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Economic Rationale for Cooperation in International Waters in Africa

A Review

Regassa Ensermu Namara
Mark Giordano

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CIWA

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Executive Summary

Transboundary river basins cover 62 percent of Africa's total area and, with the exception of island states, every African country has at least one international river in its territory. Ten are shared by four or more countries (Sadoff et al. 2002). As a result of the dependence on transboundary waters, transboundary water governance in Africa is central to any national or regional water strategy and any economic, poverty reduction, and environmental strategy.

Cooperative governance of transboundary basins is important for several reasons. First, even if fears of water wars are overstated, reducing water conflicts also reduces the risk that disagreements over water will spill over to other economic or political spheres. Conversely, while disagreement over shared waters can have negative spillover effects, cooperation can facilitate broader levels of cooperation and support positive interaction outside the water sector in areas including trade and economic integration. Second, from an efficiency perspective, cooperation over transboundary waters expands opportunities (that is, Pareto improvements) to create added economic value from water and for internalizing potential negative externalities from uncoordinated action. In the case of Africa, cooperation can create scale economies needed for efficient investment. Third, and related, institutionalized cooperation over water can open opportunities for essential water infrastructure financing. Finally, cooperation over transboundary water can provide a means by which the broader environmental and social values of water can be recognized and the costs and benefits of change can be reviewed in the best interests of current and future generations.

Despite the potential payoff from water cooperation, forging meaningful agreements for shared water management faces numerous challenges. Impediments to negotiated cooperation include differences in up- and downstream views on water rights and histories of water use; negotiating philosophies focused on the belief that water is a zero-sum game; geographic and political power differentials that conflict with basin-wide solutions; and uncertainty over basic water resources data that increase the perceived risks of cooperation.

However, a large body of international water law and scholarship shows that these impediments can be overcome and provides approaches for doing so. These include:

- linking of issues beyond the water sector to neutralize the hydrology of upstream/downstream relations;
- transforming negotiations over water to negotiations over the benefits of water to overcome the zero-sum problem and increase the size of negotiating spaces;
- using side-payments and the involvement of outside parties to dissolve deadlocks; and
- improving the use of data and information to reduce the uncertainty and the sovereignty risk of formal agreement formation.

Finally, while including a broad range of stakeholders can initially slow processes, experience has shown that consideration of multiple viewpoints increases the probability of long-term success and helps ensure that cooperation brings the promised benefits.

For cooperation to occur, riparian states, other stakeholders, and the facilitators of negotiation must be aware of the possible benefits of cooperation, whether benefit distribution will be shared, and what pathways are most likely to overcome potential barriers to negotiation. Economic theory and empirical analysis can play a productive role in providing the necessary information. Cost-benefit analysis (CBA) originated in the water sector and has long been the standard framework for assessing project feasibility. Hydro-economic modeling has been used to provide much more detailed understanding of the potential for cooperation in specific hydrologic regimes and to provide an understanding of differential impacts on riparian states. Game theory has been used to show how differential impacts may influence willingness to negotiate and measures that might be taken to expand bargaining space and to create outcomes that increase overall benefits while being politically acceptable to individual riparian states. More recently real options analysis and multi-criteria analysis have been used to take the processes further and provide enhanced platforms to broaden stakeholder input in decision-making processes. Multi-criteria analysis specifically conforms to Article 6 of the 1997 Convention on the Law of the Non-Navigational Uses of International Water Courses, which states that "in determining what is a reasonable and equitable use, all relevant factors are to be considered together and a conclusion reached on the basis of the whole" (United Nations 2014).

This paper provides a review of the challenges to transboundary water cooperation, pathways for overcoming those challenges, and the role of economics in facilitating the discovery of those pathways. While it is written to focus on African transboundary waters, the report draws from broader transboundary water literature. Appendices include case studies on both game theory and hydro-economic analysis in transboundary cooperation for several river basins, including some from Africa.

Key findings include the following:

- Published studies of the economics of transboundary water cooperation have used a range of methods though the majority employ hydro-economic modeling and game theory. Though they have been applied to a wide variety of basins, a significant number focus on the Aral Sea and its tributaries, the Nile River, and the Ganges River.
- The limited studies that have quantified the gains from cooperation or costs of noncooperation show that the potential benefits are substantial. Recognizing the potential gains and costs for all parties provides a motivation for cooperation.
- Other studies have used economic analysis to discover insights for overcoming barriers to transboundary water cooperation.
- Information and analysis needs vary by the history and status of the cooperation process.
- The process of collecting the data needed for quantitative economic analysis as well as the analysis itself can also provide mechanisms to forge cooperation and, if done well, this joint effort can increase transparency in decision-making processes and help ensure hearing voices of all critical stakeholders including those supporting the environment.
- Some methodological approaches may be useful in motivating the cooperation of a broader range of stakeholders into cooperation processes. This can be valuable both to ensure broad support for a decision and to ensure that the full range of costs and benefits and their distribution among stakeholders are considered.

Abbreviations

BIP	Border Industrialization Plan
CBA	Cost-benefit Analysis
CCNR	Central Commission for Navigation of the Rhine
CGE	Computable General Equilibrium
CHR	International Commission for the Hydrology of the Rhine Basin
GDP	Gross Domestic Product
GNP	Gross National Product
ICPR	International Commission for the Protection of the Rhine
MCA	Multi-criteria Assessment
MRC	Mekong River Commission
O&M	Operations and Maintenance
SAM	Social Accounting Matrix
SCRB	Separable Costs-remaining Benefit
SSA	Sub-Saharan Africa
UN	United Nations
UNECE	United Nations Economic Commission for Europe

Chapter 1
Introduction

In Sub-Saharan Africa (SSA), water development, management, and use typically affects more than one country since most African rivers flow past international boundaries. Transboundary watersheds occupy more than 60 percent of the region's landmass, are home to the majority of the population, and produce more than half of the region's renewable water resources (Lautze and Giordano 2005; Turton et al. 2006; UNECA 2000). As a result of the dependence on transboundary waters, transboundary water governance will form a core part of almost any national or regional water strategy as well as economic, poverty reduction, and environmental strategies.

There are many formal agreements between SSA's riparian states to guide governance of internationally shared water resources (Giordano et al. 2013; Lautze and Giordano 2005). Some of these agreements are designed to address specific water-sharing needs or facilitate the construction and operation of targeted infrastructure such as dams. Others establish more general management institutions such as River Basin Organizations. However, the enactment of an agreement or River Basin Organization does not guarantee that water-allocation debates will be resolved or that shared resources will be managed and shared in an equitable and sustainable way (Dinar 2009; Jägerskog et al. 2007; Rangeley 1994). In the case of SSA, many agreements were signed in conditions of a colonial, Cold War, and apartheid period and were formed to facilitate the interests of outside powers rather than African citizens. Agreements that are more recent were facilitated as much by donor-funding priorities and international governance requirements as by riparian needs (Lautze and Giordano 2007).

More than two decades have now passed since the Cold War and apartheid, and new political and economic environments have emerged. SSA is now one of the fastest-growing regions in the world, and there is impetus for adjustments to fuel the growth and reduce the still high levels of poverty while maintaining a natural environment to provide services for current and future generations. Improvements in the quality, quantity, timing, and location of water will play a key role in this change, since it is directly connected to most economic activities and its protection is a key factor in sustainable economic growth (Brown and Lall 2006; Foster and Briceno-Garmendia 2010; Grey and Sadoff 2007). The imperative for cooperation is even greater, because of the direct and indirect linkages between water cooperation and broader economic and political cooperation (De Stefano et al. 2010; Sadoff and Grey 2002; Wolf 2007). Indeed, failure to develop mechanisms to share water resources peacefully may delay or derail investment opportunities, lead to poor investment decisions, constrain trade among riparian states, and jeopardize regional peace and stability (Strategic Foresight Group 2013). Thus, the economic implications of efficient and equitable riparian cooperation in SSA are considerable.

While the case for cooperative management of SSA's internationally shared water resources is strong, the design and implementation of workable institutional frameworks are neither automatic nor easy. This report reviews challenges to transboundary water management and approaches that can be used to address those challenges. It then reviews the role of economic methods and analyses in supporting those approaches and provides a discussion of considerations in their use.

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Chapter 2
Challenges of Transboundary Water Institutions

2.1 Borders, Inflexible Bargaining Positions, and Water Rights

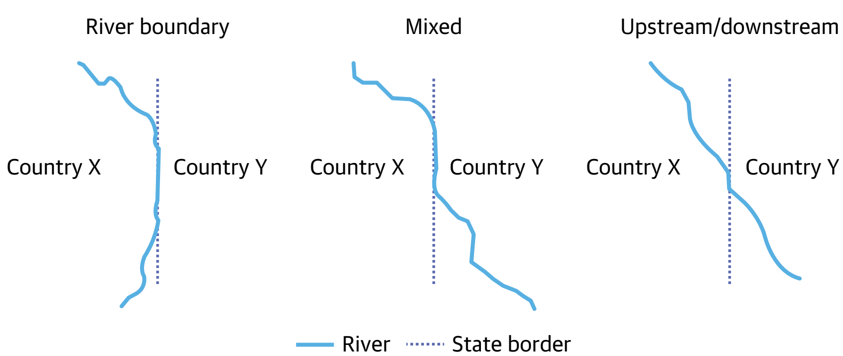
Every river basin is unique, and African basins have their own unique attributes that set them apart from others (Sadoff et al. 2002). These attributes include highly variable climate and river flow; major rivers are part of the lives and livelihoods of Africa's peoples, as for instance articulated in the Africa Water Vision 2025; and international borders were determined with little regard for the hydrologic integrity of watersheds and natural water boundaries.

However, the creation of mechanisms to divide transboundary waters and their associated infrastructure is typically complicated by the upstream/downstream location hydrology associated with water resources management. Downstream countries naturally prefer what has come to be known as the Doctrine of Absolute Riverine Integrity. This doctrine suggests that every riparian has a right to the use of waters that would naturally flow into its territory (Dombrowsky 2007; Giordano and Wolf 2003; Wolf 1999). This position is often further reinforced by historic use. Downstream states, especially in the case of exotic rivers, typically have longer histories of water resources development than their upstream neighbors and claim the right to continued water use based on precedent. Upstream countries, on the other hand, tend toward a position known as the Doctrine of Absolute Sovereignty, which holds that a state has the right to the use of any waters that flow within its territories (Wolf 1999). In Africa, the problem of predefined bargaining positions and upstream-downstream relations is exemplified by the long-standing deadlock in negotiations over the Nile.

A doctrine of Limited Territorial Sovereignty has been put forward as a moderating position between the two above positions and recognizes the right to reasonable and equitable use of international waters by one riparian state as long as no significant harm is inflicted on other co-riparians. The concept is embodied in the 1997 United Nations (UN) convention on the Non-Navigational Use of Transboundary Waters. Not surprisingly, upstream states tend to place more weight on reasonable and equitable use part of the doctrine while downstream states in general favor the no significant harm clause and the interpretation that it protects historic uses (Wolf 1999). As a result of these differences, the UN Convention itself took decades to negotiate and ratify (ratified recently in August 2014), and contains no specific guidance as to how the competing principles should be worked out in practice.

Further complicating matters, riparian states can rarely be classified as simply upstream or downstream. Dombrowsky (2007) highlighted that while international boundaries can create upstream/downstream relations, in other cases they form boundaries between states, and in yet other cases a mixed outcome is possible (Figure 2.1). In the case of multilateral basins (basins with more than two riparian states), the

FIGURE 2.1. Geographical Configuration of a River Depicting Externalities



Source: Toset et al. 2000.

situation can be even more complex. A country may be upstream with respect to one riparian, downstream with respect to another, and use a river to create a boundary with respect to a third. These more complicated patterns are particularly common in Africa because of its high proportion of multilateral basins (Lautze and Giordano 2007). While in bilateral basins cooperation tends to be easiest to facilitate when rivers form boundaries rather than create upstream/downstream relations (LeMarquand 1977; Toset et al. 2000), there is little evidence of the complicating role of multilateral basins (though see below on the role of hegemonic powers in multilateral basins).

