the narrowly defined costs and values of water to individual users, to the wider costs and values of water to societies and ecosystems, are then presented. Two alternative approaches for calculating the value of water are then presented—user values and system values. This is followed by a brief discussion of the ways in which economic tools can be used to both inform and implement water resources management decisions.

Part III explores the challenges of cooperative, transboundary management. The first one is to identify the benefits of cooperation. The multidirectional nature of externalities in international river basins is examined in this context. The second—and sometimes greater—challenge is to design and negotiate management regimes that are both feasible and fair. This discussion emphasizes the analysis of incentives for riparians in specific regimes and criteria that may be used to assess fairness. Finally, the paper explores some principles, practices, and mechanisms of benefit sharing in the cooperative management of international rivers.

Part I
Africa's International Rivers

Unique Legacies

Because it is often difficult to separate water resources from other factors, it is common to overlook their specific contribution to social and economic development. Yet they play a critical role. Nowhere is this truer than in Africa, where water (or lack of it) frequently brings major shocks to fragile economies. In this new century, the continent's many international rivers will become increasingly prominent features of the political landscape. They can pose a threat to peaceful relations between nations, or through effective management, they can become a major force for bringing nations together.

Africa's international rivers[1] present a great management challenge—arguably greater than do the rivers of any other continent. There are several reasons for this. First, Africa has a highly variable climate, with extremes of precipitation and temperature, and considerable variability in river flow. Second, its cultural and socioeconomic conditions have been profoundly affected by its water resources. The major rivers, most of them shared by more than one nation, are a fundamental part of the past, present, and future lives and livelihoods of Africa's peoples. Rapidly growing populations remain predominantly agrarian and poor and are highly vulnerable to water availability, droughts, and floods. Water has been, and remains, a primary factor in the location and production patterns of human settlements and the structure and productivity of African economies. Third, Africa's historical legacy is defined to a certain extent by the former colonial powers that drew international borders with little regard for the hydrologic integrity of watersheds and natural water boundaries (or for ethnic and other important boundaries). As a consequence, Africa has more rivers shared by three or more countries than any other continent.

Rivers and Variability: The Natural Endowment

At first glance, Africa's water resources endowment appears generous. The continent is characterized by many great rivers, including some 55 international ones. It also has more than 150 lakes larger than 10 square miles and many important wetlands (Sharma and others 1996). Playing essential economic, social, and environmental roles, the rivers, lakes, and wetlands supply water for domestic, agricultural, livestock, and industrial use, and they serve extensively as avenues for transport. Flood-recession agriculture, livestock and wildlife watering through lengthy dry seasons, and fishing have long ensured sustainable livelihoods, with freshwater fish remaining an important source of protein for people. In addition, the rivers sustain environmental systems and biodiversity, the wetlands provide important habitats for wildlife and migratory birds, and many lakes are home to numerous endemic fish species. Lakes and wetlands also play key roles as natural reservoirs for storing and regulating river flows and recharging groundwater aquifers.

Yet limited water resources and rapidly growing populations are already straining the ability of the resource base to meet demand in many countries, and this situation is likely to worsen. In 1990, eight countries were suffering from water stress or scarcity; by 2025, as many as 20 are expected to be similarly afflicted. In these countries, water scarcity threatens to constrain economic development.

One natural feature of African water resources in particular poses an enormous challenge: precipitation across much of the region is exceptionally variable—both in time and in space. This is due to the strong influence of the Intertropical Convergence Zone on the climate. The variable precipitation, in turn, results in wide interseasonal and interannual variations in the flows of Africa's rivers.

Endemic and unpredictable drought is perhaps the most catastrophic consequence of rainfall variability in Africa. In the past several decades, extended periods of rainfall deficits and major droughts in the Sahel and eastern and southern Africa have resulted in widespread famine. This has influenced patterns of human and livestock migration and created additional pressures on an already fragile semiarid environment, exacerbating land degradation and desertification. Extended rainfall deficit in the Sahel has also led to the inexorable shrinking of Lake Chad, greatly affecting the livelihoods of many people.

Floods also can have major adverse economic impacts in terms of both direct damages and reconstruction requirements. Mozambique suffered severe flooding and cyclone damage in February and March 2000. Preliminary damage estimates of the flood episode reached $270 million in direct costs and some $425 million in reconstruction costs (all dollar amounts in this document are U.S. dollars).[2] There was no flow-control infrastructure (such as reservoirs) within the borders of Mozambique to mitigate the floods of 2000. The coordinated operation of an existing flow-control infrastructure in upstream riparian countries, however, could have done so.

While one expression of climate and river flow variability is endemic drought and flood, another, less-recognized expression is production falloff. This risk to the production of farmers, pastoralists, and fishermen, as well as that of industries, cities, and even nations, may lead to investment disincentives at all levels and in all years and could result in pervasive, economy-wide effects, as will be discussed below.

Rainfall variability poses a serious threat to agricultural production, and poor agricultural practices exacerbate the negative impact of rainfall variability. Unlike hydropower generation or fish production, agricultural production necessarily consumes water and therefore modifies the hydrologic cycle. Cultivation and livestock rearing on marginal lands can degrade them and change the pattern of runoff to rivers and groundwater. One consequence of these changes is flashy river flows, which increase the threat of serious floods in rainy periods and lower base flows in dry periods, intensifying the scale and impact of already prevalent droughts and floods.

Africa also is characterized by relatively few areas of concentrated and reliable runoff. Particularly important areas of high runoff include the upland regions of the Fouta Djallon in Guinea, the Ethiopian highlands, the mountains of the Equatorial Lakes region, and the Lesotho and Angolan highlands in southern Africa, all of which are sources of major subregional river systems. Many of the rivers fed from these confined highlands, such as the Senegal, Niger, Nile, Zambezi, and Orange, travel long distances through dry terrain without receiving significant additional waters. As a consequence, these river basins have few sites for significant water storage where evaporation levels are low and inundation areas are minimal.

The standard strategy for managing rainfall variability, even where much less extreme than in Africa, is the construction of river regulation and water storage infrastructure. Although storage reservoirs have been constructed in Africa for regulating seasonal and annual discharges, geologic and topographic conditions limit the number of good potential sites, and limited financial and institutional capacity has resulted in very little hydraulic infrastructure development. Water storage capacity in Africa is thus relatively low. Although hydrologic variability in Sub-Saharan Africa is typically some three times higher than in the United States, water storage capacity per capita is less than one-sixth as great (International Commission on Irrigation and Drainage Register 1998). This limits the ability of African water resources managers to mitigate major variations in water flows. Increasing storage capacity will be a likely priority in the coming years.

Because the development of large-scale storage infrastructure has significant social and environmental effects, smaller-scale infrastructure and alternative storage solutions—such as the conservation and rehabilitation of wetlands and watersheds, which enhance natural groundwater recharge and storage and provide natural regulation of river flows—need to be explored. Another, though more complex, solution is the employment of artificial groundwater recharge to increase water storage in aquifers, particularly relevant in Africa's more arid regions. At the same time, nonstructural alternatives, such as targeted economic incentives and pricing schemes, could be used to modify water use patterns and mitigate the adverse economic impacts of hydrologic variability.

Rivers and People: The Cultural Endowment

Water resources and their management have played important roles in the evolution of human society, in relatively wet climates as well as arid. The Rhine valley, a locus of both cooperation and conflict, has long been a primary engine of economic growth in Europe. In Africa, the early civilizations along the lower Nile are perhaps the best-known examples of societies bound closely to rivers, although others, such as the kingdoms of Lake Victoria and the great cultures along the Senegal, Niger, and Zambezi Rivers, have also flourished.

Some of the earliest civilizations, such as those of the Nile, developed where valleys were seasonally inundated with surface waters, providing water and fertile soils for agricultural development. These rivers and their floodplains brought great opportunity for navigation and food production. However, with their cycles of flooding and receding, they also brought great risk of inundation and drought. Managing this risk required labor, organization, and engineering. The scale and skill of the labor needed to construct, manage, and maintain the huge water diversionary structures in the major alluvial basins gave small communities significant incentives to cooperate and develop the state apparatuses essential for managing people and water. Similarly, the decline of some civilizations was linked in part to problems of water management—such as the siltation of irrigation canals in Mesopotamia and the salinization of land in the Indus—or the destruction of water works by invaders.

The migrations across Africa over the past several millennia suggest a general picture of strong groups moving down the great rivers and lakes, with weaker peoples forced away to the interfluves, farther from abundant water sources. This pattern of settlement reinforced the divide between strong and weak by constraining the weaker groups' access to water and raising its cost of use.

Settlement patterns still tend to reflect this phenomenon, with the poorest segments of the population having the least access to water sources and being the most vulnerable to hydrologic variation. In urban areas, the poorest communities usually are the last to be served by municipal water utilities. They are thus forced to either gather their own water—often from polluted urban sources—or purchase water from vendors at several times the price paid by those connected to the municipal system. In addition, the urban poor often establish shantytowns in river flood zones. In rural areas, the poorest farmers tend to settle in vulnerable floodplains or on marginal lands with inadequate or highly variable rainfall and no economical irrigation potential.

Water is a political and cultural issue that is central in defining settlement patterns, the structures of economies, and individual and societal opportunities. Perceptions of water rights shape concepts of national security and sovereignty as well as belief systems. For these reasons, disputes over water rarely lend themselves to simple, rational solutions.

Rivers and Borders: The Historical Endowment

The patchwork of borders that divides African countries comes in large part from the colonial legacy of the late nineteenth and early twentieth centuries. Lines drawn on maps in London, Paris, Lisbon, Brussels, and Berlin took limited account of natural and social divides. As a consequence, every country on the continent has at least one shared river. Few of these international rivers are effectively jointly managed.

The number of international basins and of countries that share them offer one way to measure the scale of the management challenge presented by Africa's international rivers. There are at least 34 rivers shared by two countries, and 28—virtually half of the international rivers—shared by three or more countries. Ten river basins—the Congo, Limpopo, Niger, Nile, Ogooué, Okavango, Orange, Senegal, Volta, and the Zambezi—are shared by four or more African nations.

Another measure of the challenge is the number of international basins found in an individual country. Within its territorial borders, every country in Africa has at least one international river, 37 nations have two or more, and 15 countries have five or more. Guinea has 14 international rivers, Côte d'Ivoire 9, and Mozambique 8.

If joint management of one river basin is a challenge, joint management of many basins by one country is especially difficult, requiring extensive international diplomacy and multiple political negotiation tracks. Categorizing international river basins by their constituent countries highlights which basins will require particular attention to secure coordination and cooperation. Looking at the number of international basins in a particular country highlights which countries need to pay particular attention to the issue.

The challenges African countries face in terms of managing their international rivers are considerably greater than those faced in many other parts of the world. Yet the institutional and administrative capacity necessary to tackle these issues is often weak in Africa. Countries that form part of several international basins are in particular need of a strong capacity for conducting political negotiations and carrying out coordinated investment and management actions with coriparian states.

Table 1 and the table in the annex provide some perspective on the extent to which international rivers tie African countries to their neighbors. Table 1 shows the number of rivers that two countries share. The annex table gives the name of each river at the intersection of the countries sharing it. A casual perusal of these tables reveals the complex web of hydrologic ties between almost all African nations.

The economic importance of water resources to many countries in Africa is displayed in table 2, which shows the extent of irrigated agricultural land and the proportion of the energy supply derived from hydropower. Twenty countries have significant irrigated agricultural areas, with more than 500 square kilometers of land under irrigation: Algeria, Angola, Cote d'Ivoire, Egypt, Ethiopia, Guinea, Kenya, Mali, Morocco, Mozambique, Niger, Nigeria, Senegal, Somalia, South Africa, Sudan, Swaziland, Tanzania, Tunisia, and Zimbabwe. Six of these countries—Algeria, Egypt, Morocco, Nigeria, South Africa, and Sudan—have more than 5,000 square kilometers under irrigation. Eighteen African countries obtain a majority of their electricity from hydropower.

Riparian Dynamics

With so many countries in Africa sharing so many rivers, there are myriad relationships among riparian countries on any given river, and it is impossible to adequately characterize these relationships in any simple way. Each international river system is unique in terms of its hydrology, ecology, cultures, economies, and political systems. Yet there are certain characteristics of these shared systems—such as the presence of power and capacity asymmetries, the magnitude and distribution of potential benefits from cooperation, and historical relationships—that may provide insights into the incentives and obstacles that will be encountered in attempts to engender cooperation.

On the majority of Africa's international river systems, there are few clear hegemons in population and economic size. Most international

Table 1. Countries with Shared River Basins

	Algeria	*Angola*	*Benin*	*Botswana*	*Burkina Faso*	*Burundi*	*Cameroon*	*Central African Rep.*	*Chad*	*Congo, Dem. Rep. of*	*Congo, Rep. of*	*Côte d'Ivoire*	*Djibouti*	*Egypt*	*Equatorial Guinea*	*Eritrea*	*Ethiopia*	*Gabon*	*Gambia, The*	*Ghana*	*Guinea*	*Guinea-Bissau*	*Kenya*	*Lesotho*	*Liberia*	*Malawi*	*Mali*	*Mauritania*	*Morocco*	*Mozambique*	*Namibia*	*Niger*	*Nigeria*	*Rwanda*	*Senegal*	*Sierra Leone*	*Somalia*	*South Africa*	*Sudan*	*Swaziland*	*Tanzania*	*Togo*	*Tunisia*	*Uganda*	*Zambia*	*Zimbabwe*
Algeria			1		1		1		1			1									1						1		5			1	1			1							1			
Angola				2		1	1	1		3	2							1								2				1	4			1							2				2	2
Benin	1				2		1		1			2								1	1						2					1	3			1						3				
Botswana		2								1														1		1				2	3							2			1				1	3
Burkina Faso	1		2				1		1			3								2	1						3					1	1			1						1				
Burundi		1					1	1		2	2			1		1	1	1					1			1								2					1		2			1	1	
Cameroon	1	1	1		1	1		2	2	1	2	1			2			3			1					1	1					1	3	1		1					1				1	
Central African Rep.		1				1	2		1	1	1							1								1								1							1				1	
Chad	1		1		1		2	1				1									1						1					1	1			1										
Congo, Dem. Rep. of		3		1		2	1	1			2			1		1	1	1					1			2				1	1			2					1		3			1	2	1
Congo, Rep. of		2				2	2	1		2					1			3								1								1							1				2	
Côte d'Ivoire	1		2		3		1		1											4	5				3		3					1	1			1						1				
Djibouti																	1																				1									
Egypt						1				1						1	1						1											1					1		1			1		
Equatorial Guinea							2				1							5																												
Eritrea						1				1				1			2						1											1					3		1			1		
Ethiopia						1				1			1	1		2							2											1			2		2		1			1		
Gabon		1				1	3	1		1	3				5											1								1							1				1	
Gambia, The																					1														1											
Ghana			1		2							4															2															1				
Guinea	1		1		1		1		1			5							1			2			6		3	1				1	1		3	4										
Guinea-Bissau																					2														1											
Kenya						1				1				1		1	2																	1			1		1		3			1		
Lesotho				1																											1							1								
Liberia													3									6														2										

(*Table continues on the following page.*)

Table 1. (continued)