2.2 Water as a Zero-Sum Game

In game theory, a zero-sum game is a situation in which each participant's gain (or loss) of utility is exactly balanced by the losses (or gains) of the utility of the other participant. Thus, a gain (loss) for one must result in a loss (gain) for one or more others. The payoff from a state maintaining one of the positions described above is especially high when water sharing occurs under conditions of a zero-sum game. If an upstream country consumes some of the water in a shared river, that quantity is not available for downstream neighbors. While there has been a global trend in international water agreements away from allocation of fixed volumes and toward more flexible approaches, including allocation of shares (Giordano et al. 2013) and other mechanisms to deal with variability in flows (Drieschova et al. 2009; Drieschova et al. 2011), these approaches cannot address the fundamental zero-sum calculus. The space for negotiation thus remains extremely narrow, if quantities of water are the only resource under negotiation.

2.3 The Role of Externalities

The geography of transboundary rivers often creates another negotiating problem, that of externalities. An externality is present when the production or consumption activities of one economic agent have direct, non-price-mediated effects on the production or consumption activities of another economic agent (Mas-Colell et al. 1995). Externalities can give rise to a Pareto-inefficient allocation of scarce resources. That means that at least one other allocation would improve conditions for at least one party without necessarily having a negative impact on any other party. The search for a Pareto-improving allocation of water could be a foundation to guide transboundary water-sharing agreements.

Externalities occur in many transboundary rivers by the upstream-to-downstream flow of water. If an upstream state pollutes, some of the costs of that pollution flow to its lower riparian neighbors. Similarly, dams operated under rules for the benefit of upstream states can change flow patterns and water temperatures (Petr and Swar 2002) in ways that harm downstream state interests. Dam construction upstream can also create positive externalities through flood control or otherwise regulating flows in ways useful to downstream states. Economic theory teaches that if the upstream state cannot capture the value of the total basin-wide benefits it creates, it will underinvest in measures that would increase those benefits. While rivers are generally associated with one-way externalities, this does not have to occur. For example, when transportation of water-related outputs, such as irrigated food production, is possible or internationally migratory fish are present, both up- and downstream states can be harmed or benefited by the choices their riparian neighbors make with regard to flow maintenance, pollution levels, or fish catch. Fisheries have been especially important in transboundary politics for some North American rivers as related to salmon, and in the Mekong River for a variety of economically and environmentally important species. Invasive species and groundwater may also provide similar examples. Reciprocal externalities can occur when the river forms a border as shown in Figure 2.1, panel 2 above.

2.4 Transaction Costs and Uncertainty

Creating formal treaties or even agreements (for example, Memoranda of Understanding) to cooperatively manage internationally shared waters is not a low-cost process. There has been no research for Africa or elsewhere on the average time from initial negotiation to final signing and enactment, but it is certainly measured in years rather than months. Furthermore, there is no certainty that negotiations will end with a successful outcome. The time and effort for negotiation comes at political and financial costs. The expected costs increase when the expected probability of a successful negotiation falls.

In addition to uncertainty in negotiation outcomes, riparian states also face other uncertainties that accompany international negotiation. These include how agreements will be implemented as well as the validity and interpretation of data used to support implementation, treaty finance, and dispute resolution (Fischhendler 2008). The risk of these uncertainties is increased by dimensions of the physical and chemical nature of shared water resources including variability in water quality and quantity and in the vulnerability of resource systems. The possible occurrence of drought and flood is an example of the former while the general lack of knowledge about the impact of climate change on basin ecosystems illustrates the latter.

Entry into an international agreement also introduces the risk of reduced sovereignty. States give up or limit their right to some unilateral actions in exchange for specified action or inaction by other signatory states. International relations principles teach that countries are motivated to enter agreements when the perceived cost is less than the perceived benefits gained. The relative sovereignty costs depend in part on the traditional elements of state power in its political, economic, and military dimensions. In the case of riparian states, power also comes in part from relative basin position (for example, upstream or downstream) and can complicate negotiation. For example, cooperation may be less likely if the more powerful state is upstream, since the upstream state holds the stronger politico-economic and geographic position (Lowi 1993). This is the case of China in the Mekong River Basin.

Extreme unequal power can pose other problems for cooperation in the case of multilateral basins where the value of basin-wide solutions may in some cases be greatest. When a regional stronger power enters into negotiations with multiple weaker states, its relative power may be diluted (Nader 1995). If, on the other hand, it negotiates bilaterally with a series of single states, it may maintain or enhance its power positions. While it has been argued that the small number of truly hegemonic states (South Africa, Nigeria, and Egypt) that exist within Africa's transboundary basins may limit this effect (Sadoff et al. 2002), a large percentage of the agreements signed by these states are bilateral and these states are involved in a high proportion of the total agreements signed in Africa (Lautze and Giordano 2007).

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Chapter 3
A Framework for Action: Overcoming the Challenges

The challenges of establishing transboundary water cooperation identified above are significant and are partly why there is such concern over water as a source of international conflict. However, there is a growing body of scholarship that highlights the role of water in cooperation as opposed to conflict. In addition, there is a growing understanding of the overall direction and body of transboundary water agreements (Giordano et al. 2013) and how it has been used to address specific issues such as groundwater, water quality, conflict resolution, and uncertainty. There is now a better understanding of how and why treaties are formed (for instance, Espey and Towfique 2004) and how some of the apparent negotiating hurdles have been overcome (for example, Dinar 2006). Four key approaches are reviewed before turning to the critical role economic principles and methods can play in their implementation.

3.1 Benefit Sharing

While water is directly required for human survival, the majority of its human use is for agriculture, industry, and energy generation rather than for drinking and domestic use. Conceptualizing negotiations as occurring over the benefits that can be derived from water, rather than the water itself, can be an important step in overcoming both the predefined bargaining positions created by riparian geography as well as the zero-sum nature of physical water sharing. This approach, known as benefit sharing, was first described for transboundary waters by Sadoff and Grey (2002). They identified four sets of benefits related to cooperation in international waters: (a) benefits to the river emanating from improved ecosystem services, conservation, and water quality; (b) benefits from the river through improved productivity, flood and drought management, and increased food and energy production; (c) decreased costs, such as political costs, due to policy shifts toward cooperation and development; and (d) benefits beyond the river, such as indirect economic benefits due to broader regional cooperation and integration. Since their work, the concept has been developed in more detail such as that provided by the United Nations Economic Commission for Europe (UNECE 2014) (Table 3.1).

The shift to recognition of the economic benefits from water and water infrastructure cooperation is a broader view of water cooperation. When that view is followed by a shift from negotiation over water to negotiation for the increase and sharing of water's broader benefits, it allows three key transformations for diplomacy. First, it can reduce the role of location in deterring the creation and capture of benefits and so reduce or eliminate the initial upstream/downstream blockage in negotiation. For example, if negotiations shift from the allocation of water to the allocation of mutual gains derived from the sharing of the benefits from hydropower production and use, the role of riparian positions and predefined negotiating positions is diminished as the location of water use becomes less relevant. Second, an opportunity for moving toward a Pareto-improvement is created and negotiation is no longer over the sharing of water but rather the economic benefits created from water development, allocation, and use. Finally, benefit sharing can provide a mechanism for incorporating and internationalizing both negative and positive externalities.

The extent to which a benefit-sharing approach can facilitate positive-sum cooperation depends on a number of basin-specific factors. First, cooperation must create joint benefits greater than the sum of those that would be provided by a simple sharing of water. Second, the benefits must be recognized by all parties and explicitly identified, assessed, and communicated. Finally, the benefits must be distributed so that

TABLE 3.1. Typology of Cooperation Benefits

Types of Benefits of Transboundary Cooperation	Description or Examples
Economic Benefits within the Transboundary Water Basin	• Changes in net value added the benefits of expanded activity and productivity in economic sectors (such as aquaculture, irrigated agriculture, energy generation, nature-based tourism, water-based transport) • Reduced cost of productive activities (avoided costs of supplying water from more expensive sources, lower cost of water for human consumption and economic uses, lower cost of energy inputs from hydropower, savings from using river transport) • Reduced risks (avoided human and economic losses from floods and droughts, avoided food shortages, avoided energy shortages and improved energy security) • Increased value of property in the basin from improvements in riparian ecosystems • Reduced cost of managing water (for example, more efficient responses to pollution accidents)
Economic Benefits beyond the Transboundary Water Basin	• Economic impacts in the national economies due to backward and forward links of basin-based economic activity with other economic activities in riparian countries (for example, reductions in costs of factors of production such as water and energy) • Benefits gained from cooperating in economic policy areas after trust has been built in the water area such as the economic benefits of opening markets (for goods, services, and labor), cross-border investments, or the development of international energy or transport infrastructure networks
Social Benefits within and beyond the Transboundary Basin	• Impacts on unemployment, reduced poverty, improved access to services • Improved human health (reduced incidence of water-borne diseases), and improved satisfaction (due to the preservation of cultural resources or improved recreation)
Environmental Benefits within and beyond the Transboundary Basin	• Avoided habitat degradation and biodiversity loss • Preservation of spawning grounds for marine fish species and migratory bird habitats
Geopolitical Benefits	• Security-related benefits (such as costs avoided from reduced military conflicts)

Source: UNECE 2014.

all parties involved are better off than they would have been through unilateral action.

A long-standing series of agreements signed by the United States and Canada on the Columbia River to create storage, generate hydropower, provide shipping, and reduce flooding provides an example of the advantages of the benefit-sharing approach. The agreements have been widely considered as a success, creating economic value for both countries. At the same time, they failed to consider the impact of the required dams on salmon and Native American/First People interests and broader and changing interests and valuation in salmon and the environment. This case demonstrates the potential for benefit-sharing approaches as well as the need for inclusive approaches to fully understand costs and benefits and understand equity in sharing.

3.2 Expanding the Negotiating Space

A second, related, method for expanding the negotiating space over transboundary waters is through issue linkages (Haas 1980). While the negotiating positions over a particular water debate might appear locked, the negotiation space can be expanded when combined with other issues. Negotiation over policy packages offer opportunities to reach mutually agreeable bargaining outcomes on what may be a collection of zero-sum or intractable policy issues if addressed individually (Dinar 2006; Fischhendler and Zilberman 2005; Susskind 1994; Tinbergen 1966). These policy packages allow for trade-offs between policy objectives, as parties can make concessions on issues with a lower economic impact in exchange for concessions on issues of more importance to them. Katz and Fishendler (2011) describe how this has occurred in Israel/Palestinian negotiations as does Daoudy (2009) in the case of Syria and Turkey. Water is a natural candidate for linkage approaches given its multiple uses in a broad range of policy areas. These include security, environment, health, and economic development. Linkage strategies may be especially useful in overcoming upstream/downstream problems and other forms of power asymmetry (Daoudy 2009; Dinar 2006; Fischhendler et al. 2004; LeMarquand 1977; Wolf 1998).

A related approach for overcoming the negotiation challenges brought by the spatial nature of shared waters is by moving away from the single-basin approach often considered part of integrated water resources management. This approach was used in negotiations between the United States and Mexico over their shared waters. In the case of the Colorado, Mexico was the downstream state. In the case of the Rio Grande, the United States was the downstream state. Combining negotiations put both states in up- and downstream and minimized the degree to which bargaining positions would have been predefined had the negotiations taken place separately (see Fischhendler and Feitelson 2003, 2005; Feitelson and Fischhendler 2009; Katz and Fischhendler 2011, for related examples and approaches).

3.3 Power Asymmetry, Side-Payments, and the Role of Outside Actors

As discussed above, geographic advantage within a basin as well as asymmetries in sources of political power can reduce the chances for true cooperation or entice states with larger power to influence less powerful states into agreements disadvantageous to them. However, the large body of transboundary water law shows that this realist view of international water politics does not always predict outcomes. For example, there are instances where economically powerful, upstream riparian countries have entered into agreements with poorer, downstream countries (Fernandez 2005). Dinar (2006) used case studies to outline some of the mechanisms that induce cooperative behavior when geographic and political power asymmetry would predict otherwise. One key mechanism has been the linkage of water and non-water issues. Issue linkage can broaden negotiating spaces as also described above. In addition, differences in issue-specific structural power can give bargaining strength to a water-weak state, offsetting water-related power asymmetries. Dinar also highlights that powerful states often value cooperation with weaker states on non-water issues and do not want to jeopardize broader cooperation because of water disagreements. He further argues that the actions of the stronger states over water are often, or even typically, more benign than malignant.