	Algeria	*Angola*	*Benin*	*Botswana*	*Burkina Faso*	*Burundi*	*Cameroon*	*Central African Rep.*	*Chad*	*Congo, Dem. Rep. of*	*Congo, Rep. of*	*Côte d'Ivoire*	*Djibouti*	*Egypt*	*Equatorial Guinea*	*Eritrea*	*Ethiopia*	*Gabon*	*Gambia, The*	*Ghana*	*Guinea*	*Guinea-Bissau*	*Kenya*	*Lesotho*
Malawi		2		1	1	1	1		2	1						1		2	1			1		
Mali	1		2		3		1		1			3								2	2			
Mauritania																					1			
Morocco	5																							
Mozambique		1		2						1														
Namibia		4		3						1														1
Niger	1		1		1		1		1			1									1			
Nigeria	1		3		1		3		1			1									1			
Rwanda		1				2	1	1		2	1			1		1	1	1					1	
Senegal																			1		3	1		
Sierra Leone	1		1		1		1		1			1									4			
Somalia													1				2						1	
South Africa				2																				1
Sudan						1				1				1		3	2						1	
Swaziland																								
Tanzania		2		1		2	1	1		3	1			1		1	1	1					3	
Togo			3		1							1								1				
Tunisia	1																							
Uganda						1				1				1		1	1						1	
Zambia		2		1		1	1	1		2	2							1						
Zimbabwe		2		3						1														

	Liberia	*Malawi*	*Mali*	*Mauritania*	*Morocco*	*Mozambique*	*Namibia*	*Niger*	*Nigeria*	*Rwanda*	*Senegal*	*Sierra Leone*	*Somalia*	*South Africa*	*Sudan*	*Swaziland*	*Tanzania*	*Togo*	*Tunisia*	*Uganda*	*Zambia*	*Zimbabwe*
Malawi					4				2	1												
Mali				1				1	1		1	1						1				
Mauritania			1								1											
Morocco																						
Mozambique		2					1							4		3	2				1	5
Namibia		1				1								1			1				1	2
Niger			1						2			1										
Nigeria			1					2				1						1				
Rwanda		1													1		1			1	1	
Senegal			1	1																		
Sierra Leone	2		1					1	1													
Somalia																						
South Africa						4	1									3						1
Sudan										1							1			1		
Swaziland						3								3								
Tanzania		4				2	1			2					1					1	2	1
Togo			1						1													
Tunisia																						
Uganda										1					1		1					
Zambia		2				1	1			1							2					1
Zimbabwe		1				5	2							1			1				1	

Table 2. International River Basins and Country Statistics

Country	*International rivers*	*GDP per capita (US$)*	*Irrigated land (sq km)*	*Electricity from hydro-power*[a] *(%)*
Algeria	Daoura, Dra, Guir, Medjerda, Niger, Oued Bon Naima, Tafna	4,600	5,550	1
Angola	Chiloango, Congo, Etosha-Cuvelai, Kunene, Okavango, Zambezi	1,000	750	75
Benin	Mono, Niger, Oueme, Volta, Yewa	1,300	100	0
Botswana	Limpopo, Okavango, Orange, Zambezi	3,600	20	0
Burkina Faso	Komoe, Niger, Volta	1,000	200	36
Burundi	Congo, Nile, Rusizi	740	140	98
Cameroon	Akpa Yafi, Congo, Cross, Logone/Chari, Niger, Ntem, Ogooué	2,000	210	97
Central African Rep.	Congo, Logone/Chari	1,640	N/A	80
Chad	Logone/Chani, Níger	1,000	140	0
Congo, Dem. Rep. of	Chiloango, Congo, Nile, Zambezi	710	100	94
Congo, Rep. of	Chiloango, Congo, Luapula, Nyanga, Ogooué, Rusizi	1,500	10	99
Côte d'Ivoire	Bia, Cavally, Cestos, Komoe, Niger, Sassandra, St. John, Tano, Volta	1,680	680	47
Djibouti	Awash	1,200	N/A	0
Egypt	Nile	2,850	32,460	24
Equatorial Guinea	Benito, Mbe, Ntem, Ogooué, Utamboni	1,500	N/A	11
Eritrea	Baraka, Gash, Nile	660	280	N/A
Ethiopia	Awash, Gash, Juba-Shibeli, Nile	560	1,900	87
Gabon	Benito, Congo, Mbe, Ntem, Nyanga, Ogooue, Utamboni	6,400	40	78
Gambia, The	Gambia	1,000	150	0
Ghana	Bia, Komoe, Tano, Volta	1,800	60	99
Guinea	Cavally, Cestos, Corubal, Gambia, Gêba, Great Scarcies, Little Scarcies, Loffa, Moa, Niger, Sassandra, Senegal, St. John, St. Paul	1,180	930	36
Guinea-Bissau	Corubal, Géba	1,000	17	0
Kenya	Juba-Shibeli, Mara, Nile, Umba	1,550	660	82

(*Table continues on the following page.*)

Table 2. (continued)

Country	*International rivers*	*GDP per capita (US$)*	*Irrigated land (sq km)*	*Electricity from hydro-power[a] (%)*
Lesotho	Orange	2,400	30	N/A
Liberia	Cavally, Cestos, Loffa, Mana-Morro, Moa, St. John, St. Paul	1,000	20	0
Malawi	Congo, Ruvuma, Songwe, Zambezi	940	280	98
Mali	Komoe, Niger, Senegal, Volta	790	780	78
Mauritania	Atui, Senegal	1,890	490	20
Morocco	Daoura, Dra, Guir, Oued Bon Naima, Tafna	3,200	12,580	4
Mozambique	Buzi, Incomati, Limpopo, Maputo, Pungue, Ruvuma, Sabi, Umbeluzi, Zambezi	900	1,180	N/A
Namibia	Etosha-Cuvelai, Kunene, Okavango, Orange, Zambezi	4,100	60	N/A
Niger	Hadejia, Niger	970	660	0
Nigeria	Akpa Yafi, Cross, Hadejia, Niger, Oueme, Yewa	960	9,570	39
Rwanda	Congo, Nile	690	40	98
Senegal	Gambia, Gêba, Senegal	1,600	710	0
Sierra Leone	Great Scarcies, Little Scarcies, Mana-Morro, Moa, Niger	530	290	0
Somalia	Awash, Juba-Shibeli	600	1,800	0
South Africa	Incomati, Limpopo, Maputo, Orange, Umbeluzi	6,800	12,700	1
Sudan	Baraka, Gash, Nile	930	19,460	72
Swaziland	Incomati, Maputo, Umbeluzi	4,200	670	51
Tanzania	Congo, Mara, Nile, Ruvuma, Songwe, Umba, Zambezi	730	1,500	88
Togo	Mono, Oueme, Volta	1,670	70	7
Tunisia	Medjerda	5,200	3,850	0
Uganda	Nile	1,020	90	99
Western Sahara	Atui	N/A	N/A	0
Zambia	Congo, Luapula, Zambezi	880	460	99
Zimbabwe	Buzi, Limpopo, Okavango, Pungue, Sabi, Zambezi	2,400	1,930	28

a. Electricity included fossil fuels, hydropower, nuclear power, and other.

rivers are shared by riparians with comparable, or at least countervailing, economic situations and populations, and where marked asymmetries exist they are unsurprising—Egypt, Nigeria, and South Africa, the continent's dominant economies, are obvious examples. Hegemonic behavior should, therefore, affect relatively few of the international rivers.

The same hydrologic characteristics that create significant challenges for the national-level management of water resources also create great potential for benefits from cooperation. Reduced effects of rainfall and river flow variability, flood and drought mitigation, increased systemwide yields of water, and improved environmental management can all be gained. For example, by battling the encroaching water hyacinth together, Lake Victoria countries are reaping environmental benefits. Similarly, as mentioned above, the coordinated operation of existing dams in upstream riparian states might have mitigated the devastating 2000 spring floods in Mozambique. The systemwide yield of water in the Nile could likely be increased by several percentage points per annum if cooperation led to the storage of water upstream and coordinated reservoir operation with existing structures in the arid plains downstream (Guariso and Whittington 1987).

The relative distribution of gains under different scenarios of infrastructure investment and management will affect riparians' incentives for cooperatively developing and managing their international rivers. However, even significant net gains may not provide incentives for all riparians if the distribution of those additional benefits is highly skewed. A cooperative solution that provides net gains to the riparians as a group may provide fewer benefits to a particular riparian than an alternative, noncooperative scheme. In such cases, a cooperative arrangement is unlikely without further redistribution or compensation.

Incentives for cooperation on a specific river system, therefore, can be assessed by characterizing a basin in terms of its potential to generate gains from cooperation and the relative distribution of those gains. For rivers that offer great potential benefits that would be distributed relatively evenly among riparians, cooperative solutions are more likely to be achieved. For rivers that offer few potential benefits, or whose benefits are skewed in their distribution, cooperation is less likely, and third-party mediation and innovative compensation schemes may be needed to facilitate possible solutions.

Historical relationships will affect whether cooperative management agreements can be reached and what benefits might be realized. In some basins, there exist long-standing animosities concerning the control of shared waters. Over time, tensions among neighboring countries can lead to fragmented regional infrastructure systems, which isolate riparians from one another and from broader markets. In basins where historical tensions have arisen over issues not related to water resources management, efforts to facilitate cooperation on shared waters may prove simply intractable—or they may provide a mutually acceptable and constructive alternative point of entry for dialogue among riparians.

Across Africa there is growing dialogue on shared rivers, which will only intensify. This is in part because the development plans of many countries require significant increases in water use. Most lack viable alternatives to developing international basins, which are increasingly unlikely to be able to accommodate the uncoordinated development demands of all riparians. In many cases, development goals in different countries are premised on mutually exclusive claims for water from international basins. For example, several Zambezi basin nations (and nonbasin states) have at some time considered large-scale abstraction from that river.

Negotiations and opportunities for joint development, however, are constrained by considerable capacity imbalances among countries and an inability in many to analyze and inform policy positions and decisions. Furthermore, the threat of hegemony often arises when the strongest nations appear to face the greatest water scarcity because of their relatively large populations or dynamic economies. Information acquisition and data sharing are often contentious issues in riparian negotiations, and information asymmetries create fear and distrust. In the long run it will be in the interests of all riparians to build partnerships for data sharing. But building confidence and capacity can take decades.

In summary, Africa's many shared rivers weave a complex web of relationships across the continent. These rivers can be a source of conflict or a gateway for engagement among riparians. The next section explores the economic concepts that can help promote riparian dialogue and cooperation in managing and developing international rivers.

Part II
The Economics of Shared Waters

Hydrologic Risk and Economic Growth

Water is a basic human need—central to survival, critical for human health and productivity, and a prerequisite for poverty alleviation. Water is an important productive input as well, particularly in agrarian economies, and it is a crucial environmental asset.

Water resources, and the management of them, also have broad macroeconomic impacts, affecting both the structure and the performance of economies. The extreme variability in rainfall and river flows in Africa clearly affects real output performance, most acutely in the agriculture sector but to some extent in almost all sectors of these agrarian economies. Catastrophic events such as floods and droughts are the most visible examples of the impact of climatic variability on real growth. Yet even when rainfall is at levels considered normal, the expectation of variability alone tends to discourage investment and constrain economic potential.

Where rainfall variability is great, investment patterns will reflect risk-averse behavior. Individuals, entrepreneurs, and states will make location, investment, and production decisions that lessen vulnerability to water shocks. Many of these decisions will improve efficiency by locating activities where they are most economic and adopting appropriate technologies. But others will constrain investment because the risk relative to expected rewards is simply too high.

Individuals will attempt to mitigate, or adopt coping strategies to address, the risks posed by hydrologic variability. Farmers, for example, might shift crop mixes, alter production technologies, or purchase crop insurance. If, however, it is uneconomic or unfeasible to implement measures that substantially mitigate the risks of rainfall—and hence output—variability, they will be less likely to invest in land improvements and capital-intensive inputs and production technologies. This is compounded by the fact that most African farmers are poor and often unwilling or unable to access capital to improve their lands or production techniques. Agriculture, for these and other reasons, receives relatively little capital investment in Africa.

To address the risks associated with hydrologic variability, manufacturing and service industries are likely to locate in areas with sufficient, reliable water supplies and adopt water-saving technologies when there are economic incentives for doing so. Where water supply is unreliable, fewer enterprises will invest, and those that do will often construct their own water supplies, such as private boreholes. Standard coping strategies in much of Africa, these independent water supply arrangements raise the cost of production and affect competitiveness and profitability. They are frequently drawn from groundwater without adequate regulation and monitoring, which can decrease water table levels and compromise groundwater quality. In addition, when major users such as urban industries and wealthy individuals provide their own water, municipal utilities do not achieve the full advantage of economies of scale in production and distribution. This results in poor maintenance and operation, increased tariffs, and the inability of utilities to extend service coverage. All of these factors affect the performance and structure of the manufacturing and service sectors.

States can seek to mitigate hydrologic risk by cooperatively managing and developing international rivers. For some countries, the most effective control infrastructure may exist upstream, in another nation. Cooperation on international river basins could allow downstream riparian interests to be represented in decisions on building upstream infrastructure.

Countries faced with extreme climatic variability can also adopt policies designed to buffer their economies from water shocks. To reduce the economic impacts of high rainfall variability, for example, states can adopt policies that promote food security (the capacity to secure a food supply through trade or production) rather than food self-sufficiency (in-country production of all the food needed). These policies would seek to decrease uneconomic agricultural production and increase agricultural imports. This structural shift from agriculture to trade, particularly if imports of water-intensive and drought-sensitive crops increased, would mitigate the economic impacts of rainfall variability. Structural shifts away from water-intensive industries could similarly decrease economic vulnerability to hydrologic shocks.

Whatever the combination of storage enhancement and economic mitigation measures pursued, managing major hydrologic risk requires the engagement of a state's top political leadership. The construction of large dams and other large-scale water control infrastructure involves a level of funding and legal, social, environmental, and political complexities possible only for the national government, particularly in shared river systems. Overseeing these risks calls for capacity, strong institutions, and considerable skill, as well as substantial investment financing.

With limited institutional capacity and capital, African states can find themselves in a low-level equilibrium trap. They cannot afford, or perhaps reach international agreement on, the major investments needed to significantly mitigate hydrologic variability and minimize the risks this poses for individual farmers, vulnerable communities, water-dependent sectors, and the broader economy. Their inability to reduce these risks constrains economic growth, investment incentives, and capital availability.

To break out of this low-level equilibrium trap, African states will need to address the risks generated by variability by implementing a diversified portfolio of policies and investments. The structure of their economies will need to be strengthened to make them more resilient to the risks of variability. Strategies might include improving water resources management (such as seeking conservation and efficiency gains and developing source and storage solutions), placing greater emphasis on food and energy security (rather than self-sufficiency), encouraging trade and agricultural production patterns less vulnerable to variability, and seeking to generate employment and growth in less water-dependent sectors. At the same time, economically, socially, and environmentally sound investments in river management infrastructure could be pursued nationally and internationally on shared river systems. The design of such a diversified portfolio of policies and investments requires a thorough understanding of the concept of water as an economic good.

Water as an Economic Good: Values and Costs

The Economic Value of Water to a User

The economic value of water to a user derives from the specific use to which this resource will be put.[3] Users may reveal the value they place on water by the amount they are willing to pay for it, and this information will be embodied in their demand curve for water. To satisfy their highest priority needs, users are typically willing to pay a premium for the first units of water. In most cases the total value of water to a user will increase as the quantity used increases, but at a decreasing rate. This suggests that the marginal value of each additional unit of water decreases as use increases because additional units are put to less valuable uses. This assumption of decreasing marginal returns causes the familiar downward slope of the demand curve. This relationship between the quantity of water used and the marginal value of water holds for groups as well as for individuals.

It is the marginal value of water (the value to the user of the last unit purchased or used) that will determine the user's economic value of it. Users will continue to purchase (use) water until the value they place on the last unit (its marginal value) is just equal to the cost of obtaining it. For example, suppose a user bought more water than this amount, and the price he paid was equal to the marginal cost of supply. The cost of the water would exceed its value to that user (that is, he would be paying more for the unit than it was worth to him). On the other hand, if the user bought less water, he would be foregoing an opportunity to purchase water at a price that was less than the water's value to him.