One result is that weaker states are often able to extract side-payments from more powerful states for taking specific actions such as pollution control or cooperation in hydropower generation (Dinar 2006; Milner 1992; Olson and Zeckhauser 1966; Russett and Sullivan 1971). For example, states that are more powerful may choose to finance water quality projects in neighboring countries rather than argue for polluter-pays principles via uncertain negotiating processes (Linnerooth 1990; Shmueli 1999).

In a related way, outside actors can provide financial or technical contributions that facilitate cooperation that might otherwise not occur. The most famous and successful case of this is the World Bank's involvement in the Indus agreement that has turned one of the most internationally contentious rivers into a long-standing example of peaceful sharing, even if not outright cooperation, that has lasted through two wars and other hostilities (Alam 2002). While not an international case, the role of the Australian national government in helping to forge the intra-state water reform on the Murray-Darling basins also provides an educational example.

3.4 Achieving Economies of Scale

One of the challenges of joint transboundary water infrastructure investment is the high transaction cost involved in its preparation and implementation. Effective implementation and operation of such infrastructure hinges on international requirements and sound operational practices and guidelines. Compared to joint development and management, a single country is less able to capture economies of scale of major infrastructure investments. This is in part because of low income levels and resulting small market size and in part because of the high development cost of infrastructure such as dams, power plants, and transmission lines. The opportunities to overcome scale problems through international cooperation in the water sector are especially high in Africa both because of the size of many domestic markets and the ubiquity of its shared waters. Each country has its own comparative advantage, and these advantages can be pooled through cooperative development. Country A may have engineering expertise, country B may have better access to energy resources, while country C may have the largest absolute water supply.

In addition, joint water projects serving more than one country or region can be more efficient and provide greater total net benefits than the sum of alternative, individual projects undertaken in isolation. Such joint developments may increase the economic value of projects that cannot be justified if they were to serve only one individual country due to a greater opportunity to pool cost advantages while avoiding cost disadvantages. In addition, linking existing facilities may result in higher utilization rates, thereby reducing unit costs overall. A recognition of scale economies may provide an incentive to motivate cooperation. Including the gains from scale economies in implementing benefit sharing, while issue linkage and side-payments can also increase other negotiation options, overcoming other impediments to cooperation.

3.5 Overcoming Barriers to Data Sharing

Failure to collect and share data weakens the capacity to analyze the benefits and costs of cooperation and reduces information on how those benefits and costs can be equitably shared, and limits planning for cooperation strategies. One of the findings of the World Bank's recent Ganga study was that any assessment of opportunities on the Ganga was difficult because of limited data and the failure to share available data. Uncertainty over data and its analysis can also increase the sovereignty risks of entering into agreements.

Data is a form of power and so reluctance to share it is understandable. However, the nature of hydrologic data collection is rapidly changing. Space-based technologies coupled with more powerful software analytics are increasingly making it possible to monitor rainfall, flow, evapotranspiration, and even groundwater withdrawal remotely. Furthermore, this data can be collected by many, especially as collection and analysis costs continue to decline. While ground-truthing will remain important, control of physical measurements will be increasingly reduced in value as will the value of maintaining data secrecy. At the same time, the role of scientific collaboration in furthering diplomatic cooperation is widely recognized and sharing the use of data can be a step forward in building a shared understanding of the issues and opportunities, networks of experts across basin states, and overall cooperation. Recent research has also provided an understanding of how data and information-sharing mechanisms have been used in formal transboundary negotiations (Gerlak et al. 2010).

3.6 Broader Stakeholder Dialogue and Inclusion

National governments alone have traditionally been defined as the primary stakeholders in transboundary negotiation and decision making. This limited view of stakeholders approach hinders the development of public understanding of the potential gains to cooperation and can cause many stakeholders to feel excluded from the debate. The result can be limited buy-in and increased risk for later difficulties of implementing of agreements.

Recent experience of cooperation in five international river basins indicated that perceptions of risks related to capacity and knowledge (that is, confidence in ability to negotiate a fair deal and having the right information and knowledge); accountability and voice; sovereignty and autonomy in making decisions independently; equity and access (that is, fairness of benefit-sharing methods); stability of basin agreements; and support to agreements within a country all exert an influence on cooperation outcomes (Subramanian et al. 2012). The 2015 World Development Report also stresses the significance of psychological, social, and cultural influences on decision making, human behavior, and development outcomes (World Bank 2015). Hence, for basin-wide cooperative development initiatives to succeed, solutions must be viable economically, technically, environmentally, and politically.

Consultation and dialogue by national governments with broader stakeholder coalition on the issues and options, combined with sharing data and information more broadly with this coalition, can help address this problem. The coalition might include affected states and local governments, civil society representation from directly affected populations and environmental organizations, as well as industry or their representatives. In some cases, stakeholder groups can themselves be cross-border in nature (for example, the famous 'picnic table' talks between Israel and Jordan). For example, 'upstream' populations in both India and Nepal may have interests more in common with each other than with their national governments, at least concerning water resources development. Understanding the perspectives of such groups can help to forge better agreements and, just as importantly, better ensure their support after negotiations have ended.

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Chapter 4
Role of Economic Analysis in Informing Transboundary Water Solutions

A key element for successful negotiation is that the parties are aware of the possible benefits of cooperation and their distribution among important stakeholders. Nearly 100 years of advances in applied welfare economic analysis known as cost-benefit analysis (CBA) can play a productive role in providing the necessary information and support the implementation of many of the approaches discussed in the previous section.

CBA originated in the United States water sector in the 1930s and has long been the standard tool for assessing project feasibility. Hydro-economic modeling has been used as a method to implement CBA using hydrologic, economic, and institutional foundations. Results produced by these models are an important piece of information to promote cooperation through understanding of the differential impacts on riparian states of any given proposal. Game theory has been used to show how differential impacts may influence willingness to negotiate. It has also been used to identify measures to expand bargaining space and create outcomes that increase overall benefits and are at the same time politically acceptable to individual riparian states. Real options analysis has taken this further by examining the capacity of stakeholders to learn from what is happening around them and their willingness and the ability to modify behavior based on that learning. Finally, multi-criteria analysis has been used to incorporate a variety of approaches and to provide a platform to broaden stakeholder input in decision-making processes.

To varying degrees, each of these approaches can identify externalities, guide the creation of side-payments to overcome the distribution of power, and indicate how outside parties may constructively facilitate cooperation. Collecting the data needed for quantitative economic analysis and the analysis itself can also provide mechanisms to forge cooperation and, if done well, increase transparency in decision-making processes and help to ensure that voices of all critical stakeholders are heard and issues such as the environment are not forgotten.

We turn now to a review of methods from the economics literature applied to transboundary waters and how and where they have been applied in practice. The studies reviewed are included in the overall bibliography. In addition, many are attached in separate appendices according to their approaches and focus. The appendices are described below.

4.1 Cost-Benefit Analysis

CBA originated with water resources development planning exercises conducted in the United Sates and has traditionally been used to assess the net national benefits of federal projects of basin-wide significance and interregional or joint projects. The most important difference between standard (one country) and multi-country basin-wide CBA is that the latter comprises N+1 separate analyses, one for each of the N member countries, and one for the whole basin or countries as a whole (Sehramm 1986). It could be for a single basin, with distribution impacts split out by country. The overall analysis provides a measure of the total basin-wide net benefits and its distribution that can be obtained from cooperation, whereas the individual analyses provide a measure of the net benefits for each country. The sum of the latter, however, does not necessarily add up to the former.

Estimating the net benefits from projects with basin-wide implications is complex. While the principles of CBA provide the basic analytical framework, the necessity to take into account the viewpoints of independent jurisdictions, the likelihood of differences in social discount rates or economic opportunity costs, differences in the optimum timing of specific projects, the prevalence of secondary benefits, the added costs of complex negotiations and administration, the likely time delays in negotiating and implementing such projects, as well as the constraints imposed upon independent decision making and sovereignty, all add special complexities to joint transboundary projects (ECA 2012). A common critique of many CBAs used to justify specific projects is the difficulty of quantifying environmental costs as well as negative social impacts of the project. Affected groups have been often ignored or undervalued. Moving from the use of CBA for project analysis to analysis of potential cooperation regimes over an entire basin makes the use of CBA difficult.

While CBA is in many ways explicit or implicit in many of the studies reviewed later in this paper, it sees more application to project decision making than in published economic literature. Madani (2010, Table 1) reviews how cost-benefit approaches have been integrated in broader economic work on transboundary basins.

4.2 Multi-Criteria Assessment

Due to the difficulty of valuing intangible environmental and social costs and benefits and the desire to ensure that they receive a more comprehensive accounting by decision makers, the multi-criteria assessment (MCA) methodology is often advocated. MCA is more complex than CBA. CBA has only one objective, economic efficiency, with various side constraints. MCA attempts to weigh many objectives. MCA can help specify and comprehensively describe the impacts of water cooperation and hence fill out the first and the second stages of the building blocks in the assessment framework (section 5). The difference between CBA and MCA is that instead of valuing the impacts, MCA derives non-monetary scores and weights for various impacts.

MCA can be more difficult and time consuming than CBA. Moreover, there is no guarantee that the MCA scores will demonstrate that the selected development priorities are worthwhile, because the standard for being worthwhile cannot be defined and measured rigorously. In addition, the MCA weights and the derived MCA scores may not be representative of the priorities of all basin water stakeholders. Thus, MCA scores can be susceptible to arguments and disputes because of its arbitrary weighting scheme.

4.3 Hydro-Economic Modeling

Hydro-economic modeling provides a comprehensive framework for implementing CBA for quantifying the potential gains from cooperation and how the gains (and costs) may be distributed amongst riparian states, other political units, or economic sectors (see table 4.1). It does this by modeling the complexity of interactions between water and the overall economy through mathematical models linking hydrological processes to the supply and demand for water-related services. The models typically incorporate a basin-specific hydrological module and node networks to delineate water flows and stocks, sometimes including quality, coupled with models of economic activity.

Bekchanov et al. (2015) recently provided a comprehensive review of the use of hydro-economic models in general including their specific application in transboundary waters. They identified three approaches in integrated hydro-economic modeling, namely, modular, holistic, and computable general equilibrium (CGE) models. In the modular approach, a connection is built between the hydrological and economic model, and output data from one module usually provides the input to the other. The modules operate independently of each other and systems of equations are solved separately, with considerable iteration between the models. In the holistic approach, there is one single unit with both the hydrological and economic component determined simultaneously in a consistent endogenous model. Most of the holistic and modular models are partial equilibrium and do not account for economy-wide impacts. The CGE model is an advanced

TABLE 4.1. Design Choices, Options, and Implications for Building a Hydro-Economic Model

Options	Summary	Advantages	Limitations
Simulation/optimization			
Simulation	Time-marching, rule-based algorithms; Answers question: "what if?"	Conceptually simple; existing simulation models can be used, reproduces complexity and rules of real systems	Model only investigates simulated scenarios, requires trial and error to search for the best solution over wide feasibility region
Optimization	Maximizes/minimizes an objective subject to constraints; answers question: "what is best?"	Optimal solutions can recommend system improvements; reveals what areas of decision space promising for detailed simulation	Economic objectives require economic valuation of water uses; ideal solutions often assume perfect knowledge, central planning or complete institutional flexibility
Representing time			
Deterministic time series	Model inputs and decision variables are time series, historical or synthetically generated	Conceptually simple: easy to compare with time series of historical data or simulated results	Inputs may not represent future conditions; limited representation of hydrologic uncertainty (system performance obtained just for a single sequence of events)
Stochastic and multi-stage stochastic	Probability distributions of model parameters or inputs; use of multiple input sequences ('Monte-Carlo' when equiprobable sequences, or 'ensemble approach' if weighted	Accounts for stochasticity inherent in real systems	Probability distributions must be estimated, synthetic time series generated; presentation of results more difficult; difficulties reproducing persistence (Hurst phenomenon) and non-stationarity of time series.
Dynamic optimization	Inter-temporal substitution represented	Considers the time varying aspect of value; helps address sustainability issues	Requires optimal control or dynamic programming
Submodel integration			
Modular	Components of final model developed and run separately	Easier to develop, calibrate and solve individual models	Each model must be updated and run separately; difficult to connect models with different scales
Holistic	All components housed in a single model	Easier to represent causal relationships and interdependencies and perform scenario analyses	Must solve all models at once; increased complexity of holistic model requires simpler model components

Source: Harou et al. 2009.

approach to integrated hydro-economic modeling. In contrast to most modular and holistic models, CGE models start the integration procedure from the economic system and attempt to link economic relationships to the hydrological system. Hydro-economic models are especially useful in quantifying how the value of water might be increased using benefit-sharing approaches. This is the approach of the World Bank's work on the Nile and Ganges Basins in using hydro-economic models to broaden negotiation discussions and highlight possibilities of and limits to negotiation.

There have been a large number of published studies utilizing hydro-economic models for the study of transboundary waters. These studies are referenced in Appendix A.

4.4 Agent-Based Modeling

Recently, agent-based modeling techniques have been applied to the analysis of transboundary water cooperation problems as an alternative to hydro-economic modeling (Ding et al. 2016; Giuliani and Castelletti 2013). Agent-based modeling occurs where behavioral rules of individuals (or agents) help understand or predict how the whole system functions. One of the distinctive features of transboundary water systems is the presence of multiple, institutionally independent, spatially dispersed but physically interconnected decision makers. Since these decision makers can belong to different countries, institutions, and sectors, they are motivated to act considering only their local objectives and produce externalities that affect others' objectives. This is particularly so in the absence of full information exchange. Despite this reality, hydro-economic modeling techniques assume a centralized decision-making framework and explore the potential for a more efficient water management at the system-wide scale. The use of centralized optimization for water management modeling for systems without well-functioning water markets or limited possibilities for full information sharing is rarely practiced (Giuliani and Castelletti 2013; Yang et al. 2009). Agent-based modeling can be considered a major improvement in such situations.

4.5 Game Theory

Even if hydro-economic or CBAs show large, overall potential gains from cooperation, a state may choose not to cooperate because the gains are unevenly distributed or because they will change power balances. Game theoretic approaches provide insights into these differentiated payoffs and, how some of the approaches identified earlier in this paper such as benefits sharing, issue linkage, and side-payments can contribute to positive-sum solutions and overcome impediments to cooperation. Game theoretic approaches can be combined with approaches such as hydro-economic modeling to illustrate how the payoff matrix might be changed to increase the likelihood of mutually beneficial cooperation (Sadoff et al. 2002). A substantial body of literature has been developed concerning interconnected games as an extension of traditional game theory (Diaz and Morehouse 2003). The insights from this theory may also help explain the resolution of unidirectional externalities where water appears as the first object of bargaining, but where other objectives are present.

The application of game theory to transboundary water resources offers three perspectives: a noncooperative approach, a cooperative approach, and a more general bargaining approach. The two former approaches are only unique from standard game theory with regard to the intent of the parties. Noncooperative approaches involve an upstream country, which enacts decisions to maximize its own welfare without regard for the downstream country (Bhaduri et al. 2011; Li 2015). On the other hand, cooperative approaches indicate economic benefits realized by each player with coalitions and sub-coalitions forming between the players (Dinar and Wolf 1997).

In the bargaining approach, game players sequentially make offers to all other players simultaneously. The game continues until an offer is accepted, with any player who accepts an offer leaving the game in exchange for the payoff. In the case of transboundary water resources, states are clearly the players and the offers are allocations of water (Heintzelman 2010). Countries can continue to make counter-offers until an agreement is made, or just end without an agreement. There are three factors in negotiations that affect the outcome: risk averseness of each country; which side can make quicker counter-proposals; and which side is more certain that negotiations will break down (Frisvold 2005). According to the bargaining model, the less risk averse, the quicker, and the more confident in the outcome of the negotiations a country is, the more likely that the country will achieve an acceptable bargain.

Heintzelman (2010) described three complications to the bargaining model: flow constraints, outside options, and externalities. Flow constraints mean that there is a limit to the allocations of water that can be supplied or used in a river system. Outside options are rarer, but they consist of a third choice in addition to being able to accept or reject an offer. For example, in federal contexts, states can file a suit with the United States Supreme Court and receive payoffs from the Court. Outside options are only implemented in cases where the option is higher than what a state could receive through bargaining. Externalities remove the guarantee that there is a unique equilibrium allocation. Frisvold (2005) additionally explains external aid specifically, arguing that it changes the power asymmetries between the two countries, affecting the outcome by making one party stronger or perhaps even weaker (Frisvold 2005).

While the number of game theoretic studies are not as high as those using just hydro-economic modeling, it is still significant (Appendix B).

4.6 Real Options Analysis

Large water storage or withdrawals in the upstream part of a transboundary river basin is often the main source of conflict, discouraging cooperation among riparian countries. Designing and building large water infrastructure in transboundary river basins in a piecemeal fashion without careful consideration of basin-wide consequences leads to suboptimal economic outcomes and degrades the motivation for cooperation among riparian countries in a way that goes beyond the water sector. Real options analysis is an approach that has been used to support investment decision making in such contexts (Jeuland and Whittington 2014).

The major difference between the real options approach and traditional economic optimization models such as those typically used in hydro-economic modeling is that the latter require the planner to assign probabilities to possible future states of the world to identify optimal solutions. The real options approach recognizes that it is difficult to assign even subjective probabilities to future states of the world and may not offer compelling guidance on planning solutions. In addition, the real options approach avoids narrowly defined optimality rules and therefore may be more appropriate for complicated, multi-objective (for example, social, political, and environmental) water infrastructure projects.

As applied in practice (Jeuland 2010; Jeuland and Whittington 2014) real options analysis begins with definition of planning alternatives and options based on design and operational features such as planned infrastructure, its size, timing and sequencing of implementation, and operational rules. Permutations or combinations of design and operational features result in a menu of specific planning alternatives. The robustness of each planning alternative is then evaluated with respect to different hydrological runoff (for example, climate change) and water withdrawals (water demand) scenarios using linked models for stochastic runoff generation, hydrological routing, and Monte Carlo simulation of economic outcomes for the different project alternatives (Jeuland 2010).

Jeuland (2010) used this framework and three models to analyze possible hydropower projects along the Blue Nile in Ethiopia, including possibilities of climate change. The three models are a stochastic streamflow generator, a hydrological simulation model, and an economic appraisal model. The study found that climate change produced reduced runoff in the Blue Nile and therefore less hydropower production; a reduction in the generation of hydropower in the High Aswan Dam; and higher temperatures that will lead to an increase in water demand. In empirical terms, the net present value shrinks from US$7.2 billion to US$5.0 billion. As such, Jeuland concluded that a dam would add enough energy to offset any decreases from climate change. Even with uncertainty, the Blue Nile Dam would increase net present value and provide an increase in overall value. However, the study also highlighted that benefits were not equally shared, with Sudan actually harmed when the physical linkages with climate change are considered. This information provides insights into how a cooperation package might be constructed through benefits sharing, side-payments, or other mechanisms (Jeuland 2010).

4.7 Comprehensive Impact Assessment

Comprehensive coverage of impacts has been used recently in the Mekong River Basin (Mekong River Commission 2011) and builds on MCAs that are more traditional. The purpose is to provide an appreciation of the impacts of different possible water-related developments within the basin considering the economic, environmental, and social objectives of member states or other stakeholders so as to enable examination of trade-offs. The development scenarios are formulated and selected by participating actors and include a baseline scenario and likely development trajectories. The approach is the triple bottom line, embracing economic, social, and environmental benefits cumulatively.

Table 4.2 shows the various impact criteria and categories that the Mekong River Commission (2011) applied in using this approach to assess the economic, environmental, and social impacts of options for managing the Mekong River Basin. The net economic impacts on energy, agriculture, commercial navigation, and commercial fisheries are quantified using market values. Environmental impacts of change are described and quantified and the number of people affected are estimated. Techniques for valuing impacts included surveys of a representative sample of those affected along with their willingness to pay/avoid. Techniques for assessing the social benefits include quantifying and disaggregating the economic and environmental benefits for affected vulnerable or poor groups. A variety of economic tools could be used within the framework. The overall point is that the analysis involves the stakeholders and their objections.

TABLE 4.2. Mekong River Commission Impact Criteria and Categories

Primary objectives	Specific development objective	Assessment criteria
Economic	*1. Economic development*	
	1.1. Increase irrigated agricultural production	Incremental area
		Crop production
		Net economic value
	1.2. Increase hydropower production	Installed capacity
		Power generated
		Net economic value from generation
		Net economic value from purchased
	1.3. Improve navigation	Navigable days by class
		Net economic value
	1.4. Decrease damages by floods	Average area flooded annually to max 1.0 m depth
		Average area flooded annually > 1.0 m depth
		Net economic value of flood damage
	1.5. Maintain productivity of fishery sector	Annual average capture fish availability
		Annual average aquaculture production
		Net economic value of capture fish

table continues next page

TABLE 4.2. continued

Primary objectives	Specific development objective	Assessment criteria
Environment	*2. Environmental protection*	
	2.1. Maintain water quality and acceptable flow conditions	Total pollutant discharge
		Water quality conditions
		Average flow in March
		Average wet season peak daily flow
		Average flow volume entering Tonle Sap
		Forest, marshes and grasslands flooded at Tonle Sap
		Net economic value
	2.2. Maintain wetland productivity and ecosystem services	Are of wetlands (forest, marshes, wetland)
		Net economic value
	2.3. Manage salinity intrusion in the Mekong delta	Area within delta within threshold level of salinity
		Net economic value
	2.4. Minimize channel effects on bank erosion and deep pools	Area at risk to erosion
		Net economic value
		Functioning deep pools
		Induced geomorphological changes
	2.5. Conservation of biodiversity	Status of river channel habitats
		Flagship species
		Unaffected environmental hot spots
		Biodiversity condition
		Incremental net economic value of habitat areas
Social	*3. Social development*	
	3.1. Maintain livelihoods of vulnerable resource-users	No. of people affected
		Severity of impact on health, food and income security
	3.2. Increased employment generation in water related sectors	Incremental number of people engaged in:
		Agriculture
		Fisheries
		Water-related service industries
		Tourism
Equity	*4. Equitable development*	
	4.1. Ensure that all four LMB countries benefit from the development of water and related resources	Total net economic value
		No. of people affected vulnerable to changes
		No. of jobs generated
		Overall environment impact

Source: MKC 2011.

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Chapter 5
Discussion

A wide variety of economic methods have been applied to the study of transboundary waters for purposes ranging from understanding if a project is financially viable to showing if benefit sharing may provide new ideas for increasing the value of water and overcoming noncooperation, to understanding the politics of noncooperation and how noncooperation might be overcome. The level of technical skill, know-how, and resources required to implement some of these methods could be fairly high. However, given the vital importance of credible information regarding the benefits and costs of cooperation/noncooperation and its distribution in shaping the decisions of the stakeholders, these methodologies merit consideration.

An analysis of the efficiency and equity of treaties or cooperative investments on transboundary waters should involve a thorough analysis of alternatives available to each of the countries as, for example, done ex post for Columbia River Treaty by Krutilla in 1967.

The specific economic methods and analysis most suited to the facilitation of transboundary cooperation depends in part on the stage of cooperation formation in a particular basin. UNECE (2014) identified four stages of cooperation:

Step 1: Qualitative description of the problem and the benefits of cooperative actions in terms that the policy makers and stakeholders can readily understand and to which they can relate.

Step 2: Quantification of the impacts on the number of people affected (for example, the number of households flooded or people killed by floods), hectares of land affected, energy generated, kilograms of pollutants reduced, kilometers of rivers improved, and so on. Often, these numbers are sufficiently striking in their own right to trigger cooperation without moving on to the next step of valuation.

Step 3: The outputs of steps 1 and 2 may not reveal the complete picture of the benefits because it is difficult to aggregate and compare the measured quantities. Moreover, realizing these quantified benefits entails significant costs, which must be considered. How significant are these benefits? Are they worth the extra costs? Answering these questions requires valuation of the benefits and costs to calculate the net benefits of cooperation. However, it has to be noted that not all of the environmental and social benefits can be monetized.