The economists' definition of the economic value of water to a user—the user value—is thus not based on some abstract notion that water is intrinsically desirable but is fundamentally determined by the transaction value of water in a world of scarcity. However, the transaction need not actually take place for the economic value to exist; it only matters that the transaction is possible. The amount of money a user is willing to give to obtain more water (the economic value of water to the user) will be determined by the use to which this water will be put and the amount of money the user has. It is difficult to generalize about the economic value of water to different users in different locations because both the intended uses of water and users' incomes differ in different times and locations.

Still, evidence clearly indicates that municipal and industrial users typically have the highest user values of water (Briscoe 1996). Some urban households (for example, those in Khartoum, Addis Ababa, and Kampala) purchase water from vendors and often pay $3.00 per cubic meter or more for small quantities of water for domestic use. Increasing the amount of water supplied to such households would generate great economic value[4] because for such users water is very scarce, and they are willing to pay a great deal to obtain it (even though their incomes are often quite low). It should be noted, however, that this extremely high value of water will likely pertain only to the small quantities required for basic needs and should not be extrapolated to the higher quantities that would be used if cheaper water were available.

The user values of water in irrigated agriculture are much lower. How much a farmer is willing to pay for water for irrigation depends on, among other factors, the crop being cultivated, the amount of rainfall, the prices of agricultural products, and the prices of other inputs such as fertilizer and labor, but it is typically $0.01–$0.25 per cubic meter. The user value for large-scale irrigation of cereal crops such as wheat is at the low end of this range. The user value for the irrigation of high-value fruits and vegetables is occasionally at the high end of this range but depends to a great extent on market conditions and the transportation costs of delivering produce to market.

The economic value of water to an individual need not depend only on whether that person actually extracts water for use in some economically productive activity or for final consumption. Some people may be willing to exchange scarce resources or money to leave water in its natural state in the environment. Water generates economic value for them by continuing to do what it already does: sustaining natural ecological systems. These individuals may value water in its natural state because this enables them to harvest certain products and wildlife (such as fish) from the ecosystem. Many people living near the Sudd swamps in Sudan, for instance, harvest fish and graze cattle on the grasses sustained by the retreating waters of the White Nile's annual floods. The willingness of such groups to pay for these ecological services, despite their economic value, must be very low in absolute terms simply because incomes are minimal.

Those people with greater incomes, on the other hand, may be willing to pay substantial amounts of money just to maintain natural flows. For example, some Europeans are willing to pay to preserve the current hydrologic regime of the Sudd swamps in order to sustain the migratory bird life that winters there and summers in Europe (Whittington and McClelland 1992). Still other individuals may be willing to pay to leave water in its natural state, not because they want to fish or preserve bird life that they may enjoy seeing, but simply to maintain a natural environment for its own sake—because it is the "right," or moral thing, to do. Environmental economists have termed such values "nonuse," "existence," or "passive use" values because they arise without an individual's using the resource in any material sense. Nonuse values often reflect a person's desire to preserve or bequeath a resource to future generations, rather than to "consume" it, even in a recreational or aesthetic sense.

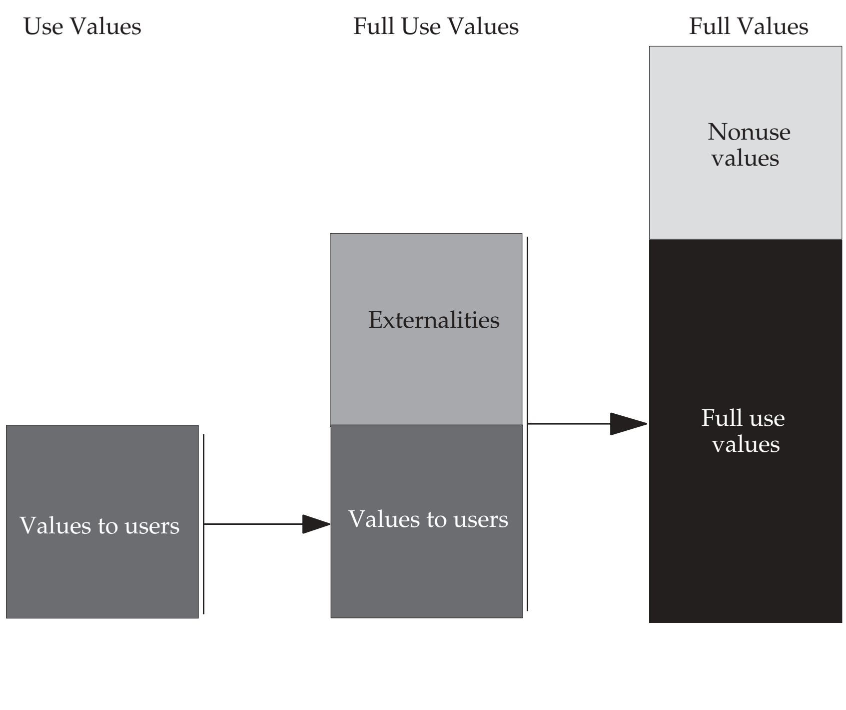
The economic value of water to an individual is not equivalent to the economic value of water to society as a whole because an individual's use of water at one time and place may have unintended consequences for others. Externalities occur when the actions of one water user affect the interests or well-being of another. Externalities can be positive or negative, and they can also run both downstream and upstream.

The most commonly recognized negative externality occurs when an upstream riparian withdraws water, reducing the supply of water for a downstream user. The upstream irrigator does not use water to intentionally inflict harm on the downstream irrigator, but this may well be the consequence of his actions. Negative externalities can be generated by changes in quality as well as quantity. For example, upstream water pollution may adversely affect health and productivity downstream. The use and development of water by a downstream riparian, however, can similarly reduce the water available to the upstream riparian in the future, by foreclosing future opportunities for upstream use of water that is claimed and developed by the downstream riparian.

Important positive externalities occur in river systems as well. For instance, if river regulation infrastructure were built by an upstream riparian to generate hydropower for that country, downstream riparians could enjoy the positive externalities of drought and flood mitigation and reduced siltation. The magnitude of the economic value of positive externalities can be estimated by the maximum amount the individuals receiving such externalities would be willing to pay for them. Negative externalities, by contrast, result in economic losses to other individuals (or countries); the magnitude of such losses can be estimated by the amount of money that other individuals would be willing to pay to avoid them (or the minimum amount they would be willing to accept in compensation for incurring them).

Figure 1 summarizes the different components of the economic value of water. *Use values* reflect the value of water to the user and are often called "values-in-use." *Full use values* correspond to the use values plus any externalities that result from the user's decision to use water. *Full values* reflect full use and nonuse values and relate to the benefits and costs derived from current use, both directly and indirectly. Employing these economic concepts of the use value, full use value, and full value of

Figure 1. Values of Water



water, it is now possible to define more precisely the economic cost of supplying water to a user.

The Economic Cost of Supplying Water to a User

Today water resources are becoming scarce as populations grow, economic development intensifies, and pollution increases. Historically, however, water was often abundant relative to human use. Because water was not considered scarce, economists and others typically ignored its economic value, assuming it was an infinitely available free good. Economists instead focused their analyses only on resources that had limited availability that might constrain economic activity. Economic analyses of water resources development projects therefore typically focused on the optimal allocation of scarce infrastructure investment funds for which there were competing demands, rather than on the water resources that were considered plentiful enough to meet all existing and potential demands.

The economic costs of water were often conceived as simply the cost of building and maintaining the infrastructure necessary to supply this resource; the water running through the system was generally not considered to have a separate economic value. The economics of water resources development, appropriately under circumstances of abundant supply, focused on the least-cost analysis of water provision and narrowly defined the cost-benefit analysis of water supply augmentation.

Water scarcity, however, necessitates recognition of the opportunity cost of using water for particular purposes. *Opportunity costs* are the benefits that could have been generated had a resource (here, water) been put to its next-best use. If a certain amount of water, for example, is used to irrigate crops, the opportunity cost of this water would be the forgone benefits that could have been generated had that water been used for livestock, to produce electricity, or to meet domestic needs, whichever value is highest. Where water resources are scarce relative to demands and the utilization by one party precludes alternative uses by others, water use decisions carry opportunity costs, sometimes referred to as "scarcity rents."

Scarcity obligates economists, when assessing options for water resource development, to look beyond the traditional capital-focused, least-cost approach to the broader economic issues of opportunity costs, the impacts of externalities, and the growth and equity implications of management decisions. The environmental, social, and broad economic results brought about by water projects represent real costs (or benefits) to society and should be incorporated into the analysis of water resources management and development options.

The Dublin principles reflect a growing recognition that water is a scarce and productive resource, stating that "water has an economic value in all its competing uses and should be recognized as an economic good."[5] Treating water as an economic good means allocating it as a scarce resource, with due regard given to economic principles of efficiency and equity. That does not necessarily mean it must be sold at a market price; markets are not everywhere competitive. Social and private costs and values of water often diverge because externalities and opportunity costs generally attend the use of water resources.

If water is treated as an economic good, the value of the resource itself will be reflected by the opportunity cost of consuming water in one use, thereby precluding alternative uses. Recognizing water itself as an economic good requires that an analyst weigh management options to assess broader economic costs (opportunity costs and economic and environmental externalities) as well as the more traditional financial costs (infrastructure, operations and management).

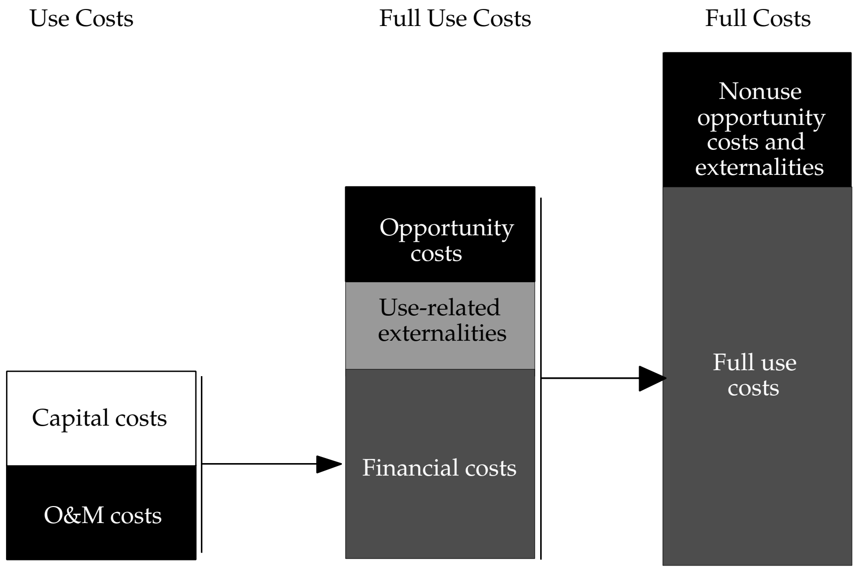
The Dublin principles touch on another implicit assumption often made about water: because it is a basic requirement for sustaining life, it is a *social good*[6] and therefore not an *economic good*. Arguably, water is both and more. It can be seen as a social good because it fulfills basic human needs, an economic good as both a factor of production and a final consumer product; it can also be viewed as an environmental good since it is a critical element of ecosystems. Treating water as an economic good simply acknowledges that water is a valuable, increasingly scarce commodity and that the economic consequences of its use should be understood and weighed, along with social and environmental benefits, so that decisionmakers understand all the implications of a chosen policy. In fact, a call to recognize water as an economic good enhances (rather than diminishes) the importance of its social and environmental dimensions.

Components of the Costs of Supplying Water

Capturing the range of costs and values associated with water resources management and development is not a straightforward process. As a heuristic device to explore the financial, economic, environmental, and social dimensions of water, the costs of water resources can be distinguished on three levels (see figure 2):[7]

- *Use costs*—out-of-pocket financial expenses required to use the resource, a traditional approach to analyzing the costs associated with water provision
- *Full use costs*—use costs plus the opportunity costs and any externalities associated with a particular pattern of use

Figure 2. Costs of Water



- *Full costs*—full use costs plus the nonuse values attached to water, that is, the broader environmental and social impacts of decisions on water resources management arising from the multifaceted nature of water as an economic, environmental, and social good.

Use costs

Use costs are those costs traditionally associated with the water sector. They are expenditures required to "use" water or deliver water services to the user and can be broadly thought of as supply costs or financial costs paid out of pocket by water service providers.[8] Use costs fall into two basic categories: the capital costs of building infrastructure and the operations and maintenance costs of running the system. It also can be helpful to think of these cost categories as fixed (capital) and variable (operations and maintenance). Capital costs include investment capital and the interest payments associated with use of that capital, that is, the construction of dams, pipelines, reservoirs, boreholes, treatment systems, and distribution networks. These tend to be large, lumpy expenditures and are therefore considered fixed costs for a certain time period.

Capital costs were traditionally calculated by looking backward, as the cost of repaying the prior investments made in existing infrastructure.

From an economic perspective, however, capital costs should be calculated looking forward, that is, by determining the future cost of replacing the existing infrastructure. The forward-looking approach generally leads to higher capital costs. Variable costs are based on the recurrent operation and maintenance costs associated with water delivery systems, such as labor, power, and treatment chemicals. In an integrated water resources management system, operating costs could also include the administrative expenses of resource allocation, regulation, monitoring, and protection.

Full Use Costs

Along with the use cost of water, full use costs include opportunity costs and externalities associated with a particular pattern of water use. Although opportunity costs and externalities nearly always accompany water use decisions, they are not routinely incorporated in the decision-making process. The distinction between opportunity costs and externalities is not always clear-cut. The line to be drawn between the two is essentially one of scope, delineating what is external to the water use decision. The issue of scope is quite important for water resources management. For instance, an individual user would consider the impact of his own water use on his immediate downstream neighbor to be an externality. By contrast, a river basin manager would treat downstream impacts as opportunity costs, rather than dismiss them as externalities. Integrated management thus effectively internalizes all externalities within a planning area. This notion is central to integrated river basin management.

The distinction between the two categories is also important in that all opportunity costs are not unintended externalities. The diversion of water may be quite deliberate, and the resulting costs fully anticipated and accepted. While externalities will by definition not be taken into account in the water user's calculations, users may be well aware of the cost their actions impose on other riparians.

Opportunity costs and externalities may be simple to quantify at times and quite difficult at others, even when defined in relation to use values only. Issues of information availability and reliability and the complexity of direct and indirect effects of water use make the identification and calculation of such costs challenging. They are particularly difficult to quantify when environmental in nature. In systems with sophisticated environmental safeguards that require polluters to pay, what might otherwise be considered environmental externalities could be internalized and reflected in use costs. In systems not internalizing environmental externalities, externalities may nonetheless be quantified and incorporated in full use costs. Techniques for the economic valuation of environmental externalities are becoming increasingly sophisticated, and it is now accepted practice to include these costs in thorough benefit-cost analysis.[9] Similarly, social externalities, such as decreased productivity and income losses associated with increased incidence of waterborne diseases resulting from management decisions, could be captured in analyses of full use costs.

Opportunity costs will outweigh the use value generated by water when it is not put to its highest value use. In other words, society will "pay" more for the water resources (as forgone opportunities), than it "earns" (in the value generated by the use of the water resources). From a social perspective, this is a misallocation of resources because it does not maximize aggregate benefits. A common economic argument is that aggregate benefits to society should be maximized, and thereafter issues of distribution can be addressed through redistribution, compensation, or both. In reality, however, large-scale redistribution of economic gains has proven extremely complex and often infeasible. In Africa, where fiscal systems are not highly sophisticated, such schemes are particularly challenging. Redistribution across borders—in the case of international rivers—adds another level of complexity, with few successful precedents anywhere in the world. This issue will be discussed at greater length in the next part.