Step 4: Assessment of the distribution of benefits among countries and possibly also among socioeconomic groups. This step provides the answer to equity-related questions. Who are the beneficiaries of cooperative developments? Who are the losers? Can the losers be adequately compensated?

How information and analysis needs (‘benefit assessment needs’) correspond to changing levels of cooperation and coordination are summarized in Table 5.1.

In essence, more supporting evidence of the benefits of cooperation is needed as one moves through the stages of cooperation. At the initial stage, indicative estimates of the benefits of cooperation are needed to increase awareness and achieve a common understanding about the need to cooperate and begin work on a basin management plan. As cooperation moves toward the development of concrete joint management plans, greater substantiation of the benefits and costs, including environmental and social costs, is required to demonstrate that cooperation has net benefits for each state concerned and how groups and sectors within a state will be affected. Where options could yield important benefits for some countries and groups but entail costs for others, more evidence is required for their justification (UNECE 2014) but

TABLE 5.1. Benefit Assessment Framework

Stage of cooperation	Needs	Benefit assessment needed
Basin with no international coordinating body and no international agreement	• Identify benefits and need for cooperation • Raise awareness • Highlight need to cooperate • Show extent of problems and benefits of cooperation	• Overview of problems • Potential opportunities and benefits of cooperation • Costs of inaction or noncooperation
Basin with international agreement or cooperating mechanism, but no coordinating body	• As above, plus the need for a body to address these problems	• As above, plus economies of scale, benefits of sharing evidence/data, and joint work
Basins with international agreement and a coordinating body, but no river basin plan	• As above, plus the need for efficient integrated and cooperative solutions in a coherent plan	• As above, plus highlight the extent of mutual problems and opportunities for collaboration and benefits of cooperation, especially on integrated management
Basin with a formal agreement, coordinating body, and international river basin plan	• Management options that enhance flexibility and resilience, and buy time to develop integrated approaches • Appraise costs and benefits of options to determine worthwhile options	• Problem, and costs and benefits of options • Sustainable benefits of integrated options • Assessment of costs and benefits
Negotiations and compensation in a formal international agreement	• Detailed appraisals and optimization • Institutional development	• Detailed assessment of distribution of short- and long-term costs and benefits for upstream and downstream beneficiaries • Reverse auctions to determine minimum compensation

Source: UNECE 2014.

analysis also needs to focus on the mechanism for compensating those who might lose.

While few studies have tried to evaluate overall gains from transboundary cooperation or losses from noncooperation, those that have done have shown significant numbers. In the Zambezi Basin, for example, the annual average cost of noncooperation was estimated at US$350 million, and during a dry year, the opportunity cost can be as high as US$600 million per year (Tilmant and Kinzelbach 2012). In the Ganges Basin, the potential gross economic benefits of developing the full suite of new hydropower investments was estimated in the range of US$7 billion to US$8 billion annually (Wu et al. 2013). In the Nile Basin, the total potential annual direct gross economic benefits of Nile water utilization in irrigation and hydroelectric power generation stand at US$7 billion to US$11 billion (Whittington et al. 2005). The Nile benefits were considered to be on the lower end of the spectrum as they did not account for the economic multiplier effect or economy-wide impacts of collaborative investments. However, they attest to the fact that unilateral actions entail significant opportunity costs.

However, successful cooperation depends on the adoption of equitable benefit- and cost-sharing mechanisms supported by agreed legal provisions such as conventions or treaties. In the Zambezi Basin, water cooperation resulting in increased basin-scale economic efficiency comes at a cost to sectors that are viewed disproportionately in upstream counties

(World Bank 2010). The production of energy increases throughout the basin, but irrigation upstream is reduced. In the Nile Basin, although the overall basin-wide benefits of cooperation may be positive, Sudan actually suffers when physical linkages are considered (Jeuland 2010; Whittington et al. 2005). Economic analysis has been used in cases like these to highlight where equity issues may arise and therefore where side-payments, third-party intervention or other action may be needed to produce positive sum outcomes considered equitable by all parties.

Recognizing differential impacts between nation states of cooperation options is critical for forging cooperative solutions. However, for economic analysis to best support long-term cooperation, it must also include the full range of impacts and represent or acknowledge the perspectives of a broad range of relevant stakeholders. This is not easy. As mentioned in the Nile case, some benefits were underestimated, because multiplier effects could not be taken into account. The value of cooperation in improving overall political relations and the economic benefits that may eventually bring are even more difficult to assess and quantify. While underestimation of some benefits occurs, more problematic and likely more common is the failure to consider all of the costs resulting from cooperation, especially when infrastructure is involved, and the differential impacts of those costs.

The Columbia River provides a specific case showing the value of economic analysis in forging lasting cooperation as well as the need for inclusive approaches. Strong economic study based on forms of cost-benefit and hydro-economic analysis underpinned a series of agreements signed between the United States and Canada in the decades after World War II to facilitate storage creation for hydropower production, flood control, and transport on the Columbia River. The U.S.-Canada relations on the Columbia River have been a case study in transboundary cooperation and the benefit-sharing model. However, the initial analysis and later action did not give strong consideration to the environment nor did it consider the rights and viewpoints of Native Americans in the United States and First Peoples in Canada or commercial and sport fisheries. This lack of consideration has led, within the United States, to real fears of Supreme-Court-level law suits, significant payments by hydropower producers and others to restore flows for salmon, and perhaps the most serious discussion in the world on the removal of fully operational large dams. The treaties are now at the end of their agreed life and are currently under re-negotiation with much broader analysis and stakeholder participation than that which supported the original agreements.

However, the case underpins the need for analysis and negotiation to be based on the input of multiple stakeholder groups, and the need to consider that values, perhaps particularly those related to the environment, may change over time. In addition, the question is not simply whether cooperation over water is beneficial and how to best facilitate it, but rather how the benefits and costs of water cooperation compare to other options for meeting national goals such as economic growth, poverty reduction and maintaining environmental services for current and future generations. International cooperation over water is important, but the value of specific development choices, such as hydropower, must be considered among a range of other options in a world where energy technology is rapidly changing and the environment is increasingly valued.

Cooperation dialogue is triggered by emerging economic, environmental, and social realities of the basin, which is exemplified by the transboundary cooperation trajectory of the Rhine Basin. In the Rhine Basin, the initial trigger for cooperation dialogue has been the strategic importance of the river for navigation (see Appendix D). Therefore, the Central Commission for Navigation of the Rhine (CCNR) was the first institution formed to deal with the cooperative development of the navigation system in the Rhine River. However, investments made to improve the navigability of the river negatively affected the fish (specifically salmon) population. Consequently, the treaty for regulation of salmon fishery in the Rhine River Basin was enacted to ameliorate the problem of dwindling fish population. As industrial development (including chemical industries) accelerated, the basin faced enormous pollution problems, necessitating the establishment of International Commission for Protection of the Rhine River Basin. Cooperatively managing the complex problems of navigation, aquatic ecosystems, pollution, and so on, required sophisticated science-based solutions that are supported by indisputable scientific assessment of facts including the distribution of costs and benefits of interventions. Thus, the International Commission for the Hydrology of the Rhine Basin (CHR) was established.

The incentive to cooperate is greatest when basin member countries have interlocked economic interests as evidenced by the situations of many case study basins (see Appendix D for details):

- In the Rhine and Scheldt River Basins, upstream countries are highly dependent on downstream countries for maritime access; while the downstream countries are prone to pollution hazard, which largely results from the actions of upstream countries.
- In the Syr Darya Basin, upstream countries are endowed with abundant water resources, while the downstream countries have substantial energy and arable land resources.
- In the case of India-Bhutan (Raidak River) and Kosi River Basin, upstream countries have great hydropower potential, while India (downstream country) has huge market for energy, arable land, financial resources, and is dependent on upstream countries cooperation to implement measures to curb the recurrent flooding problem.
- Economic interests may even supersede political issues in influencing cooperation incentives as for example observed by relations between Thailand and Laos Mekong Basin.
- The joint development of hydropower production by Thailand and Laos, even in times of highly tense political relations, is testimony to the underlying significance of shared economic interest in fostering basin cooperation.

A scrutiny of the development trajectory of the Syr Darya Basin, which transitioned from cooperation pre-1991 (when the basin member countries were members of the USSR) to noncooperation post 1991 (when basin countries become independent and sovereign states), illustrates the cost of noncooperation on transboundary water resources (see Appendix D). Since gaining independence in 1991, the basin countries repeatedly clashed over the Syr Darya River, which caused substantial economic costs to both the upstream and downstream countries. The Kyrgyz Republic was forced to bear the operations and maintenance (O&M) costs of the massive infrastructure, built primarily to support irrigated agriculture in downstream countries in exchange for energy supplies from downstream countries. The O&M cost is estimated to be US$25 million per year, which the Kyrgyz Republic cannot afford alone. In response to inadequate energy supply from downstream countries, the Kyrgyz Republic changed the operating regime of reservoirs and dams (that is, water releases in winter) to generate its own energy; creating flooding in the winter and severe water deficits in the summer for downstream countries. In 2001 alone, the winter water discharges by the Kyrgyz Republic cost about US$1 billion to Uzbekistan. In Kazakhstan, inadequate water releases in summer reduced cotton yield on 15,000 hectares by as much as 30 percent. These losses demonstrate the cost of insistence on state sovereignty and independence in transboundary water dialogue.

The situation of the Murray-Darling River Basin in Australia exemplifies the case of cooperative management of transboundary water resources in federal states and the role of rigorous economic analysis in justifying re-allocation of the already committed water resources among sectors (see Appendix D). The federal government has no constitutional responsibility for water, although it can indirectly exert considerable influence on the water sector through political, financial, and economic policy measures. It was recognized that a cooperative arrangement was needed between the states to manage the river for the benefit of all, in a way that individual states could not achieve alone and the basin enjoyed successful interstate collaboration for over 80 years with initial focus on equitable development and sharing of the basin's scarce water resources to satisfy the economic needs of the population. Consequently, economic development flourished in the basin but with it came environmental damage. Reforms have been initiated to tackle the water scarcity and environmental problems in the basin. These reforms, specifically the policy of re-allocating water to environment, were subjected to rigorous economic analysis to understand the benefits and costs of these initiatives and identify the winners and losers to enhance the acceptance and practicability of the reforms.

The case of the Ganges demonstrates how rigorous hydro-economic analysis can debunk a long-held myth and enhance the quality of investment decisions and dialogue. There was a long-standing opinion that constructing large dams on the upstream tributaries of the Ganges helps to control downstream floods and delivers significant low-flow augmentation benefits. A hydro-economic analysis revealed that constructing large dams on the upstream tributaries of the Ganges may in fact have less of an impact on controlling downstream floods than is thought and that the benefits of low-flow augmentation delivered by storage infrastructures are low. The model results suggest that Nepal and India may concentrate on jointly developing dams for hydropower generation instead of seeking elusive deals designed to take full account of multipurpose benefits since construction of large dams upstream in Nepal would have a limited effect on flood control, low-flow augmentation, and irrigated agriculture downstream (Wu et al. 2013).

The Zambezi case study (see Appendix D2) illustrates the power of hydro-economic analysis in illuminating the potential sectoral trade-offs and distribution of benefits and costs among basin member countries. It shows that with cooperation and economically efficient allocation of water resources of the basin, upstream countries see their irrigation entitlements reduced, while the production of energy increases throughout the basin. For instance, Zambia would have to forgo two-thirds of its irrigation projects for a 12.5 percent gain in energy, while at the same time contributing much of the 8.5 percent increase in energy benefits observed in downstream Mozambique. Angola and Namibia would have to forgo about 40 percent of their irrigation projects should downstream countries choose to exploit their hydropower potential. Implementation of all identified national irrigation projects would expand equipped area by 184 percent but this would reduce hydropower generation of firm energy by 21 percent. If identified irrigation projects and regional hydropower plans were developed cooperatively, the resulting reduction in generated firm energy would be only about 8 percent. Restoration of natural flooding for beneficial uses in the Delta including fisheries, agriculture, environmental uses, and flood protection could cause significant reduction in hydropower production. These trade-offs can be attenuated through coordinated planning and development of the basin's water resources. One important implication of these analyses is that without some form of compensation or benefit-sharing mechanism, upstream countries will have little incentive to move toward a cooperative framework.

Economics provides powerful tools for doing just this. At the same time, its ability to quantify gives it a special power, since that which is not specifically quantified is often ignored. Those producing economic analysis to support transboundary cooperation thus carry a special responsibility.

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Chapter 6
Conclusions and Implications for Policy and Operations

Despite sustained donor support, examples of effective basin-wide cooperation and collaborative investment initiatives are scarce, particularly in SSA (UNECA 2000). Many basins lack formal mechanisms to govern an acceptable development and management of water resources. Some have formal mechanisms, such as treaties or agreements, in place that are not particularly effective or sustainable and rely on continued donor support for finances and technical backup (Jägerskog et al. 2007; Rangeley 1994). Both result in missed opportunities and even raise the prospect of conflict or instability. Water cooperation between countries sharing transboundary water resources is directly correlated with the security of nations involved in such cooperation and with peace of their region (Strategic Foresight Group 2013).

Economic analysis provides multiple frameworks to facilitate cooperation and provide pathways for overcoming barriers. As a whole, the studies reviewed approached cooperation on the basis of rational self-interest, while recognizing that economic benefits may not be the only factor driving cooperation decisions—environmental, social, political, or strategic considerations may also play a role in influencing hydro-cooperation. Some factors also contribute to our understanding by recognizing that riparian states are interlinked in ways that extend beyond the economic advantages of utilizing basin waters (Dinar and Alemu 2000; Sadoff and Grey 2002; Song and Whittington 2004; Waterbury 2002). Though not reviewed, yet others highlight that in addition to economic concerns, an understanding of other issues such as the spiritual, ethical, and moral dimensions may contribute to resolving water-related conflicts (Wolf 2012).

This report has reviewed the problems of cooperation, methods for resolution, and the role of economic analysis in the resolution. The results of the review indicate that cooperation initiatives that are not based on a sound understanding of the mutual benefits of cooperation would have limited likelihood of success. Thus, economic analysis is one of the most important approaches we have for understanding the potential of transboundary cooperation. Cooperation over transboundary waters can have high economic and political payoff and that, conversely, failure to cooperate can bring high avoidable costs. In other words, insistence on state sovereignty and independence in water disputes may lead to situations in which all parties lose in the long run. The perceptions of the magnitude of benefits and costs as well as the perceptions of fairness in the distribution of benefits and costs form the basis of incentives for cooperation. The potential payoff to cooperation within Africa may be especially high for a variety of reasons not the least of which are the large scale and importance of transboundary waters.

The key implications for policy makers and project managers engaged in fostering cooperative development and management of transboundary water resources that may be inferred from this report are summarized as follows:

- Basin-wide cost-benefit assessment should be based on transparent and sound scientific approaches to enhance the credibility and acceptability of the results among basin countries. Transparency in the benefit quantification process is as important as the knowledge of the benefits itself.

- To be most effective, the process of cooperation over shared water resources needs to follow an incremental approach. Cooperation often begins around a perceived priority development issue (for example, hydropower, irrigation). As confidence builds around the initial key shared economic issue, the window for entertaining other issues such as pollution, biodiversity loss, and so on, widens.

- There is need for instituting a dynamic benefit-sharing formula. At first, the benefit- and cost-sharing arrangements adopted may not be efficient and equitable. Over time, due to the availability of more scientific data and information and changes in markets or prices, the perception of a lack of fairness in the initial agreed benefit- and cost-sharing arrangement may arise. Thus, the arrangements should not be static and need to be revised as more credible data emerges and situations change.

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Appendix 1
Hydro-Economic Analysis

TABLE A1.1. Key Literature on Hydro-Economic Modelling

Study	Geographic application	Primary purpose
	Africa	
Van Heerden et al. 2008	South Africa	CGE
	Middle East and North Africa	
Satti et al. 2015	Nile River Basin	Hydro-economic modeling
Strzepek et al. 2008	Nile River Basin	CGE
Guldmann and Kucukmehmetoglu 2002	Tigris and Euphrates River Basin	Linear programming model/cooperative game theory
Kucukmehmetoglu and Guldmann 2010	Tigris and Euphrates River Basin	Multi-objective allocation
Mahjouri and Ardestani 2009	Sefidrud River Basin	Optimization model with game theory
Roozbahani et al. 2014	Sefidrud River Basin	Multi-objective optimization model
Roozbahani et al. 2013	Sefidrud River Basin	Linear programming
	Central Asia	
Bekchanov et al. 2016	Aral Sea Basin	Field efficiency and optimization
McKinney and Cai 1996	Aral Sea Basin	Multi-objective optimization model
Cai and McKinney 1997	Syr Darya River Basin	Multi-objective analysis
Cai et al. 2002	Syr Darya River Basin	Integrated hydrologic-agronomic-economic model
McKinney et al. 1999	Syr Darya River Basin	Integrated hydrologic-agronomic-economic model
	Europe	
Heinz et al. 2007	Jucar Pilot River Basin	Simulation, optimization, and marginal resource opportunity cost
Pulido-Velázquez et al. 2008	Adra River Basin	Holistic
	North America	
Booker and Young 1992	Colorado Basin	Optimization
Ward et al. 2006	Rio Grande Basin	Optimization, nonlinear model
Ward and Pulido-Velázquez 2008	Rio Grande Basin	Optimization
	South America	
Cai et al. 2003	Maipo River Basin	Holistic
de Moraes et al. 2010	Pirapama River Basin	Nonlinear optimization model
Rosegrant et al. 2000	Maipo River Basin	Optimization model

Note: Synthesis of methods, geographic location, and primary application of transboundary water analysis in the economic literature on hydro-economic modeling. Studies in the shaded yellow boxes are intra-national as opposed to international.

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Appendix 2
Game Theory Analysis

TABLE A2.1. Key Literature on Game Theory Analysis

Study	Geographic application	Primary purpose
	Africa	
Bhaduri et al. 2011	Volta Basin	Non-cooperative game theory/issue linkage
Bhaduri and Liebe 2013	Volta Basin	Issue linkage
Daoudy 2010	Lesotho Highlands Project	Benefit sharing
Wolf and Newton 2010	Lesotho Highlands Project	Benefit sharing
	Middle East and North Africa	
Kucukmehmetoglu 2012	Euphrates and Tigris Basin	Pareto-frontier concepts
Luterbacher and Wiegandt 2002	Jordan River Basin	Cooperative and non-cooperative
Saab and Chóliz 2011	Jordan River Basin	Negotiation
Netanyahu et al. 1998	Mountain Aquifer between Israel and Palestine	Cooperative and non-cooperative
Cascão and Zeitoon 2010	Nile River Basin	Power asymmetry
Dinar and Wolf 1997	Nile River Basin	cooperative and non-cooperative
Jeuland 2010	Nile River Basin	Monte Carlo simulation with linkages
Whittington et al. 1995	Nile River Basin	Benefit sharing
Wu and Whittington 2006	Nile River Basin	Incentives
	Europe	
Bennett et al. 1998	Aral Sea Basin	Issue linkage
Bennett et al. 1998	Euphrates and Orontes River Basin	Issue linkage
Daoudy 2007	Euphrates and Tigris	Benefit sharing
Dombrowsky 2010	Scheldt River	Issue linkage
	North America	
Daoudy 2010	Columbia River Basin	Benefit sharing
Dombrowsky 2010	Rio Grande Basin	Issue linkage
Lord et al. 1995	Rio Grande Basin	Drought gaming theory
Teasley and McKinney 2011	Rio Grande/Bravo Basin	Cooperative game theory
Frisvold and Caswell 2000	U.S.-Mexico Water Resources	Cooperative bargaining game with Pareto efficiency
Shabman and Cox 1995	U.S.-Mexico Water Resources	Benefit sharing
	Asia	
Jalilov et al. 2015	Amu Darya River Basin	Benefit sharing
Grey et al. 2009	Ganges-Brahmaputra-Meghna Basin	Benefit sharing
Rogers 1993, 1994	Ganges-Brahmaputra Basin	Cooperative theory with Pareto-frontier analysis
Bhagabati et al. 2014	Mekong River Basin	Cooperative game

Note: Synthesis of methods, geographic location and primary application of transboundary water analysis in the economic literature on game theory.

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Appendix 4
Select Case Studies on the Economics of Transboundary Water Cooperation

Literature shows that there are many examples of the economic benefits of cooperation on international waters from both developed and developing countries (Scheumann and Neubert 2006). Most of the available evidence shows the potential benefits of cooperation based on ex ante analyses of varying degrees of rigor. Often, the result of an appraisal of treaties or cooperation after implementation reflects a significant difference between the predicted, or potential, and actual benefits (Krutilla 1967; Yu 2008). Even if it can be shown that the total net benefits of cooperation are greater than the sum of the net benefits of non-cooperative actions, it does not necessarily follow that cooperation can and will lead to equitable improvements for all stakeholders as this depends very much on the respective distribution of the benefits and costs. Given that there is always a considerable degree of bargaining involved in such cooperation, ex ante agreements about the distribution of net benefits are required.

In the following sections, evidence derived from the available literature is presented basin by basin in two batches. First, evidence drawn from basins across the world is highlighted, followed by presentations of evidence from African basins.

Evidence from Basins Outside of Africa

1. Columbia Basin

The 1964 Treaty between Canada and the United States of America on the Columbia Basin is largely based on the recognition that joint development of the basin's water resources can make significant contributions to the economic progress of both countries and to the welfare of their people[1] (Columbia River Treaty 1964). The treaty recognizes that the greatest benefit to each country can be secured by cooperative measures for the purposes of hydroelectric power generation, flood control, and more. The Columbia River posed two problems to the United States: one was flood damage, which caused the death of 50 people and more than US$100 million in damages in 1948 alone, and the other was that the best sites for water storage to generate hydroelectricity and prevent flood damage were located upstream in Canada. The unilateral development of hydropower storage upstream by Canada would effectively regulate the flow of water downstream to the benefit of the United States, which is an example of positive unidirectional externality. The United States would, therefore, receive a significant portion of the benefits of upstream development at little or no cost.

Recognition of the economic advantage of joint development of the Columbia River was followed by proposals for dividing the gains derived from cooperation, detailed in the 1964 treaty. Two alternative benefit-sharing mechanisms were proposed: the first would subtract the net benefits of unilateral action from those of joint action, and share the difference; the second was based on dividing the gross benefits of cooperative development. The treaty adopted the second proposal, or sharing the gross benefits. In exchange for upstream regulation provided by storage in Canada, the United States agreed to share the increase in energy equally and to advance payment equal to one-half of the estimated total for damage reduction in the flood plains of the lower Columbia.

2. Rhine Basin

The Rhine River Basin is a good example of how economic factors motivate riparian countries to cooperate despite historically strained political relationships (IHP/HWRP 2005). The countries affected by actions undertaken within the Rhine Basin include Austria, Belgium, France, Germany, Liechtenstein, Luxembourg, the Netherlands, and Switzerland.

The river borders Germany, France, Switzerland, the Netherlands, and Liechtenstein.

The Rhine provides numerous economic services to the riparian countries: navigation, drinking water, sewage disposal, fishing, irrigation, hydropower, amenities, and process water. Of these, navigation, sewage disposal, and process water are the most important benefits for all of the major riparian states (Chase 2012; Marney 2008). The Rhine is also Europe's most densely navigated shipping route, connecting the world's largest seaport (Rotterdam) with the world's largest inland port. Thus, cooperation on the river began with the resolution of conflicts surrounding navigation through the establishment of the CCNR, whose function is to encourage riparian prosperity by guaranteeing a high level of security for navigation of the Rhine River and its environs. Rhine nations negotiated an agreement to provide free navigation of the river and to promote the use of canals along the river to facilitate shipping.

Initially, cooperation focused on navigation and hydropower generation. However, as the basin developed, other economic interests begin to emerge, necessitating further cooperation. One-sided promotion of navigation and hydropower interests harmed the ecosystem and fishery interests as weirs and dams made it impossible for fish to migrate to their spawning grounds and impeded the reproduction of migratory fish. Furthermore, the weirs and dams produced higher water levels, changing the velocity and sedimentation conditions in the spawning areas. The consequence has been a substantial reduction in the salmon population in the Rhine. As a result, the Treaty Concerning the Regulation of Salmon Fishery in the Rhine River Basin was signed on June 30, 1885 and entered into force on June 7, 1886.