The drive to maximize overall benefits from water use must therefore be tempered by recognition of the possible distributional effects of allocation decisions. The highest value water use might prove regressive in its distributional impacts. For example, where wealthy farmers with more capital-intensive production capabilities can generate higher returns than poorer farmers, the allocation of water resources to their highest value uses will compound income disparities. Although overall benefits to society will be maximized by providing additional water to the wealthier farmers, in the absence of an effective compensation scheme the opportunity costs in such a scenario will fall on those least able to pay them. In such cases, equity concerns might lead to a second-best pattern of water use, in which opportunity costs in excess of use costs may be acceptable to meet the basic needs of the least advantaged. The farmer analogy can be extended beyond the individual to the community, region, and state.

An economically more efficient, and more complex, solution would be to allocate water resources to those who generate the greatest value for the economy, while charging those users an economic price for the water. This revenue could then be spent in a transparent and targeted manner for poverty interventions, assuming there is sufficient capacity to design and implement such programs.

The relative magnitude of use costs and opportunity costs in the full use cost of water will depend largely on resource abundance and location. In water-rich countries, use costs usually preponderate because supply will be adequate to meet the great majority of high-value demands, generating minimal opportunity costs. In water-scarce countries, opportunity costs can outweigh use costs if water is allocated away from high-value uses. The location of water resources will also affect the relative size of use and opportunity costs. The relative size of use costs will rise where water sources are far from centers of demand, and water must be transported over longer distances to final users. Again, complexities are introduced where river basins include areas of both water scarcity and abundance.

Full Costs

Full costs can be defined as the sum of full use costs and nonuse costs. Nonuse costs are the loss of nonuse benefits of water as the result of a particular use. Nonuse costs are logically a component of opportunity costs in circumstances where water is diverted for irrigation from a unique lake or ecosystem to which people attach value. Similarly, nonuse costs can be externalities where a diversion destroys a downstream habitat with species of wildlife people care about, even if they never intended to visit the habitat or see the animals.

Nonuse costs can be environmental, social, cultural, ethical, or political, relating to custom, tradition, beliefs, religion, sovereignty, national identity, or property. The loss or destruction of species, pristine ecosystems, sites of social or religious significance, and traditional ways of life are examples of potential nonuse costs (the loss of nonuse benefits). These nonuse costs can be high, although they are rarely quantified. While it is hard to assign monetary values to nonuse components of opportunity costs and externalities, it is not impossible. At a minimum, identification of nonuse costs and benefits can remind policymakers of the range of tradeoffs involved in water resources management.

The Economic Value of River-Basin Cooperation

The economic value of water to a specific user and that of cooperation (or a cooperative investment and management program) on an international river basin are conceptually distinct, though to arrive at the latter, analysts must know the former. The components of the economic value of water to a user and of the economic cost of supplying that water are the fundamental building blocks for constructing estimates of the economic benefits to be gained from cooperative action. But a full, nuanced understanding of such benefits requires much more than a simple aggregation of the economic value of water to different users and the economic costs of supplying water to users.

User Values and System Values

In the context of a river basin, there are (at least) two notions of the economic value of water that are both conceptually correct and commonly confused. The first is user value—the value that can be derived from a single, specific use of water. In the case of international shared waters, the user can be thought of as an individual, a group of individuals, and a country using water for a specific purpose in a specific place and manner. The distinction between this first notion and the second is primarily one of aggregation—discerning the value of one water use within a river system (the user value) from the aggregate value of a pattern of multiple uses within the river basin (the system value).

The system value, as the above indicates, is the aggregate value that a unit of water can generate as it moves through the river system before it is consumed or lost. Or to put it another way, it is the sum of benefits and costs to all the riparians (or users) under a specific configuration of uses or development path. By aggregating the value of water in all of its uses within the river basin, this approach effectively forces an integrated systems management perspective by internalizing the externalities (and opportunity costs) of a given development path or configuration of water uses in a basin. The distinction here is primarily one of aggregation—discerning the value of one water use within a river system (the user value) from the aggregate value of a pattern of multiple uses within the river basin (the system value).

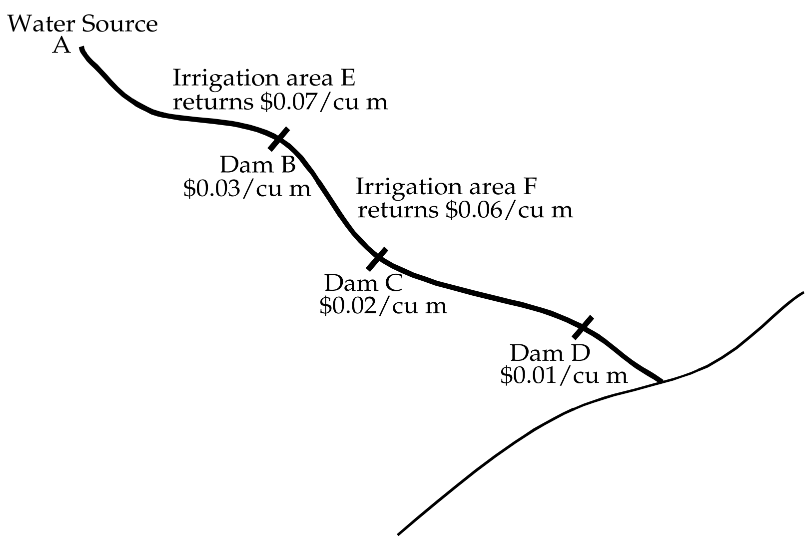
Thus the system value incorporates the economic value of water to users while taking the broader perspective made possible with cooperation. The economic value of water from a systems perspective will not to be same as that from a single user's perspective because of the physical interdependencies of water use in a river basin that result in opportunity costs and positive and negative externalities. The first level of economic benefits from cooperation is achieved with a shift from maximizing user values to maximizing system values.

To begin moving toward this objective, analysts must ascertain the aggregate value of water to all the interrelated users in the river basin under a given water resources management or investment scenario. When looking at user values, we ask how much individual users would be willing to pay for an additional unit of water. From the systems perspective, we look at how changes in water availability—perhaps caused by changes in the management strategy for a basin—would affect all users and hence the cumulative value of water in the system. Alternatively, the difference between the user value of water and the system value can be seen as a shift in the definition of the user—from an individual economic entity in a specific location along the river to the sum of all river users throughout the system.

When analyzing a project, policy, or regulation, the planner who takes a systems perspective considers the physical interdependencies that generate externalities. A simple example will illustrate the point. Figure 3 shows a river basin system with an upstream source of water (A), three dams (B, C, and D), and two irrigation schemes (E and F).

Assume that the economic user value of water to farmers at the site of the first irrigation scheme, E, is $0.07 per cubic meter, and the user value at the second site, F, is $0.06. Assume that the different dam sites have different net heads. Assume also that a cubic meter of water flowing through the hydropower facilities at the first dam, point B, generates hydropower worth $0.03, a cubic meter of water through the dam at point C generates hydropower worth $0.02, and a cubic meter of water flowing through the dam at point D generates hydropower worth $0.01. Evaporation and seepage losses along the stretch from the source to the first dam (A to B) are assumed to be equal to 5 percent of the water that leaves the source at A. Losses from the first dam to the second (B to C) are 10 percent, and losses from the second to the third (C to D) are 5 percent. We

Figure 3. River Basin System with Irrigation and Hydropower



assume for purposes of illustration that water remaining at the source has no economic value, either user value or nonuse (existence) value.

Alternative plans or management strategies for allocating a unit of water from the source can be thought of as development paths. In each, a unit of water has an associated economic system value. A water resources manager might consider three development paths:

Development path 1—Send water from the source at A to the reservoir at the dam at B, and withdraw the water for irrigation at E before it passes through the hydropower facilities at the dam at point B (A→B→E). This strategy allocates water to upstream irrigation only. A cubic meter of water generates \$0.066 in economic system value: (1–0.05) × \$0.07 per cu m = \$0.066 per cu m.

Development path 2—Send water from the source, A, through the hydropower facilities at the dam at B and then to the reservoir created by the dam at C, and withdraw water from this reservoir for irrigation at F before it passes through the hydropower facilities at the dam at C (A→B→C→F). This strategy allocates water both to hydropower generation and irrigation. A cubic meter of water generates \$0.08 in economic system value: (1–0.05) × \$0.03 per cu m + (1–0.05)(1–0.1) × \$0.06 per cu m = \$0.08 per cu m.

Development path 3—Send water from the source, A, through the hydropower facilities at the dams at B, C, and D, and then out of the river basin; do not send any to irrigation sites at E or F (A→B→C→D→). This strategy allocates water to hydropower only. A cubic meter of water generates \$0.05 in economic system value: (1–0.05) × \$0.03 per cu m + (1–0.05)(1–0.1) × \$0.02 per cu m + (1–0.05)(1–0.1)(1–0.05) × \$0.01 per cu m = \$0.05 per cu m.

These are not the economic values of allocating a cubic meter of water to one particular user, but rather the total economic value generated by a cubic meter in a particular development path (or, alternatively, a specific cooperative management strategy) for all users in the river system. The system values of some of the possible development paths here are greater than some user values because hydropower is a nonconsumptive use and the same cubic meter of water can generate value in both hydropower and irrigation. However, in development path 3 the user value of water for irrigation at both points E and F is greater than the system value.

Thus user values may or may not be greater than system values. Two interesting points follow from this observation. First, when user values are the greater, incremental benefits may be realized by reconfiguring the river's development path or management scheme. This provides incentives for cooperative management, although such reconfiguration may require provisions for compensation. This idea of incentives for cooperative management is at the heart of the economics of international rivers.

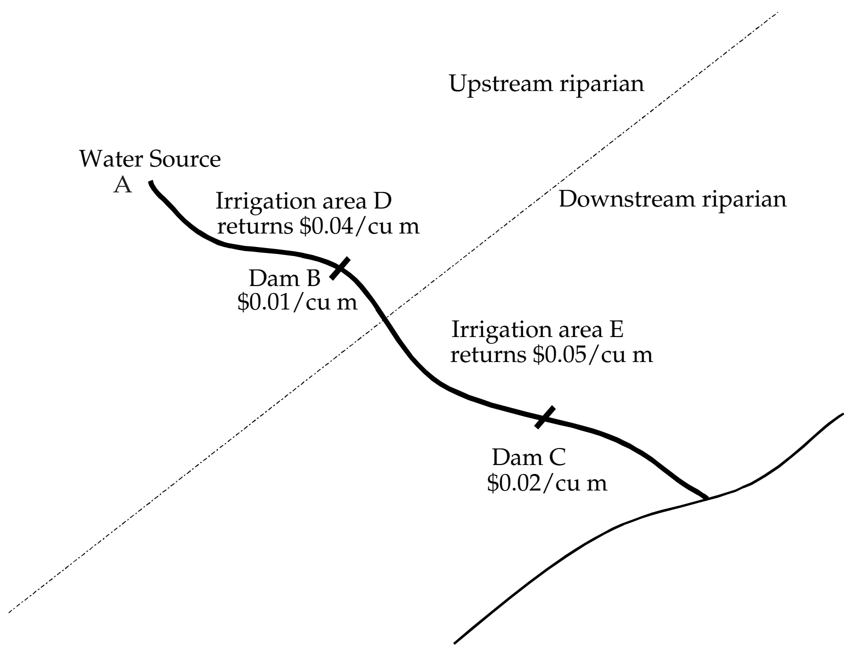
Second, an optimal development path will not preclude the allocation of water to low-value uses. Optimizing basin management does not necessarily mean that every activity undertaken must be a high-return one; the unique characteristics of each basin and the interplay among activities there will drive the allocation of water under such a path. Particularly if high-value use options are available downstream, low-value, nonconsumptive upstream uses may be part of an optimal basin management plan.

The schematic in figure 4 shows a two-riparian river system with two potential hydropower sites (B and C) and two potential irrigation schemes (D and E). Assume the economic user value of water per cubic meter at hydropower site B is \$0.01 and that at site C is \$0.02. Further assume that different soil, infrastructure, and rainfall conditions result in an economic user value of water per cubic meter in irrigation area D of \$0.04, and in area E of \$0.05. Evaporation and seepage losses from the source, A, to site B are assumed to be 5 percent, and losses from B to C 10 percent.

Consider two different development paths:

Development path 1—Send water from the source, A, to the dam at B, and withdraw the water for irrigation at site D before it passes through

Figure 4. Two-Riparian System with Irrigation and Hydropower



the dam B hydropower facilities (A→B→D). This allocates water for irrigation in the upstream riparian country only and will generate \$0.038 in economic system value: (1–0.05) × \$0.04 per cu m = \$0.038 per cu m.

Development path 2—Send water from source, A, through the hydropower facilities at dam B and then withdraw the water for irrigation at area E (A→B→E). This provides for hydropower generation in the country upstream and irrigation in the one downstream and will generate \$0.052 in economic system value: (1–0.05) × \$0.01 per cu m + (1–0.05)(1–0.1) × \$0.05 per cu m = \$0.052 per cu m.

The second path generates a higher system value for water than the first, despite the fact that it allocates water to hydropower generation at site B, the lowest value use of water in the system. This is because, as noted above, hydropower is a nonconsumptive use of water that can generate value without precluding the allocation of the same cubic meter to higher value extractive uses downstream.

While water is not extracted for hydropower generation, the economic value of water is typically reduced when it is moved from a higher to a lower elevation because water's head, or elevation, has an economic value. Water at higher elevations not only is more likely to be suitable for hydropower generation but also may be more valuable (for example, in irrigation) due to the lower cost of transporting by using gravity.

In general, the range of potential user values will drive the system value of water in the river basin; and a development path that coordinates and combines consumptive and nonconsumptive uses will maximize system values. The coordination of uses within an international river system, however, will require cooperative management of water resources among riparians.

Figure 4 also illustrates the importance of the distribution of benefits. It is not always the case that a cooperative management scheme that maximizes system values will be preferable to all riparians in the absence of compensation. Here, the upstream riparian will reap the full benefits of development path 1 (\$0.038) and thus prefer it to path 2, where the system value of water would be higher (\$0.052), but the value generated in the upstream country would be only \$0.0095. To maximize system values, the riparian downstream would need to compensate the one upstream in some way.

As these examples demonstrate, the distinction between the concepts of user values and system values is one of scope. The former focuses only on single uses of water, without taking into account the externalities and opportunity costs that link water use decisions to other activities in the basin. The latter aggregates all of the user values generated under a given river management scenario, and then incorporates the interactions, externalities, and opportunity costs that arise across the basin.

The calculation of user and system values can provide insights into the potential benefits of cooperative river basin management. Where system values exceed user values, there is strong incentive for cooperative management. The system values of water may not, however, be evenly distributed among riparians, and the optimal development path from a systems perspective may not be the best option for any single riparian. Yet cooperative action on international rivers can enable riparians to move closer to realizing the greatest potential system values of the river.

Cooperative action may also lead to benefits beyond the river. Strengthened cooperation in the management of international rivers can serve to lessen the geopolitical tensions that sometimes arise over conflicting claims to shared resources as well as to promote economic cooperation and integration in nonwater activities such as trade and power production.