Vast industrial complexes were built along the river making the Rhine Europe's most important chemical production area. Approximately 20 percent of the world's chemicals are manufactured in the Rhine River region (Frijters and Leentvaar 2003; Ruchay 1995), and for decades, untreated industrial and domestic waste flowed into the river, heavily polluting the river and causing substantial economic losses. Millions of fish and other aquatic creatures died. To keep their port operational, the city of Rotterdam spent significant funds to dredge the harbor of millions of cubic meters of toxic sludge every year during the 1970s and 1980s. These economic and environmental problems triggered the establishment of the International Commission for the Protection of the Rhine (ICPR), which devises cost-sharing mechanisms in the implementation of water pollution control and strategies for transferring finances from downstream countries to upstream countries.

The complex problems faced by the basin required sophisticated science-based solutions. A sound, indisputable scientific assessment of facts was required to provide strong support for sustainable cooperation on the Rhine River Basin. This assessment was achieved through the establishment of the research-oriented CHR. Although the major Rhine River Basin commissions focus on one specific aspect of the river such as navigation, water quality, or research, all have proved their importance. It should be noted, however, that a River Basin Organization responsible for integrated water resource management for the whole Rhine catchment area does not exist.

3. Scheldt Basin

Cooperation over the Scheldt and Meuse Rivers among the Netherlands, Belgium, and France demonstrates the conclusion of long-standing conflicting economic interests, particularly between Belgium and the Netherlands. A mutually beneficial solution was achieved by linking downstream navigation and harbor projects to the upstream improvements in water quality and quantity in addition to cost-sharing mechanisms (Meijerink 2008).

The Scheldt estuary has multiple economic and environmental functions, including navigation, ecology, recreation, and fishery, and provides maritime access to the port of Antwerp, one of the largest ports in the world. A considerable part of the fresh water discharge of the Scheldt is diverted to the North Sea by several canals to improve navigation possibilities on these canals as well as for industrial purposes. However, the quality of the Scheldt and its estuary is affected by the drainage of untreated domestic water, and pollution with heavy metals and organic micro pollutants is still significant. Agriculture also contributes significant nutrient load, particularly of nitrogen, to the Scheldt estuary.

The Scheldt estuary is also an international water system, shared between the Netherlands and the Belgian region of Flanders. The economic issue of prime importance for Belgium is maritime access to the port of Antwerp. Given that the navigation channel in the Scheldt estuary and the waterways to Antwerp are situated on Dutch territory, Belgium is fully dependent on the willingness of the Netherlands to cooperate on maintenance or improvement of maritime access to Antwerp. On the other hand, the economic issue of prime importance to the Netherlands is water and sediment pollution, which is caused by high population density and industrialization in the Scheldt River Basin, along with a lack of sewage and wastewater treatment. On this issue, the Netherlands as a downstream basin state is largely dependent on the water quality policies of all upstream basin states and regions, namely, France and the Belgian regions of Flanders, Wallonia, and Brussels, the capital (Meijerink 2008).

To improve maritime access for Belgium to the port of Antwerp, an agreement was reached on the development of two new channels (the Bath and Baalhoek channels) and deepening of the existing navigation channel in Western Scheldt. To address the concerns of the Netherlands, the agreement contained provisions for (a) compensation for the loss of nature; (b) the improvement of the water quality of the Scheldt and Meuse Rivers; and (c) water distribution in the Meuse River. Including the Meuse River in the agreement was very important to the Netherlands since water from the Meuse is a crucial source of drinking water in southern Randstad, the urbanized western part of the Netherlands.

One key aspect of this agreement is that it showed that the success of negotiations over river basin development is influenced by the economic and political interests of subnational entities or regions within a country. Initially, politicians of the Walloon region opposed the proposed deal because they did not see any benefit for their region (Meijerink 2008).

4. Tijuana Basin

The Tijuana River is part of a 1,735 square mile watershed. About 73 percent of the watershed is in Mexico and 27 percent is in California. California is both an upstream and downstream state in relation to the Tijuana River as runoff from the Tijuana River flows northward into the Pacific Ocean. Two major cities, Tijuana and San Diego, are located in the Tijuana Basin.

Pollution has been the principal problem facing the population of the basin, with several factors contributing to the severity of the issue. Chief among these was the rapid economic progress of Tijuana following the adoption of the concept of the *maquiladora* industry in 1965 with the creation of the Border Industrialization Plan (BIP), inspired by the success of export processing zones in South Korea and Taiwan. The attractiveness of the maquiladora industry stems from companies' ability to access relatively low-cost labor and remain close to the U.S. market.

The maquiladora industry generates over US$10 million monthly, a level of economic activity that prompted the migration of Mexican workers to the area. A rapid increase in the population and in industry resulted in a challenging sewage problem owing to excess industrial and human waste. This pollution affects the San Diego-Tijuana area and the Tijuana River, and is particularly detrimental to the coastal beaches. Sewage and pollution flow from the city of

Tijuana down the river and into the ocean at Imperial Beach, and the production of pollutants in each city affects the other. In particular, the Tijuana lacks proper sanitation services and, during severe storms, untreated sewage spills into the streets. Yet, proper treatment of this problem requires an amount of financing that far exceeds the capacity of the city.

The pollution problem has significant economic, health, and ecological consequences. First, it affects the beaches in San Diego County through its impact on the tourist industry. The beaches of San Diego are a popular tourist destination. The revenue generated from tourism in San Diego County was estimated to be in the range of US$3.1 billion to US$3.6 billion per year in the early 1990s (Fernandez 2005), while tourism in California is approximately US$7 billion annually. There is also the potential for recreational activity in the Tijuana River watershed, which adds to the appeal of the area for tourism, provided the environment is clean and safe.

Moreover, the health risks of pollution are severe. Anyone venturing into the Tijuana River estuary must be extremely careful as there is the risk of exposure to *Salmonella*, *Shigella*, *fibrial*, cholera, hepatitis A, and malaria. Some people living in the colonias in and around Tijuana are exposed to dangerous levels of toxins from polluted drinking water, and in the hospitals in San Diego County, cases of tuberculosis have increased. Women on both sides of the border are giving birth to children who are deformed and mentally disabled (Fernandez 2005), with these health hazards disproportionately affecting poor neighborhoods. The ecological consequences of pollution may also be daunting. The Tijuana River estuary comprises 20 percent of all the wetlands in southern California. There are at least 29 species of fish and 298 species of birds that live in the estuary, a few of which are endangered.

Thus, cleaning up and increasing the economic integration of San Diego and Tijuana would enhance the area's tourism potential. The United States and Mexico have worked together for many years to solve this problem. The two countries signed the Border Environmental Agreement, which addressed a host of environmental problems and allows both countries to prevent, reduce, and eliminate sources of air, water, and land pollution in a 100 kilometer zone along each side of the boundary. Local, state, and federal management agencies, along with nongovernmental organizations and other stakeholders, have invested significant effort and funding in project planning and implementation to improve conditions both in the United States and in Mexico. In addition, investments to improve wastewater treatment began in the 1980s and 1990s, with the United States providing most of the financing for the treatment of polluted upstream water.

It is also well known that source control and pollution prevention activities can be the most cost-effective solutions for reducing sediment and trash loading (Tijuana River Valley Recovery Team 2012). Hence, recent activities have included pollution prevention and source control for sediment and trash, water quality improvements, flood control, improved recreational opportunities, and public education and outreach.

5. Meric Basin

The Meric basin is one of the major river systems of the eastern Balkans and is shared by Bulgaria, Greece, and Turkey. Turkey receives about 5.8 km^3/year of water from Bulgaria through the Meric River, which forms the border between Turkey and Greece. The river has a total length of 550 km and a total catchment area of 39,000 km^2, about 66 percent of which belongs to Bulgaria, 28 percent to Turkey, and 6 percent to Greece. Water from the basin is used mainly for irrigation and to supply water to cities and villages in the three countries.

The Meric Delta's surface water and groundwater are important for rice production, however, water discharge from the Meric depends on the operating rules of the Bulgarian dams where water storage occurs during the summer period. When the water level is too low because of limited releases from the Bulgarian dams, saltwater intrusion occurs, affecting water quality and the wetland life. Therefore, water needs for irrigation and flood control are a major source of disputes in the basin, particularly between Turkey and Bulgaria. In addition, the absence of a controlled water supply for irrigation and industrial purposes is an important problem, which requires agreement from the three countries for all discharge and ecological issues.

In the past, political distrust between these three countries hampered cooperation. However, recent rapprochement between Turkey and Greece, Bulgaria's joining the European Union, and the prospect of European Union membership for Turkey are expected to have positive effects on transboundary water management. There is ongoing cooperation between Bulgaria and Turkey to coordinate the release of reservoir water in the dry season. Consequently, in Turkey irrigation capacities have increased to 40,000 hectares. Turkey has also occasionally paid Bulgaria for the release of additional water for irrigation purposes in the dry season (Sezen and Gundog 2007).

6. Syr Darya Basin

The Syr Darya River Basin covers an area of 99,458 km^2, including 55 percent of the territory of the Kyrgyz Republic, and is shared by Uzbekistan, Tajikistan, and Kazakhstan. The river has diversified hydraulic infrastructure constructed during the Soviet period, designed for water storage and flood control in the basin. The network includes dams, reservoirs, and irrigation canals along the territories of the Kyrgyz Republic, Uzbekistan, Tajikistan, and Kazakhstan.

The degree of dependence on water within these basins varies from country to country and is influenced by the geographical location of each state. The Kyrgyz Republic and Tajikistan possess abundant water resources and could be regarded as upstream states. Uzbekistan and Kazakhstan are downstream states, the national economies of which depend on water resources flowing from their upstream neighbors. While most of the energy resources and the arable land are located in Kazakhstan and Uzbekistan, the Kyrgyz Republic and Tajikistan possess the majority of freshwater resources in the basin. Eighty-one percent of renewable surface water resources in the region falls within the territories of the latter states.

Since gaining independence in 1991, the basin countries repeatedly clashed over the Syr Darya River. These clashes stemmed from the new geopolitical situation in the region arising from the disintegration of the Soviet Union in 1991 and the creation of new sovereign states. With the varying degrees of economic power enjoyed by the new states, the formerly friendly republics found themselves in fierce political and economic competition, the spirit of which penetrated the sphere of management of the Syr Darya River.

During the Soviet era, the Kyrgyz Republic was assigned the role of water supplier for the irrigation needs of the republics situated downstream of the Syr Darya River. Water infrastructure was constructed and made operational on the rivers of this upstream country to develop rice and cotton farming and associated industries in Kazakhstan and Uzbekistan. As a result, 400,000 hectares of irrigated land were developed in the neighboring republics. The Kyrgyz Republic in turn received compensation of energy resources coal, oil, and gas, in addition to money from the federal budget for the maintenance of dams and irrigation systems.

Following the disintegration of the Soviet Union, the Kyrgyz Republic and Tajikistan redefined their water resource priorities, with a focus on using them for hydropower generation during the winter months. While Uzbekistan and Kazakhstan still believed that the water resources of the Syr Darya River would primarily serve the needs of their cotton and rice industries—as had previously been the case during the Soviet period—upstream, the Kyrgyz Republic prioritized its national interests and gradually changed the operating regime of the hydraulic system from largely serving the irrigation needs of the lower riparian countries in the basin to producing more than 80 percent of the energy required for domestic and export purposes during the winter.

This disagreement had repercussions for all of the riparian states. The downstream states suffered economic losses caused by shortages of irrigation water during the summer season and floods during the winter. Conversely, the upper riparian nation has repeatedly found itself on the brink of an energy crisis as the lower riparian states have continued to inflate the prices of their energy resources, driving the Kyrgyz Republic into a debt. This situation prompted the Kyrgyz Republic to take counter measures. In the winter of 2001, the Kyrgyz Republic directed all of its water resources into hydropower generation to compensate for the shortage of gas and coal. These actions resulted in a depletion of the water reservoirs in Kyrgyzstan and crop failures in neighboring states.