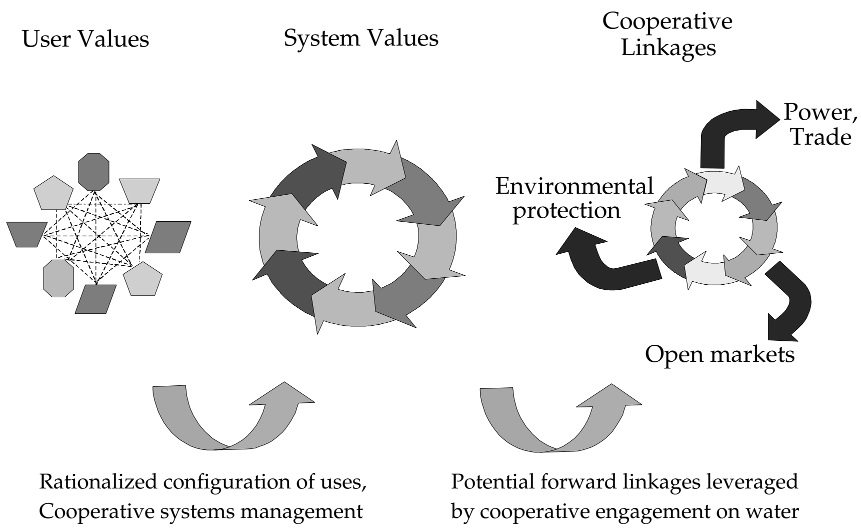
Summary

There are major complexities in moving from a focus on user values to a focus on system values, but, ultimately, everyone can gain by optimizing system values rather than user values. Moreover, this shift to a systemwide perspective can potentially lead to broader cooperation in a river basin. As figure 5 illustrates, shifting objectives—from maximizing user values for individuals or states to maximizing the system values of water in a national or international river basin—can increase the productivity and quality of that water and strengthen the sustainability of the resource. With a focus on system values, the configuration of individual uses can be rationalized, and the river basin can, for example, yield more food, more power, greater navigational opportunities, and higher quality water. This increased productivity, and the trust and relationships established in the basin as a result of this shift in perspective, might spur greater cooperation in related, and even unrelated, sectors and activities.

Economic tools can be used to assess the value of water resources, identify and analyze optimal management scenarios, and provide incentives for the desirable use and conservation of water resources. Economics can thus help to inform and implement water resources management and to motivate riparians to engage in joint management of international waters.

In some regions of Africa, the total supply of water simply is not sufficient to meet all possible demands, and decisions must be made to allocate it among competing users. Particularly in poor, water-scarce countries, the allocation of water resources among sectors in the economy will have significant impact on the country's development pattern, macroeconomic growth potential, and poverty burden.

Figure 5. User and System Values and Cooperative Linkages



Allocative decisions should not be based on economic considerations alone, but the economic implications of such decisions must be clarified in order for policymakers to assess the merits of various options. As water management becomes more sophisticated, informing policy decisions becomes more challenging. Management innovations on the national level—such as commercialization of water delivery and tradable water rights—have the potential to deliver efficient and equitable services if designed with adequate regard for basic needs, consumer preferences and ability to pay, and appropriate economic incentives for all parties. Similarly, cooperative management of international waters often has the potential to achieve greater efficiency and equity in the use of a basin's water resources.

In addition to helping to inform policymakers regarding the anticipated costs and effects of water resources management decisions, economic tools, including market mechanisms, can be used to implement water policies. Water pricing, license fees, and pollution charges are examples of economic tools that send clear, strong signals to users and help direct water resources to the uses considered most valuable to society. Public expenditure constraints make the efficiency of government infrastructure investments and service delivery an important issue everywhere. In many African countries where public investment funds are particularly scarce or costly, efficiency is a critical concern. Governments increasingly find that the traditional strategy of seeking engineering solutions to meet all water demands, as well as constructing and subsidizing the operation of their delivery schemes with public funds, is unaffordable. A thorough economic analysis of supply-enhancement schemes is needed to guard against the tendency of such projects to be financially unsustainable without perpetual government subsidies and economically inefficient by failing to promote the most socially productive uses of valuable water resources.

The management of international waters presents an even more complex challenge for policymakers, adding international conflict and regional cooperation to the list of risks and potential benefits of water sector policy reforms and water resources infrastructure investments. Economics can provide a means to clarify these complex tradeoffs and a language to facilitate the discussion of options for developing and managing shared waters.

Part III
Crafting Cooperative Solutions

The search for cooperative solutions on Africa's international rivers will require in-depth knowledge of the various kinds of interdependencies that exist among riparians. Externalities are thus of particular interest because they are often the motivating factors behind the search for cooperative solutions or the sources of conflict.

Externalities on Africa's International Rivers

River basins are often said to be characterized by pervasive unidirectional externalities—that is, the actions of riparians upstream affect all those downstream, but the reverse is not true. In Africa, such an assumption is too simplistic and, moreover, can be counterproductive when it obscures opportunities for mutual gain. If externalities, positive and negative, are assumed to be unidirectional, it would not necessarily be in the interest of upstream riparians to address them or to seek broader cooperation. If, however, externalities are shown to be multidirectional, then all riparians have an interest in managing the river from a systems perspective. The World Bank's requirement to notify both upstream and downstream riparians in advance of projects that will affect an international river reflects recognition of the multidirectionality of externalities.

It is obvious that upstream abstraction or pollution reduces river flows and water quality downstream. It is also true, though less obvious, that downstream development can generate harm upstream. If a downstream riparian develops water resources within a basin, and thereby claims acquired rights to that water, less of the resource will be available for future development by the upstream riparian. Thus, while upstream extraction generates externalities downstream by diminishing flows physically, downstream extraction can generate externalities upstream by diminishing future available flows as a consequence of acquired rights to the finite water resource.

Another exception to the characterization of unidirectional externalities are rivers that form international boundaries, where riparians share a particular stretch of water from opposite banks. In Africa, there are more than 35 of these rivers. In such cases, both countries are effectively upstream and downstream riparians, and either can generate positive or negative externalities affecting the other. Similarly, there are at least a dozen significant shared lakes in Africa, with as many as four riparian nations on their banks (see tables 3 and 4). Circumstances such as these provide motivation for cooperative management solutions that might not exist if externalities were purely unidirectional.

Less visible and less well-documented examples of multidirectional externalities in water resources management concern groundwater, which in many international river basins riparians share. Overexploitation of groundwater can give rise to problems of saline intrusion or ground subsidence. In the context of upstream and downstream riparians, if those upstream extract water from rivers in a watershed, those downstream might be forced to increase groundwater extraction, potentially affecting the water table in the upstream country. In the case of shared groundwater aquifers, these multidirectional externalities could clearly be better managed through cooperation. Africa has several internationally shared aquifers, the most well known being the Nubian Sandstone Aquifer, used by Chad, Egypt, Libya, and Sudan.

Environmental externalities may also prove multidirectional. Alien plant and fish species, water hyacinth, and degraded water quality will affect riparians on all shores of a lake and those on both banks of a river. Some environmental externalities may also affect sequential upstream-downstream riparians: bird migrations, and even some fish migrations (for example, eels that swim inland from the sea when they are young), may be affected by downstream pollution, water diversion, or the construction of control infrastructure. Alien species could also spread upstream, and groundwater pollution could threaten shared underground water resources.

Even in situations where externalities are physically unidirectional, an upstream country that ignores the effects of its actions on downstream countries may set a precedent that can be used against it; after all, it may be a downstream riparian on another of its international rivers. This concern with reciprocity and precedent has been cited as an important motivating factor in the negotiations between the United States and Canada on the Columbia River (Wolf 1999).

In addition to the issue of directionality, sometimes the absence of externalities can open up opportunities for cooperation. Many river systems have fairly distinct subbasins, or hydrologic characteristics that will compartmentalize or isolate externalities. This may sustain coalitions of interest among groups of riparians that could either help or hinder efforts toward cooperative management. Under these circumstances, in complex

Table 3. Selected International Boundary Rivers

River	*Riparians*	*River*	*Riparians*
Awash	Ethiopia, Djibouti	Limpopo	Zimbabwe and South Africa; Botswana and South Africa
Akobo	Ethiopia and Sudan	Luapula	Zambia and Dem. Rep. of Congo
Baraka	Eritrea, Sudan	Mana-Morro	Liberia, Sierra Leone
Black Volta	Ghana and Côte d'Ivoire; Burkina Faso and Ghana	Mayinga	Zambia and Angola
Bomu	Dem. Rep. of Congo and Central African Rep.	Moa	Guinea, Liberia
Buzi	Mozambique, Zimbabwe	Mono	Togo, Benin
Cavally	Côte d'Ivoire, Liberia	Okavango	Angola, Namibia
Cestos	Côte d'Ivoire, Liberia	Orange	South Africa, Namibia
Chiloango	Dem. Rep. of Congo and Angola	Oubangui	Congo and Dem. Rep. of Congo; Dem. Rep. of Congo and Central African Rep.
Congo	Dem. Rep. of Congo and Congo; Dem. Rep. of Congo and Angola	Ruvuma	Tanzania and Mozambique
Corubal	Guinea, Guinea-Bissau	Sashe	Botswana and Zimbabwe
Cross	Nigeria, Cameroon	St. Jean	Côte d'Ivoire, Guinea
Dawa	Ethiopia and Kenya	St. Paul	Liberia, Guinea
Great Scarcies	Guinea, Sierra Leone	Senegal	Senegal and Mauritania; Senegal and Mali
Kasai	Dem. Rep. of Congo, Angola	Tekeze	Eritrea, Ethiopia
Leroba	Burkina Faso, Côte d'Ivoire	Tano	Ghana, Côte d'Ivoire
Kunene	Angola, Namibia	Volta	Togo, Ghana
Kwando	Zambia, Angola	Zambezi	Zambia and Zimbabwe; Zambia and Namibia
Kwango	Dem. Rep. of Congo, Angola		

negotiations with multiple riparians it might be possible to promote cooperation on subbasin levels and realize significant gains—without causing harm to those riparians not involved.

With respect to the nonuse (existence) value of water resources, the issue of directionality is moot if upstream and downstream riparians share similar values concerning biodiversity and natural heritage.

Assessing Cooperative Benefits and Opportunities

Concentrating on the economic benefits of cooperative use, rather than the physical allocation, of water has sometimes proven a practical

Table 4. Selected Shared Lakes

Lake	*Littoral States*
Lake Albert	Uganda, Dem. Rep. of Congo
Lake Chad	Chad, Niger, Nigeria, Cameroon
Lake Chiuta	Malawi, Mozambique
Lake Edward	Uganda, Dem. Rep. of Congo
Lake Kariba	Zambia, Zimbabwe
Lake Kivu	Rwanda, Dem. Rep. of Congo
Lake Malawi	Malawi, Tanzania, Mozambique
Lake Mweru	Dem. Rep. of Congo, Zambia
Lake Nasser	Egypt, Sudan
Lake Tanganyika	Tanzania, Dem. Rep. of Congo, Zambia, Burundi
Lake Turkana	Ethiopia, Kenya, Sudan
Lake Victoria	Kenya, Tanzania, Uganda, Rwanda, Burundi

approach to negotiating cooperative water resources management schemes. The 1966 Helsinki Rules on the Uses of the Waters of International Rivers first signaled this shift in emphasis from water allocation to the distribution of benefits, stating, "Each basin State is entitled, within its territory, to a reasonable and equitable share in the beneficial uses of the waters of an international drainage basin." More recently, a focus on benefits, rather than physical allocations, was supported by the World Commission on Dams in its report "Dams and Development" (2000), and the approach has been successfully employed in facilitating dialogue on the Nile River basin. An understanding of the magnitude of benefits associated with cooperative management of international waters will provide critical information for negotiating agreements and joint investments.

Riparians will pursue the benefits of cooperative management only if the proposed implementation agreements are perceived to be feasible and fair. There are, however, no clear international standards for cooperative water management; though a range of recognized principles and precedents exist, many are conflicting.

An economic approach offers a relatively objective means by which riparians can engage in discussions of alternative management scenarios. They can search for cooperative solutions that maximize systemwide economic benefits, and then try to find win-win distributions of the resulting benefits.

The Pareto criterion gives a standard for comparison among alternative allocations of resources. A particular allocation is said to be a Pareto improvement over the status quo if at least one party gains and nobody loses. A Pareto-optimal state is one in which no reallocation of resources will result in a Pareto improvement.

In the context of international rivers, as elsewhere, it is difficult to find interventions that result in Pareto improvements, because someone almost always loses from large-scale investment projects. A less stringent criterion is the *potential* Pareto improvement, which requires that the project's winners be able to compensate the losers in such a way as to make them as well off as before, while still enabling the winners to be better off. The key point is that such compensation need not actually be paid for the project to pass the potential Pareto improvement test.

Paretian analysis may be helpful, but the question of compensation will likely be a central issue in reaching agreements. Given the transaction costs and political overtones of international shared waters negotiations, it is unlikely that a plan representing a potential Pareto improvement benefiting one riparian disproportionately would be accepted by all—much less preferred. Analyses of user values and system values can, however, identify potential benefits and clarify the benefit distribution associated with different management scenarios. When these are made explicit, the equity of various scenarios can be assessed and compensation mechanisms considered.

A body of literature dealing with the topic of fairness analysis has evolved to capture the broader preferences of actors in resource allocation schemes. Baumol (1986) has defined the concept of "superfairness" as those distributions under which each party prefers its own bundle of goods to that of any other group. His work rests on the concept of envy, defined as the preference for another's bundle of commodities in a given allocation.[10]

Baumol and others have shown that Paretian analysis and superfairness criteria can be used to modify one another, particularly when the two clash. For example, an allocation may make possible a Pareto improvement that would benefit one, but perhaps not all, of the players, or might even benefit all the players, with one receiving disproportionate gains. It is certainly possible that such a Pareto improvement would not satisfy the incremental superfairness criteria because those who did not benefit the most might envy the party who did.

Payoff matrices can help illustrate the preferences, choices, and outcomes facing two riparians who are considering cooperative management schemes. In the lower right-hand quadrant of figure 6 is the outcome obtained if neither riparian chooses to negotiate in good faith (that is, they negotiate strategically); both will receive a payoff of -1. This is the worst-case scenario. The upper left-hand quadrant reflects the systemwide best scenario, where both Riparian 1 and Riparian 2 enter discussions in good faith, with a corresponding payoff of 2 and 4, respectively. In the upper right-hand corner, Riparian 1 negotiates in good faith, Riparian 2 strategically, receiving payoffs of 0 and 1 respectively. In the lower left-hand corner, Riparian 2 cooperates in good faith with a payoff of 0, while Riparian 1 negotiates strategically and receives a payoff of 3.

In figure 6 the systemwide best-case scenario is the preferred solution for Riparian 2. Riparian 1's preferred outcome, however, is to maneuver to the lower left-hand corner, where he negotiates strategically and Riparian 2 in good faith. In this situation the incentives for cooperation facing the two riparians are at odds.

Payoffs and hence incentives for cooperation can be changed, however, if riparians make credible threats or promises regarding their actions. These strategies could be related to specific unilateral actions a party might take in managing its water resources in the absence of a cooperative agreement, or they could be made with regard to side payments or compensation.

The payoffs can be altered to reflect such threats and promises. For example, to compel good faith negotiation, Riparian 2 might make a threat that was sufficiently credible to alter Riparian 1's payoff in the lower left-hand quadrant of the matrix to -1, as shown in figure 7. In this case, the choice of negotiating strategically provides only negative payoffs for Riparian 1 and would compel Riparian 1 to negotiate in good faith instead.

Figure 6. Riparians' Payoff Matrix

Riparian 2's Payoff

Riparian 1's Payoff		Negotiates in good faith	Does not negotiate in good faith
	Negotiates in good faith	2, 4	0, 1
	Does not negotiate in good faith	3, 0	–1, –1

Similarly, the payoff matrix could be altered by promises to achieve a cooperative solution, as in figure 8. Riparian 2 might promise a transfer of gains under a cooperative solution that would persuade Riparian 1 to negotiate in good faith. Riparian 2 could change the upper left-hand quadrant payoffs by promising compensation and redistributing the incremental gains generated in the best-case scenario so Riparian 1 would receive more by cooperating than acting strategically. This could be achieved through side payments related to the payoff that Riparian 2 receives under a cooperative solution or through some other negotiated basket of benefits.

The payoffs in the matrix will also change if riparians choose to look beyond the arena of water, broadening the scope of negotiations to include benefits linking water to other resources, projects, or issues of mutual interest. The range of benefits could include irrigation, hydropower, navigation, fishing, environmental protection, or trade and labor movements (Whittington, Waterbury, and McClelland 1994). Less tangible benefits could include goodwill and enhanced international support and public image. As with threats or compensation mechanisms, expanding the range of benefits under discussion changes the incentives for cooperation and can be seen as an avenue for facilitating negotiations.

Figure 7. Riparians' Payoff Matrix after Threat

Riparian 1's Payoff \ *Riparian 2's Payoff*	Negotiates in good faith	Does not negotiate in good faith
Negotiates in good faith	2, 4	0, 1
Does not negotiate in good faith	–1, 0	–1, –1

Figure 8. Riparians' Payoff Matrix after Promise

Riparian 2's Payoff

Riparian 1's Payoff	Negotiates in good faith	Does not negotiate in good faith
Negotiates in good faith	4, 2	0, 1
Does not negotiate in good faith	3, 0	–1, –1

Discussions about the cooperative management of water could serve as an entry point to broader issues of mutual concern among neighboring countries. Shared international waters, rather than being a point of contention or hostility among riparians, could provide for cooperation and the building of trust. Then the gains in the system value of water would form only one component, potentially a small component, of the overall gains in enhanced communication and greater cooperation among riparians.

Efforts to construct payoff schemes that will foster cooperation require an in-depth understanding of which ones will be acceptable or unacceptable to riparians and why. To many riparians, the assessment of cooperative investment and management plans will come down to a perception of fairness. Economic analyses can delineate efficient distributions of water, or the benefits derived from the use of water, but these will not be accepted unless they are perceived as equitable. While questions of equity are beyond the scope of user values and system values, these calculations can prove useful for quantifying the payoffs of alternative outcomes, thus providing the bases of comparison and information on which judgments on fairness can be made.

In the complex context of international rivers, rational concerns might arise over relative gains because the relationships among riparians are broader than the issue of water allocation. When allocation might affect economic or demographic development or issues of perceived national importance, the relative gains of riparians could be quite legitimate concerns. The superfairness criterion may help capture real issues overlooked in Paretian analysis.

The prominent role of politics in securing agreements for cooperative international water resources management cannot be denied and should be part of any discussion on the benefits and incentives for cooperation. LeMarquand (1977) identifies what he considers the five most critical political issues underlying a country's position in international rivers negotiations:

- Concern for national image
- Principles of international law
- Linkage to other bilateral or multilateral issues
- Reciprocity
- Sovereignty.

Increasingly, fairness has also become a critical political issue in these negotiations. In LeMarquand's analysis, equity issues will figure prominently in both national image and linkages to other bilateral and multilateral issues, particularly in the context of donor financial support for the development of international rivers.

Political realities can create imbalances in negotiating power among riparians that may have an impact on the feasibility of certain cooperative schemes. Historical precedents and alliances may affect bargaining positions and the propensities for riparians to form coalitions. Wealth may also play a role in negotiations, specifically with regard to threats and promises. Nations that depend on international assistance to build major water infrastructure will often be required to notify both upstream and downstream riparians prior to undertaking such projects on shared waters. This provides riparians with an opportunity to express any objections they might have to such projects and to have those objections considered before project financing is secured.[11] Threats regarding unilateral actions in the absence of cooperative agreements may not be credible if governments cannot afford to self-finance their infrastructure.

Sharing Benefits

In the international arena, there is no state mechanism or principle of eminent domain that can mandate schemes for redistribution and compensation. The equitable sharing of benefits can therefore be the most difficult and sensitive challenge of negotiating the cooperative management of international rivers. The tools of economics and systems analysis may identify attractive investment and management schemes, but the natural physical distribution of benefits will not necessarily be one considered equitable. Even when cooperation could generate greater gains for all players, inequities in the distribution of gains may make those scenarios unacceptable because they are not superfair—at least in the absence of redistribution.

In many cases, equitable benefits sharing will require some sort of redistribution or compensation. The form that compensation takes will be highly situation specific and could involve monetary transfers, but they may not be enough. Enlarging the range of benefits to be included in a compensation scheme may enable negotiators to find a mutually acceptable cooperative scheme not achievable with monetary compensation alone. The range of benefits under discussion is critical; the broader it is, the more likely riparians will be to find a mutually acceptable configuration of benefits. In addition to water use–related benefits, issues of mutual interest such as trade, immigration, and environmental protection can be incorporated into international rivers negotiations. Geopolitical relationships, public image, and international support might also influence states engaged in discussions of cooperative management of shared waters. There may be situations in which no amount or mixture of compensation could rectify a perceived inequity or compromise of sovereignty.

Physical conditions may limit the scope of compensation—particularly as a tool to counter Baumol's envy. Riparian 1 might envy the bundle of commodities assigned to Riparian 2 in a particular resource allocation if, for example, Riparian 2 will obtain significant hydropower capacity and Riparian 1 will not. The hydrology of the river will typically limit the potential to redistribute hydropower capacity, however. While creative negotiations might construct compensation in terms of (perhaps discounted) power-purchase agreements or monetary transfers, the control of water flows and prestige sometimes associated with major infrastructure projects could make it difficult to eliminate envy completely. This raises a basic question about the utility of money, and whether monetary compensation can be an effective form of compensation for achieving a superfair allocation for international rivers.

Reaching agreement on compensation will be complicated by several other factors, perhaps the most obvious being an agreement on the values to be compensated, for example, the value of water. The user value of water is different for different users at different times. Should water be compensated at the value it will accrue to its user or to its seller? In theory, water generally would be reallocated to its highest value use in an optimally designed cooperative management scheme, so the value to the users would be greater than the value of that water to the seller. Compensation could be set somewhere between the value to the seller and the value to the buyer, and both would gain. However, a cooperative scheme that was not Pareto optimal, but was agreed to on principles of fairness, could conceivably reallocate water from high-value uses to lower-value uses to achieve that fairness. The direction of compensation raises the issue of the initial allocation of water rights. After those rights are established, if water is transferred from their holder, then compensation would clearly be due. In many cases, however, water rights are unclear or are matters of contention. Calling for monetary compensation for water when initial allocations are in dispute is likely to compound perceptions of inequity and frustrate efforts toward cooperation.

For example, any proposal to establish water markets will immediately focus the attention of riparians on the unresolved issue of water rights. If water markets did exist, a country with little or no productive use for water would nevertheless have a strong incentive to maximize its water rights since they could be sold to other riparians. Water rights would thus have value to riparians even if they had no productive use for the water itself. It might be advantageous initially to set aside this issue in discussions of cooperative management and allow riparians to focus instead on the distribution of incremental gains. This need not prejudice future discussion of water rights.

Benefit-Sharing Principles and Practices

There is no international consensus on the criteria for equitable allocations though numerous principles for benefit sharing exist. Criteria for allocating water and its benefits can be drawn from a growing body of international water law. The 1966 Helsinki Rules on the Uses of the Waters of International Rivers, the 1995 SADC Shared Watercourse Systems Protocol, and the 1997 United Nations Convention on the Law of the Non-navigable Uses of International Watercourses all set out similar general principles upon which "reasonable and equitable" allocations of international shared waters should be based. Nowhere are the principles prioritized,[12] except for a clause in the UN Convention stating that "special regard" should be given to "the requirements of vital human needs" (see table 5).

The application of these broad legal principles provides a range of potential negotiating positions regarding water allocation. Upstream riparians will often cite the doctrine of *absolute sovereignty,* sometimes referred to as the Harmon Doctrine after the attorney general of the

Table 5. Principles for Allocating Shared Waters

The Helsinki Rules on the Uses of the Waters of International Rivers (1966)	SADC Shared Watercourse Systems Protocol (1995)	U.N. Convention on the Law of the Non-navigable Uses of International Watercourses (1997)
What is a reasonable and equitable share within the meaning of Article IV to be determined in the light of all relevant factors in each particular case…. Relevant factors which are to be cons idered include, but are not limited to:	*Utilization of a shared watercourse system in an equitable manner… requires taking into account all relevant factors and circumstances, including:*	*Utilization of an international watercourse in an equitable and reasonable manner … requires taking into account all relevant factors and circumstances, including:*
1. The geography of the basin, including in particular the extent of the drainage area in the territory of each basin State	1. Geographical, hydrographical, hydrologic, climatical and other factors of a natural character	1. Geographic, hydrographic, hydrologic, climatic, ecological and other factors of a natural character
2. The hydrology of the basin, including in particular the contribution of water by each basin State	2. The social and economic needs of the member States concerned	2. The social and economic needs of the watercourse States concerned
3. The climate affecting the basin	3. The effects of the use of a shared watercourse system in one water-course state on another watercourse state	3. The population dependent on the water-course in each watercourse State
4. The past utilization of the waters of the basin, including in particular existing water utilization	4. Existing and potential uses of the shared watercourse system	4. The effects of the use or uses of the water-courses in one watercourse State on other watercourse States
5. The economic and social needs of each basin State	5. Guidelines and agreed standards to be adopted	5. Existing and potential uses of the water-course
6. The population dependent on the waters of the basin in each basin State		6. Conservation, protection, development and economy of use of the water resources of the watercourse and the costs of measures taken to that effect

7. The comparative costs of alternative means of satisfying the economic and social needs of each basin State 8. The availability of other resources 9. The avoidance of unnecessary waste in the utilization of waters of the basin 10. The practicability of compensation to one or more of the co-basin States as a means of adjusting conflicts among uses 11. The degree to which the needs of a basin State may be satisfied, without causing substantial injury to a co-basin State	7. The availability of alternatives, of comparable value, to a particular planned or existing use

United States who coined the phrase in an 1895 dispute over the Rio Grande. The doctrine of absolute sovereignty holds that states have absolute rights over the water that flows through their territory. The opposite, equally extreme position, which is more favorable to the circumstances of downstream riparians, is that of *absolute riverain integrity,* which protects the natural flow of the international river system.

These extreme positions, absolute sovereignty and absolute riverain integrity, were essentially discredited in international law when a 1957 tribunal in the case of Lake Lanoux upheld a doctrine of limited territorial sovereignty. Since then, the less restrictive principle of *equitable utilization* generally has been supported by upstream riparians who claim entitlement to withdraw water for consumption. Downstream riparians—particularly those with large infrastructure investments that might be adversely affected by upstream water diversions—have generally supported the principle of *no significant harm.*

Another important principle frequently cited in the context of international (and national) water negotiations is that of *prior appropriations.* This concept, often referred to as "first in time—first in right," may be particularly problematic to apply in Africa. High levels of poverty, low levels of investment, a colonial legacy of widely differing infrastructure endowments among countries, and the relatively recent independence of so many nations suggest that principles tied to historical precedent may be inappropriate and economically regressive if they propagate the systematic exclusion of certain social groups. On the other hand, to sustain and encourage economic development, those who invest in infrastructure need reasonable assurance that insecure water rights will not undermine their investments.

The principles of equitable and reasonable utilization and of no significant harm are useful starting points for negotiations on the use of international shared waters. They provide the bases upon which benefit allocations and water rights can be discussed. Policymakers need to translate these principles into practice, finding practical rules for benefit allocation and mechanisms for redistribution and compensation. It is therefore useful to examine the actual practices that have evolved to facilitate the cooperative management of international rivers.

In an examination of 149 treaties relating to the management of international water resources, Wolf (1999) noted a general shift from rights-based criteria to needs-based criteria, as well as a fairly consistent pattern of protecting existing uses. What is most striking in his analysis is the range of solutions found among international water treaties. Wolf notes seven different principles applied in international treaties allocating shared waters (in descending order of frequency):

- Compensation for lost benefits
- Half of the flow apportioned to each riparian
- Prioritization of uses
- Payments for water
- Absolute sovereignty of tributaries
- Equal allocation of benefits
- Relinquishing of prior uses.

These practices are fairly evenly distributed between those that focus on allocating water and those that focus on allocating benefits. Ten of the 149 treaties in this list called for compensation of lost benefits, but only 4 explicitly mandated monetary payments for water.

It is difficult to draw many general conclusions from the experience of international water treaties in Africa because there are so few examples that were signed by independent riparian states addressing water allocation and benefit sharing. Among the few is the 1986 Treaty on the Lesotho Highlands Water Project. This project was undertaken by the governments of Lesotho and South Africa to generate hydropower in the mountains of Lesotho and regulate the provision of water to South Africa's burgeoning industrial enclave downstream in Guateng Province. Under the treaty, South Africa receives increasing allocations of water as the multiphased project moves forward, while Lesotho retains the benefits of hydroelectricity production. This was agreed to be an equitable allocation of benefits.

In some cases, perhaps the most notable being that of the Indus River basin, efforts toward joint management and benefits sharing at the basin level have encountered intractable problems. In those situations, designating full riparian rights over subbasins or tributaries has allowed agreed development of the river basin by essentially dividing it in two. Such agreements may not be optimal from a systems standpoint but can be significant improvements over uncoordinated, or discordant, management.

Benefit-Sharing Mechanisms

The mechanisms used to redistribute benefits or to provide compensation have been as varied as the principles upon which the allocation of benefits has been based. These mechanisms range from direct payments to equity partnerships.

Direct payments might be made for water itself or for the benefits to be shared or forgone in the context of a cooperative scheme. In the Lesotho Highlands Water Project agreement, for example, South Africa agreed to pay Lesotho for water delivered. International water markets conceivably could provide a more flexible mechanism for reallocating water use among riparians within an agreed compensation structure. Water markets would allow riparians to buy and sell fixed-term water use rights that would not affect accepted water treaty rights. The price and quantity of water use rights could be decided by market forces or negotiated as a means of benefit sharing.

Examples of agreements made to compensate riparians for lost benefits associated with cooperative water use schemes include the 1952 Exchange of Notes Constituting an Agreement between the United Kingdom (Uganda) and Egypt Regarding the Construction of the Owen Falls Dam in Uganda, in which Egypt paid Uganda for a loss of hydroelectric power and land inundation. The 1959 Nile Waters Agreement required Egypt to pay Sudan for damage to the lands that would be inundated by the construction of the Aswan High Dam.

Payments for benefits have also been made implicitly through purchase agreements. In the 1969 treaty between Portugal (Angola) and South Africa (Namibia) to develop hydropower on the Cunene River, South Africa agreed to pay Portugal for hydropower generated, using an algorithm to determine the amount of payment based on the percentage of flow in the river.

Purchase agreements can be a flexible tool for benefit sharing. They are generally negotiated for power but can also be negotiated for water, as was the case in the Lesotho Highlands Development Project. The negotiated price in a purchase agreement can effectively allocate the benefits of water use between riparians. While both riparians would clearly be made better off by the purchase if they were willing to enter into the trade, a higher agreed price would transfer proportionally more benefits to the seller, while a lower agreed price would apportion more to the buyer.

Purchase agreements can enable win-win scenarios, such as when revenue guarantees are a condition for arranging financing for large-scale projects. Another example of a mutually beneficial purchase agreement is when one riparian has water resources or hydropower capacity but insufficient national demand for them, while the other has meager water resources and hydropower capacity but significant demand.

In some instances it might be appropriate to compensate upstream riparians for watershed management as a form of benefit sharing. Upstream riparians, such as Rwanda on the Nile or Guinea on the Senegal, may have little need to abstract water. Their stewardship of headwaters and watersheds, however, might entitle them to share some portion of the downstream benefits that this care helped to facilitate. Seen the other way around, if the riparians upstream did not protect the watershed, it would impose costs on those downstream.

Financing arrangements might also include compensation to particular riparians, especially when cooperative management calls for large-scale infrastructure investments. When riparians finance the construction of infrastructure within their own borders independently of one another, a decision to share either gross or net benefits will have implications for the distribution of gains. Under a net benefit arrangement, the gains to be shared are calculated as the total benefits of cooperative action, less the net benefits of unilateral action. A gross benefits arrangement is calculated to share the total gains of cooperative action, with each country providing whatever infrastructure is required within its territory. The most notable example of this was the agreement between the United States and Canada to share the gross benefits of development on the Columbia River. Unless an equal value of work is done in each country, the one that does more construction will effectively subsidize the one that does less. Of course, the allocation of gross benefits could be designed to counter this.

One riparian also could provide financing for another as a means of facilitating the endeavor, and, if the financing agreement were not concluded at strictly market terms, as a means of reapportioning gains. As part of the 1969 treaty between Portugal (Angola) and South Africa (Namibia) on the Cunene River, South Africa agreed to provide financing for dam construction at Ruacana, in addition to compensation for inundated lands.

Joint financing of cooperative projects has also been a successful means of facilitating cooperation and sharing gains. In the Lesotho Highlands Water Project, the two parties shared the cost of construction in rough proportion to their share of anticipated benefits. Table 6 lists some mechanisms used in treaties for benefit sharing on Africa's international rivers.

Joint ownership might also be a means of achieving cooperative gains if concerns over the control of water flows might otherwise outweigh the potential benefits. In one of the seminal cases in international water law, the 1958 Lake Lanoux case, France sought to divert water for hydropower generation from the Carol River, which runs into Spain. Spain protested even after France offered to provide monetary compensation and to return all waters to the river channel. Spain's objection was that construction of the facility would give France the *capability* of controlling the flow of the river. The court in that case returned a moderate ruling, enjoining France to return the full flow of the river before it reached the

Table 6. Benefit-Sharing Mechanisms in Treaties

Mechanism	*Treaty*	*Details*
Direct Payments for Water	Agreement between the Government of South Africa (Namibia) and the Government of Portugal (Angola) in Regard to the First Phase of Development of the Water Resources of the Cunene River Basin (1969)	Diversion of water for subsistence was allowed free of charge, but payment to Portugal was required if water was diverted for purposes of gain.
	Treaty on the Lesotho Highlands Water Project (1986, Lesotho and South Africa on the Senqu/Orange)	South Africa financed a scheme to transfer water from Lesotho and paid Lesotho for the water delivered.
Direct Payments for Benefits	Agreement between the Government of South Africa (Namibia) and the Government of Portugal (Angola) in Regard to the First Phase of Development of the Water Resources of the Cunene River Basin (1969)	This treaty developed a hydropower dam which resulted in a diversion of water and flooding in then-Portuguese Angola. South Africa provided compensation for inundated land and agreed to pay royalties to Portugal for hydropower produced.
	Agreement between the Government of the United Arab Republic (Egypt) and the Government of Sudan (1959, Nile River)	Egypt compensated Sudan for flooding and relocation caused by the construction of the Aswan High Dam.

Purchase Agreements	Treaty on the Lesotho Highlands Water Project (1986, Lesotho and South Africa on the Senqu/Orange)	South Africa was committed to purchasing an agreed amount of water from Lesotho.
Financing Arrangements	Treaty on the Lesotho Highlands Water Project (1986, Lesotho and South Africa on the Senqu/Orange)	South Africa financed the water transfer component of the project while Lesotho financed the hydropower generation component, making the broader scheme essentially one of joint ownership. In addition, South Africa agreed to make foreign exchange available to Lesotho if necessary for that government to meet its obligations to the project.
	Agreement between the Government of the Union of South Africa and the Government of the Republic of Portugal Regulating the Use of the Water of the Cunene River (1926)	A dam was constructed in Portuguese territory (Angola) with costs shared between Portugal and South Africa.

Spanish border, but denying Spain the right to preclude reasonable upstream development. Joint ownership or operation or both of control infrastructure, by riparian nations or riparian nationals or entities, might ease such concerns.

Conclusion

To a greater extent in Africa than anywhere else in the world, international rivers have the potential to join countries economically and politically—or, conversely, to cause economic and political tensions between them. Africa has more international rivers shared by three or more countries than any other continent. The geopolitical complexity of its international rivers is due largely to borders that were drawn with little regard for the hydrologic integrity, the topography, and the climatic characteristics of the continent. The challenge and the importance of managing these rivers are compounded by extreme inter- and intrayear rainfall variability and the vulnerability of Africa's largely poor, agrarian economies.

As water becomes increasingly scarce and competition for it grows between individual users as well as between states, the efficiency and equity implications of water management policies must be addressed. This imperative is the essence of proposals to treat water as an economic good. In the context of international river basins, this paper has explored two notions of the economic value of water. The first is the "user value" of water, which is the value that can be derived from a single, specific use of water. In the case of international shared waters, the user can be thought of as an individual, a group of individuals, or even a state using water for a specific purpose in a specific place and manner. The second notion is that of a "system value," the aggregate value that a unit of water can generate as it moves through the river system before it is consumed or lost. Because they aggregate the value of water in all of its uses within the river system, system values must incorporate opportunity costs and externalities that would not necessarily be considered in the calculation of user values.

Externalities are of particular interest in analyses of the potential benefits of cooperative management of international rivers because they are often either the motivating factors behind the search for cooperative solutions or the sources of conflict. The standard assumption that unidirectional externalities characterize rivers is too simplistic in Africa and can be counterproductive because it obscures opportunities for mutual gain.

This assumption also obscures the reality that on international rivers downstream development can generate upstream externalities by effectively foreclosing future opportunities for upstream water use. While upstream extraction generates externalities downstream by diminishing flows physically, downstream extraction generates externalities upstream by diminishing future flows available to riparians upstream, because downstream users have acquired rights to their water by developing it.

The aggregation of user values into system values effectively forces an integrated systems investment and management perspective, which is the goal of cooperative water resources management. When system values exceed user values, there is strong incentive for cooperation. The economic benefits of systemwide cooperative management may not, however, be equitably distributed among riparians, and the optimal development path from a systems perspective may not be the best option for any single riparian. Under such circumstances, compensation, the redistribution of benefits, or both will need to be explored to reach agreements among riparian countries.

In the African context of pervasive poverty, rapidly growing populations, and numerous shared rivers, real incentives for cooperative water resources management do exist. They become apparent when riparians identify cooperative investment plans or management and regulatory schemes that increase the total economic benefits (system values) of water within international basins. The benefits of cooperation can also extend beyond the river, serving to reduce the geopolitical tensions that sometimes arise over conflicting resource claims and to promote economic cooperation and integration in other sectors.

Yet even when the potential for gains from cooperation is clear, riparians will pursue those benefits only if a proposed agreement is perceived as feasible and fair. While questions of equity are beyond the scope of determining user and system values and no clear international standards for equity in cooperative water management exist, economic analyses can delineate efficient distributions of water and alternative distributions of the benefits derived from its use. Such information can serve as a basis for comparison for those who must make equity judgments. In addition, Paretian fairness analyses can provide criteria for comparison among alternative investment and management strategies.

The prominent role of politics in securing agreements for cooperative management of shared water resources cannot be denied. Historical precedents and alliances may affect negotiations by influencing states' initial bargaining positions and the propensities for riparians to form coalitions. Relative wealth may also be a factor, particularly with regard to the credibility of unilateral threats and promises that would require significant investment or financial outlays.

The equitable sharing of benefits is perhaps the most difficult and sensitive challenge in negotiating the cooperative management of international rivers. Shifting focus from sharing water to sharing the benefits derived from its use provides far greater flexibility in the design of agreements. When the natural physical distribution of benefits is not acceptable to all riparians, however, some sort of redistribution or compensation will still be needed to foster agreement. The form that compensation takes will depend on the specifics of each situation but could involve monetary transfers, granting of rights to use water, financing of investments, or the provision of unrelated goods and services.

In addition to water use–related benefits, issues of mutual interest such as trade, immigration, and environmental protection could be incorporated into negotiations. Geopolitical relationships, public image, and international support might also influence states engaged in these talks. The range of benefits under discussion is a critical issue; the broader it is, the more likely riparians will be to find a mutually acceptable configuration.

Numerous principles and practices for benefit sharing exist, but there is no international consensus on the criteria for equitable allocations. The most widely discussed principles are *equitable utilization,* which emphasizes equity for all riparians, and *no significant harm,* which emphasizes protection for all riparian interests. Another important principle often cited in the context of international water negotiations is that of *prior appropriations,* or “first in time—first in right.” This argument is more controversial in the African context given the high levels of poverty, the low levels of investment, a colonial legacy of widely differing infrastructure endowments among countries, and the relatively recent independence of so many nations. Under these circumstances, principles tied to historical precedent may be inappropriate and potentially regressive if they propagate the systematic exclusion of certain sectors of society. On the other hand, to sustain and encourage economic development, infrastructure investors must be reasonably assured that insecure water rights will not undermine their investments.

Mechanisms for benefit sharing have also evolved to facilitate redistribution of the gains from the cooperative management of international rivers. In Africa, these mechanisms have included direct payments for water, direct payments for loss of benefits, power-purchase agreements, and financing arrangements. In addition, water markets and equity partnerships have been explored and should be explored further. The terms of these agreements—for example, whether rates and conditions are more or less favorable than pure market terms—may also affect a transfer of benefits from one partner to another.

Economics does not provide incontrovertible principles upon which to base water allocation or benefit-sharing decisions. Economic tools, however, can assist policymakers in translating principles of equity into practice by helping to identify the potential scale, range, and distribution of benefits associated with cooperative international rivers management. Economic tools also can help policymakers find practical rules for benefit allocation as a point of departure for international negotiations and construct mechanisms for redistributing benefits or providing other compensation.

Annex
International Rivers by Country

	Algeria	Angola	Benin	Botswana
Algeria			Niger	
Angola				Okavango, Zambezi
Benin	Niger			
Botswana		Okavango, Zambezi		
Burkina Faso	Niger		Niger, Volta	
Burundi		Congo		
Cameroon	Niger	Congo	Niger	
Central African Rep.		Congo		
Chad	Niger		Niger	
Congo, Dem. Rep. of		Congo, Chiloango, Zambezi		Zambezi
Congo, Rep. of		Congo, Chiloango		
Côte d'Ivoire	Niger		Niger, Volta	
Djibouti				
Egypt				
Equatorial Guinea				
Eritrea				
Ethiopia				
Gabon		Congo		
Gambia, The				
Ghana			Volta	
Guinea	Niger		Niger	
Guinea-Bissau				
Kenya				
Lesotho				Orange
Liberia				
Malawi		Congo, Zambezi		Zambezi
Mali	Niger		Niger, Volta	
Mauritania				
Morocco	Daoura, Dra, Guir, Oued Bon Naima, Tafna			

	Algeria	**Angola**	**Benin**	**Botswana**
Mozambique		Zambezi		Zambezi,
Limpopo				
Namibia		Etosha-Cuvelai, Kunene, Okavango, Zambezi		Okavango, Zambezi, Orange
Niger	Niger		Niger	
Nigeria	Niger		Yewa, Niger, Oueme	
Rwanda		Congo		
Senegal				
Sierra Leone	Niger		Niger	
Somalia				
South Africa				Limpopo, Orange
Sudan				
Swaziland				
Tanzania		Congo, Zambezi		Zambezi
Togo			Mono, Oueme, Volta	
Tunisia	Medjerda			
Uganda				
Zambia		Congo, Zambezi		Zambezi
Zimbabwe		Okavango, Zambezi		Okavango, Zambezi, Limpopo

	Burkina Faso	**Burundi**	**Cameroon**	**Central African Rep.**
Algeria	Niger		Niger	
Angola		Congo	Congo	Congo
Benin	Niger, Volta		Niger	
Botswana				
Burkina Faso			Niger	
Burundi			Congo	Congo
Cameroon	Niger	Congo		Logone/Chari, Congo
Central African Rep.		Congo	Congo, Logone/Chari	
Chad	Niger		Niger, Logone/Chari	Logone/Chari
Congo, Dem. Rep. of		Congo, Nile	Congo	Congo

	Burkina Faso	Burundi	Cameroon	Central African Rep.
Congo, Rep. of		Rusizi, Congo	Congo, Ogooué	Congo
Côte d'Ivoire	Niger, Komoe, Volta		Niger	
Djibouti				
Egypt		Nile		
Equatorial Guinea			Ntem, Ogooué	
Eritrea		Nile		
Ethiopia		Nile		
Gabon		Congo	Congo, Ntem, Ogooué	Congo
Gambia, The				
Ghana	Komoe, Volta			
Guinea	Niger		Niger	
Guinea-Bissau				
Kenya		Nile		
Lesotho				
Liberia				
Malawi		Congo	Congo	Congo
Mali	Niger, Komoe, Volta		Niger	
Mauritania				
Morocco				
Mozambique				
Namibia				
Niger	Niger		Niger	
Nigeria	Niger		Akpa Yafi, Cross, Niger	
Rwanda		Congo, Nile	Congo	Congo
Senegal				
Sierra Leone	Niger		Niger	
Somalia				
South Africa				
Sudan		Nile		
Swaziland				
Tanzania		Congo, Nile	Congo	Congo
Togo	Volta			
Tunisia				
Uganda		Nile		
Zambia		Congo	Congo	Congo
Zimbabwe				

	Chad	Congo, Dem. Rep. of	Congo, Rep. of	Côte d'Ivoire
Algeria	Niger			Niger
Angola		Congo, Chiloango, Zambezi	Congo, Chiloango	
Benin	Niger			Niger, Volta
Botswana		Zambezi		
Burkina Faso	Niger			Niger, Komoe, Volta
Burundi		Congo, Nile	Rusizi, Congo	
Cameroon	Niger, Logone/Chari	Congo	Congo, Ogooué	Niger
Central African Rep.	Logone/ Chari	Congo	Congo	
Chad				Niger
Congo, Dem. Rep. of			Congo, Chiloango	
Congo, Rep. of		Congo, Chiloango		
Côte d'Ivoire	Niger			
Djibouti				
Egypt		Nile		
Equatorial Guinea			Ogooué	
Eritrea		Nile		
Ethiopia		Nile		
Gabon		Congo	Nyanga, Congo, Ogooué	
Gambia, The				
Ghana				Bia, Tano, Komoe, Volta
Guinea	Niger			Sassandra, Niger, St. John, Cestos, Cavally
Guinea-Bissau				
Kenya		Nile		
Lesotho				
Liberia				St. John, Cestos, Cavally

	Chad	Congo, Dem. Rep. of	Congo, Rep. of	Côte d'Ivoire
Malawi		Congo, Zambezi	Congo	
Mali	Niger			Niger, Komoe, Volta
Mauritania				
Morocco				
Mozambique		Zambezi		
Namibia		Zambezi		
Niger	Niger			Niger
Nigeria	Niger			Niger
Rwanda		Congo, Nile	Congo	
Senegal				
Sierra Leone	Niger			Niger
Somalia				
South Africa				
Sudan		Nile		
Swaziland				
Tanzania		Congo, Zambezi, Nile	Congo	
Togo				Volta
Tunisia				
Uganda		Nile		
Zambia		Congo, Zambezi	Luapula, Congo	
Zimbabwe		Zambezi		

	Djibouti	Egypt	Equatorial Guinea	Eritrea
Algeria				
Angola				
Benin				
Botswana				
Burkina Faso				
Burundi		Nile		Nile
Cameroon			Ntem, Ogooué	
Central African Rep.				
Chad				
Congo, Dem. Rep. of		Nile		Nile
Congo, Rep. of			Ogooué	
Côte d'Ivoire				
Djibouti				

	Djibouti	Egypt	Equatorial Guinea	Eritrea
Egypt				Nile
Equatorial Guinea				
Eritrea		Nile		
Ethiopia	Awash	Nile		Gash, Nile
Gabon			Benito, Mbe, Utamboni, Ntem, Ogooué	
Gambia, The				
Ghana				
Guinea				
Guinea-Bissau				
Kenya		Nile		Nile
Lesotho				
Liberia				
Malawi				
Mali				
Mauritania				
Morocco				
Mozambique				
Namibia				
Niger				
Nigeria				
Rwanda		Nile		Nile
Senegal				
Sierra Leone				
Somalia	Awash			
South Africa				
Sudan		Nile		Baraka, Gash, Nile
Swaziland				
Tanzania		Nile		Nile
Togo				
Tunisia				
Uganda		Nile		Nile
Zambia				
Zimbabwe				

	Ethiopia	Gabon	Gambia, The	Ghana
Algeria				
Angola		Congo		
Benin				Volta
Botswana				

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	Ethiopia	Gabon	Gambia, The	Ghana
Burkina Faso				Komoe, Volta
Burundi	Nile	Congo		
Cameroon		Congo, Ntem, Ogooué		
Central African Rep.		Congo		
Chad				
Congo, Dem. Rep. of	Nile	Congo		
Congo, Rep. of		Nyanga, Congo, Ogooué		
Côte d'Ivoire				Bia, Tano, Komoe, Volta
Djibouti	Awash			
Egypt	Nile			
Equatorial Guinea		Benito, Mbe, Utamboni, Ntem, Ogooué		
Eritrea	Gash, Nile			
Ethiopia				
Gabon				
Gambia, The				
Ghana				
Guinea			Gambia	
Guinea-Bissau				
Kenya	Juba-Shibeli, Nile			
Lesotho				
Liberia				
Malawi		Congo		
Mali				Komoe, Volta
Mauritania				
Morocco				
Mozambique				
Namibia				
Niger				
Nigeria				
Rwanda	Nile	Congo		
Senegal			Gambia	
Sierra Leone				

	Ethiopia	**Gabon**	**Gambia, The**	**Ghana**
Somalia	Awash, Juba-Shibeli			
South Africa				
Sudan	Gash, Nile			
Swaziland				
Tanzania	Nile	Congo		
Togo				Volta
Tunisia				
Uganda	Nile			
Zambia		Congo		
Zimbabwe				

	Guinea	**Guinea-Bissau**	**Kenya**	**Lesotho**
Algeria	Niger			
Angola				
Benin	Niger			
Botswana				Orange
Burkina Faso	Niger			
Burundi			Nile	
Cameroon	Niger			
Central African Rep.				
Chad	Niger			
Congo, Dem. Rep. of			Nile	
Congo, Rep. of				
Côte d'Ivoire	Sassandra, Niger, St. John, Cestos, Cavally			
Djibouti				
Egypt			Nile	
Equatorial Guinea				
Eritrea			Nile	
Ethiopia			Juba-Shibeli, Nile	
Gabon				
Gambia, The	Gambia			
Ghana				
Guinea		Corubal, Geba		

	Guinea	**Guinea-Bissau**	**Kenya**	**Lesotho**
Guinea-Bissau	Corubal, Gêba			
Kenya				
Lesotho				
Liberia	Loffa, St. Paul, St. John, Cestos, Cavally, Moa			
Malawi				
Mali	Niger, Senegal			
Mauritania	Senegal			
Morocco				
Mozambique				
Namibia				Orange
Niger	Niger			
Nigeria	Niger			
Rwanda			Nile	
Senegal	Senegal, Gambia, Gêba	Gêba		
Sierra Leone	Great Scarcies, Little Scarcies, Niger, Moa			
Somalia			Juba-Shibeli	
South Africa				Orange
Sudan			Nile	
Swaziland				
Tanzania			Mara, Umba, Nile	
Togo				
Tunisia				
Uganda			Nile	
Zambia				
Zimbabwe				

	Liberia	**Malawi**	**Mali**	**Mauritania**
Algeria			Niger	
Angola		Congo, Zambezi		
Benin			Niger, Volta	
Botswana		Zambezi		
Burkina Faso			Niger, Komoe, Volta	

	Liberia	Malawi	Mali	Mauritania
Burundi		Congo		
Cameroon		Congo	Niger	
Central African Rep.		Congo		
Chad			Niger	
Congo, Dem. Rep. of		Congo, Zambezi		
Congo, Rep. of		Congo		
Côte d'Ivoire	St. John, Cestos, Cavally		Niger, Komoe, Volta	
Djibouti				
Egypt				
Equatorial Guinea				
Eritrea				
Ethiopia				
Gabon		Congo		
Gambia, The				
Ghana			Komoe, Volta	
Guinea	Loffa, St. Paul, St. John, Cestos, Cavally, Moa		Niger, Senegal, Volta	Senegal
Guinea-Bissau				
Kenya				
Lesotho				
Liberia				
Malawi				
Mali				Senegal
Mauritania			Senegal	
Morocco				
Mozambique		Zambezi, Ruvuma		
Namibia		Zambezi		
Niger			Niger	
Nigeria			Niger	
Rwanda		Congo		
Senegal			Senegal	Senegal
Sierra Leone	Mana-Morro, Moa		Niger	
Somalia				

	Liberia	**Malawi**	**Mali**	**Mauritania**
South Africa				
Sudan				
Swaziland				
Tanzania		Songwe, Congo, Zambezi, Ruvuma		
Togo			Volta	
Tunisia				
Uganda				
Zambia		Congo, Zambezi		
Zimbabwe		Zambezi		

	Morocco	**Mozambique**	**Namibia**	**Niger**
Algeria	Daoura, Dra, Guir, Oued Bon Naima, Tafna			Niger
Angola		Zambezi	Etosha-Cuvelai, Kunene, Okavango, Zambezi	
Benin				Niger
Botswana		Zambezi, Limpopo	Okavango, Zambezi, Orange	
Burkina Faso				Niger
Burundi				
Cameroon				Niger
Central African Rep.				
Chad				Niger
Congo, Dem. Rep. of		Zambezi	Zambezi	
Congo, Rep. of				
Côte d'Ivoire				Niger
Djibouti				
Egypt				
Equatorial Guinea				
Eritrea				
Ethiopia				
Gabon				
Gambia, The				

	Morocco	**Mozambique**	**Namibia**	**Niger**
Ghana				
Guinea				Niger
Guinea-Bissau				
Kenya				
Lesotho			Orange	
Liberia				
Malawi		Zambezi, Ruvuma	Zambezi	
Mali				Niger
Mauritania				
Morocco				
Mozambique			Zambezi	
Namibia		Zambezi		
Niger				
Nigeria				Hadejia, Niger
Rwanda				
Senegal				
Sierra Leone				Niger
Somalia				
South Africa		Limpopo, Maputo, Incomati, Umbeluzi	Orange	
Sudan				
Swaziland		Maputo, Incomati, Umbeluzi		
Tanzania		Zambezi, Ruvuma	Zambezi	
Togo				
Tunisia				
Uganda				
Zambia		Zambezi	Zambezi	
Zimbabwe		Buzi, Pungue, Sabi, Zambezi, Limpopo	Okavango, Zambezi	

	Nigeria	**Rwanda**	**Senegal**	**Sierra Leone**
Algeria	Niger			Niger
Angola		Congo		
Benin	Yewa, Niger, Oueme			Niger
Botswana				

	Nigeria	Rwanda	Senegal	Sierra Leone
Burkina Faso	Niger			Niger
Burundi		Congo, Nile		
Cameroon	Akpa Yafi, Cross, Niger	Congo		Niger
Central African Rep.		Congo		
Chad	Niger			Niger
Congo, Dem. Rep. of		Congo, Nile		
Congo, Rep. of		Congo		
Côte d'Ivoire	Niger			Niger
Djibouti				
Egypt		Nile		
Equatorial Guinea				
Eritrea		Nile		
Ethiopia		Nile		
Gabon		Congo		
Gambia, The			Gambia	
Ghana				
Guinea	Niger		Senegal, Gambia, Gêba	Great Scarcies, Little Scarcies, Niger, Moa
Guinea-Bissau			Gêba	
Kenya		Nile		
Lesotho				
Liberia				Mana-Morro, Moa
Malawi		Congo		
Mali	Niger		Senegal	Niger
Mauritania			Senegal	
Morocco				
Mozambique				
Namibia				
Niger	Hadejia, Niger			Niger
Nigeria				Niger
Rwanda				

	Nigeria	Rwanda	Senegal	Sierra Leone
Senegal				
Sierra Leone	Niger			
Somalia				
South Africa				
Sudan		Nile		
Swaziland				
Tanzania		Congo, Nile		
Togo	Oueme			
Tunisia				
Uganda		Nile		
Zambia		Congo		
Zimbabwe				

	Somalia	South Africa	Sudan	Swaziland
Algeria				
Angola				
Benin				
Botswana		Limpopo, Orange		
Burkina Faso			Nile	
Burundi				
Cameroon				
Central African Rep.				
Chad				
Congo, Dem. Rep. of			Nile	
Congo, Rep. of				
Côte d'Ivoire				
Djibouti	Awash			
Egypt			Nile	
Equatorial Guinea				
Eritrea			Baraka, Gash, Nile	
Ethiopia	Awash, Juba-Shibeli		Gash, Nile	
Gabon				
Gambia, The				
Ghana				
Guinea				

	Somalia	South Africa	Sudan	Swaziland
Guinea-Bissau				
Kenya	Juba-Shibeli		Nile	
Lesotho		Orange		
Liberia				
Malawi				
Mali				
Mauritania				
Morocco				
Mozambique		Limpopo, Maputo, Incomati, Umbeluzi		Maputo, Incomati, Umbeluzi
Namibia		Orange		
Niger				
Nigeria				
Rwanda			Nile	
Senegal				
Sierra Leone				
Somalia				
South Africa				Maputo, Incomati, Umbeluzi
Sudan				
Swaziland		Maputo, Incomati, Umbeluzi		
Tanzania			Nile	
Togo				
Tunisia				
Uganda			Nile	
Zambia				
Zimbabwe		Limpopo		

	Tanzania	Togo	Tunisia	Uganda
Algeria			Medjerda	
Angola	Congo, Zambezi			
Benin		Mono, Oueme, Volta		
Botswana	Zambezi			
Burkina Faso		Volta		
Burundi	Congo, Nile			Nile
Cameroon	Congo			

	Tanzania	Togo	Tunisia	Uganda
Central African Rep.	Congo			
Chad				
Congo, Dem. Rep. of	Congo, Zambezi, Nile			Nile
Congo, Rep. of	Congo			
Côte d'Ivoire		Volta		
Djibouti				
Egypt	Nile			Nile
Equatorial Guinea				
Eritrea	Nile			Nile
Ethiopia	Nile			Nile
Gabon	Congo			
Gambia, The				
Ghana		Volta		
Guinea				
Guinea-Bissau				
Kenya	Mara, Umba, Nile			Nile
Lesotho				
Liberia				
Malawi	Songwe, Congo, Zambezi, Ruvuma			
Mali		Volta		
Mauritania				
Morocco				
Mozambique	Zambezi, Ruvuma			
Namibia	Zambezi			
Niger				
Nigeria		Oueme		
Rwanda	Congo, Nile			Nile
Senegal				
Sierra Leone				
Somalia				
South Africa				
Sudan	Nile			Nile
Swaziland				

	Tanzania	**Togo**	**Tunisia**	**Uganda**
Tanzania				Nile
Togo				
Tunisia				
Uganda	Nile			
Zambia	Congo, Zambezi			
Zimbabwe	Zambezi			

	Zambia	**Zimbabwe**
Algeria		
Angola	Congo, Zambezi	Okavango, Zambezi
Benin		
Botswana	Zambezi	Okavango, Zambezi, Limpopo
Burkina Faso		
Burundi	Congo	
Cameroon	Congo	
Central African Rep.	Congo	
Chad		
Congo, Dem. Rep. of	Congo, Zambezi	Zambezi
Congo, Rep. of	Luapula, Congo	
Côte d’Ivoire		
Djibouti		
Egypt		
Equatorial Guinea		
Eritrea		
Ethiopia		
Gabon	Congo	
Gambia, The		
Ghana		
Guinea		
Guinea-Bissau		
Kenya		
Lesotho		

	Zambia	Zimbabwe
Liberia		
Malawi	Congo, Zambezi	Zambezi
Mali		
Mauritania		
Morocco		
Mozambique	Zambezi	Buzi, Pungue, Sabi, Zambezi, Limpopo
Namibia	Zambezi	Okavango, Zambezi
Niger		
Nigeria		
Rwanda	Congo	
Senegal		
Sierra Leone		
Somalia		
South Africa		Limpopo
Sudan		
Swaziland		
Tanzania	Congo, Zambezi	Zambezi
Togo		
Tunisia		
Uganda		
Zambia		Zambezi
Zimbabwe	Zambezi	

Notes

1. There is a long-standing debate about the terminology for international rivers. In this paper, freshwater flows (whether surface water or groundwater), and the lakes and wetlands that some of these flows pass through, derive from, or terminate within, are described loosely as rivers. The term "international rivers" refers to freshwaters whose basins are situated within the borders of more than one state.

2. The estimates of reconstruction costs assume that new infrastructure and other facilities will be built to current generally accepted standards.

3. It is at least equal to the marginal value product of water in a particular use.

4. Supplying piped water at a significantly lower cost to such households would generate "consumer surplus," which reflects the surplus value of the good to the consumer relative to the price he will need to pay to obtain it. Increases in consumer surplus are considered social gains.

5. From the Dublin Statement of the 1992 International Conference on Water and the Environment held in Ireland.

6. A related argument is that water is a public good. But water does not easily fit the economist's definition of a public good—a good whose use by one party does not diminish its use by another (nonrivalry), and usually one that cannot be managed in such a way as to preclude its use by any individual (nonexcludability). Neither of these properties generally holds in the case of water. If an upstream riparian either diverts or pollutes water, he will clearly diminish its potential use by a downstream riparian, countering the principle of nonrivalry. Similarly, if water abstraction systems such as boreholes are prohibited, or simply not provided or maintained, individuals can be kept from using the resource—violating the principle of nonexcludability. It is more likely that the com-

mon reference to water as a public good reflects the sentiment that it should be deemed the responsibility of the government to provide all people with access to water that has not been compromised in quantity or quality by other users.

7. This discussion follows on the work of Rogers (1997) and Briscoe (1996), who present clear and useful discussions on the different components of water costs and values.

8. While it is intuitive to think of these as financial costs, it should be noted that when supply costs are included as a component of full use costs, they must be evaluated using economic, rather than financial input, costs.

9. For a clear exposition of accepted methods, see Dixon and others (1994), Economic Analysis of Environmental Impacts.

10. According to Baumol, "A distribution of n commodities is said to involve envy by individual 2 of the share obtained by individual 1 if 2 would rather have the bundle of commodities received by 1 under this distribution than the bundle of the distribution assigned to 2."

11. The World Bank's O.D. 7.50 is an example of an institutional mandate that requires prior notification of riparians before financing can be made available for projects on international waters.

12. The Helsinki Rules state, "The weight to be given to each factor is to be determined by its importance in comparison with that of other relevant factors. In determining what is a reasonable and equitable share, all relevant factors are to be considered together and a conclusion reached on the basis of the whole" (Article V, section 3). This same wording is found in the UN Convention (Article VI, section 3).

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