Evidently, the lack of substantive cooperation on water management in the Syr Darya Basin has resulted in economic losses for both upstream and downstream states and contributes to tense relations within the basin. While the Kyrgyz Republic has to bear the costs related to the maintenance and operation of water infrastructure and other facilities, downstream, Uzbekistan and Kazakhstan suffer mainly from economic damage caused either by floods or droughts. Maintenance of the hydrological system of the Kyrgyz Republic requires more than US$25 million in annual investment, which is well beyond the capacity of the Kyrgyz Republic. As a result of the inability of the Kyrgyz Republic to manage the situation alone as well as the refusal of Kazakhstan and Uzbekistan to share the costs, the hydraulic system is continuing to deteriorate, causing substantial water losses through evaporation, infiltration, and other means.

For the downstream states, the consequences of the transformation of the operating regime are also unfavorable, with flooding in the winter and severe water deficits in the summer. In Uzbekistan, the agricultural sector is especially vulnerable to fluctuations in the water supply, which reduce the span of irrigated land and, therefore, causes a decrease in crop yields. In Uzbekistan, unscheduled water releases by the Kyrgyz Republic in the winter resulted in the flooding of 350,000 hectares of arable land and damaged road infrastructure, the power transmission network, and social facilities. In 2001, Uzbekistan claimed that extensive water discharge by the Kyrgyz Republic cost the country almost US$1 billion (Shalpykova 2002).

Kazakhstanis are also extremely anxious about water mismanagement in the upstream area of the Syr Darya River Basin because its agriculture and fishing sectors are heavily dependent on fluvial water. For example, in 2000 approximately 15,000 hectares of the cotton fields in Kazakhstan received inadequate amounts of irrigation water. As a result, around 30 percent of the harvest was lost. For Kazakhstan, the challenge stems not just from the issue of the quantity of water, but also from concerns about the water quality. Irrigation in Uzbekistan seriously deteriorates the water quality of the Syr Darya River. As a result, Kazakhstan bears the cost of the measures required to mitigate the consequences of water quality deterioration, such as the decline of the fishing sector in Kazakhstan due to the insufficient quantity and poor quality of water from the Syr Darya River.

The riparian countries have recognized the significance of the basin's water resources for enhancing social and economic development of their people and have strived to develop a coordinated water management regime that addresses energy, irrigation, and environmental safety issues. They realized that insistence on state sovereignty and independence in water disputes leads to a situation where all parties lose. Consequently, they have devised a series of treaties, initially focusing on in-kind compensation for curbing water releases during the winter with the intention of bartering coal for water supplies in the summer (Shalpykova 2002).

The parties have also attempted to deepen these agreements through jointly considering the following issues:

- Construction of new hydropower facilities and reservoirs or alternative sources for hydropower in the region
- Replacement of barter settlements with financial relations
- Development of energy pricing mechanisms based on a single-tariff policy
- Ensuring safe operation of infrastructure facilities in the Syr Darya Basin
- Economic and rational water use of water with the application of conservation technologies and irrigation equipment
- Reduction and discontinuation of the discharge of polluted water into the Syr Darya Basin

7. Mekong Basin

The Mekong is a transboundary river in South-East Asia straddling six countries, namely China, Myanmar, Laos, Thailand, Cambodia, and Vietnam, and characterized by extreme seasonal variations. All attempts to forge cooperation among the riparian nations focused on economic issues such as navigation, irrigation, hydropower, water supply, and so on. To some degree, regional benefit sharing may be seen as already occurring in the basin (Mekong River Commission 2011).

A basin-wide cumulative impact assessment of the basin countries' national plans with and without consideration of climate change impacts was completed during 2008-2010. The assessment demonstrated the considerable transboundary synergies and trade-offs between water, energy, food, and environmental and climate security and allowed the basin countries to negotiate and agree on an integrated water resources management strategy for basin development (Mekong River Commission 2011). One of the strategic priorities highlighted is to explore options for sharing the potential benefits and risks of development. The strategy calls for the Mekong River Commission to support and facilitate negotiated solutions for sharing the benefits and risks.

The Mekong countries have identified a range of ongoing and planned national activities and projects of basin-wide significance, along with potential joint projects, which are viewed as important mechanisms for regional benefit sharing, with a focus on looking beyond borders to enhance the mutual benefits enjoyed by all of the countries.

The Mekong River Commission (MRC) evaluated the economic benefits with regard to their impact on economic growth, as measured by the incremental net economic benefits and losses of economic activities, as well as the number of jobs created and lost due to interventions. It determined that integrated water resource management in the Mekong River Basin could yield substantial net economic benefits mainly for well-established groups, such as through hydropower provision, and significant benefits in irrigated agriculture, reservoir and rice field fisheries, and navigation. However, it noted that there would also be negative impacts in the form of losses for capture fisheries, wetland area production, biodiversity, forests, and recession rice. Focusing on the main economic activities, the MRC estimated that transboundary benefits for hydropower generation and irrigated agriculture amount to US$7 billion, while costs for capture fisheries amount to US$2 billion over the 20-year assessment period. The MRC has been working with its member countries on optimizing these benefits and reducing transboundary costs. The joint development of hydropower production by Thailand and Laos, even in times of highly tense political relations, is testimony to the underlying significance of shared economic interests in fostering basin cooperation.

8. India-Bhutan Basin (Raidak River)

The Raidak River, also called Wang Chhu or Wong Chhu in Bhutan, is a tributary of the Brahmaputra River and a transboundary river, rising through the Himalayas and flowing through Bhutan, India, and Bangladesh. Transboundary cooperation on the Raidak River between India and Bhutan has been based on sharing hydropower development benefits since 1967.

Initially, Bhutan imported electricity generated at the Jaldhaka hydropower plant located in West Bengal. However, both countries recognized the huge hydroelectric potential of Bhutan and cooperatively developed a 336 MW hydroelectric power plant at Chukha Hydel, harnessing the waters of the Raidak River in 1989. The power plant was built by India on a turnkey basis, with India providing 60 percent of the capital in a grant and 40 percent in a loan at highly concessional terms and conditions. Bhutan in turn agreed to provide the land and timber required for the project free of cost. The benefit-sharing mechanism stipulated that India would receive all of the electricity generated from the project in excess of Bhutan's demand for 99 years at a tariff determined through formula that would generally result in a cheaper rate than India's power generation cost from alternative sources. The arrangement was considered beneficial to both Bhutan and India, although its terms and conditions were not inflation proof. With a rise in the inflation rate, there was a significant reallocation of the project's benefits in favor of India (Dhakal and Jenkins 1991; Tamang and Tshering 2004).

The two countries have thus agreed to develop approximately 10,000 MW of hydropower in total. The first 1,416 MW have already been developed, using a similar financing model of 60 percent loan and 40 percent grant from India. About 2,940 MW of hydropower are currently under construction, but the funding pattern is now 70 percent as a loan and 30 percent as a grant. In April 2014, the two countries made significant strides toward achieving the goal of 10,000 MW of hydropower development by 2020 by signing an agreement on four more joint hydroelectric power plant ventures, with a combined capacity of 2,120 MW.

9. Kosi Basin

The Kosi River, a tributary of the Ganges, is formed by the confluence of three streams, namely the Sun Kosi, the Arun Kosi, and Tamur Kosi, all originating in the Himalayan region of Nepal and Tibet. The Kosi drains an area of 74,500 km^2, of which only 11,070 km^2 lie within Indian territory. It is a turbulent river, whose frequent floods have caused damages in the state of Bihar in India as well as in Nepal.

Nepal has estimated hydropower potential of 84,000 MW, with the Kosi River contributing to almost half of this potential. Conversely, India is second in the world, after Bangladesh, in deaths caused due to flooding, accounting for one-fifth of global flooding deaths. While Nepal needs the Indian market for its hydropower exports, India needs Nepal's water resources to meet its agricultural needs, minimize its power deficit, and mitigate flood damage. Thus, Nepal's water resources can be exploited for the benefit of both countries.

It was believed that the long-term solution to controlling flooding in the Kosi Basin would be to construct a high dam (Adhikari et al. 2014). In 1954, Nepal and India signed an agreement to develop dams and other infrastructure on the Kosi River to control floods, irrigate land, and generate hydropower in phases. Under this agreement, the Kosi/Bhimnagar Dam and a system of earth dams and large embankments were built during the late 1950s and early 1960s. India completely financed a dam and provided compensation for inundated land, including compensation to the Nepalese Government for the loss of land revenue at the time of acquisition, as well as for upstream afforestation. The assessment of compensation and the mode of payment were determined by mutual agreement between the two countries. Nepal permitted India to quarry the construction materials required for the project from the various deposits in its territory, while India was exempted from duty charges on any articles or materials required for the project and associated works.

With respect to benefit sharing, the agreement provides India the right to regulate all the water supplies in the Kosi River at the barrage site and to generate power. Nepal receives up to 50 percent of hydroelectric power at rates fixed by India in consultation with Nepal as well as water for irrigation. In addition, Nepal receives royalties for power generated in India at mutually agreed rates. Nepal also receives payment of royalties from India for stone, gravel, and ballast obtained from the Nepalese territory and used in the construction and future maintenance of the barrage and other related works at agreed rates. India shall also give preference to the Nepalese people for labor and the selection of contractors to the extent possible and suitable for construction of the project.

There is general apprehension among the Nepalese public and political elite that the cost- and benefit-sharing arrangement disadvantages Nepal, contending that the agreement was skewed with regard to the benefits that accrued to the two countries. With irrigation, for instance, only 29,000 acres in Nepal benefited, whereas the barrage had the capacity to irrigate 1.5 million acres. Some groups also expressed their displeasure at the submergence of territory and the resultant displacement of people. India's control and management of the barrage was further considered an infringement on Nepal's territorial sovereignty. Thus, the Kosi agreement was amended repeatedly to rectify perceived wrongs. One notable addition was the definition of the land lease period, which was not specified in the 1954 agreement. The newer version of the agreement stated that Nepal would lease the land for the barrage to India for a period of 199 years, which still proved unsatisfactory to Nepal. It was argued that since the overall life-span of the barrage would not be more than 50 years, the period of 199 years was too long.

Evidently, despite recognition of the economic benefits of cooperation, failure to craft an amicable and fair benefit-sharing mechanism can derail actual cooperation. For instance, the implementation of the Panchesharwar multi-purpose dam project planned jointly by India and Nepal was delayed mainly because of diverging perceptions of fairness regarding the allocation of benefits. For the expected advantages of cooperation to be realized, arrangements must clearly convey advantages equitably to all parties involved.

10. Murray-Darling Basin

The Murray-Darling River system is a transboundary river system in the federal states of Australia that displays the features of international river systems. Although it is the largest river system in the world, draining an area roughly the size of France and Spain combined, its yield is low—by way of illustration, the Amazon River would carry the annual flow of the Murray-Darling River in less than one day (Pigram and Musgrave 1998). The Murray-Darling Basin straddles four states—Queensland, New South Wales, Victoria, and South Australia—each with jurisdiction over water use within its borders. However, it is simply not possible to tackle the physical and technical problems associated with water quantity and quality in the basin effectively on a state-by-state basis. The federal government has no constitutional responsibility for water, although it can indirectly exert considerable influence on the water sector through political, financial, and economic policy measures. It was recognized at the turn of the 20th century that a cooperative arrangement was needed between the states to manage the river for the benefit of all, in a way that individual states could not achieve alone. Aspects of its management have been the subject of successful interstate collaboration for over 80 years.

Australia has a highly variable climate and is the driest inhabited continental landmass. It has the least river water, the lowest runoff, and the smallest area of permanent wetland. Few permanent freshwater lakes exist over much of the inland. These circumstances help explain the prominence given to water resource development since the earliest days of European settlement. Australia stores more water per capita than any other country in the world, and irrigation agriculture is the largest user of water, accounting for 70 percent of all water used. The bulk of this irrigation is concentrated in the Murray-Darling Basin. Thus, the basin is a complex and stressed river system.

The initial focus was on equitable development and sharing of the basin's scarce water resources to satisfy the economic needs of the population, such as water supply, irrigation, and navigation. Thus, major storage systems and numerous smaller weirs and locks were constructed to transform the river into a regulated system, ensure reliable supply, and facilitate navigation.

Economic development flourished in the Murray-Darling Basin as a consequence of these interventions, but with it came environmental damage. There has been increasing concern for the integrity of the system as a result of evidence of unacceptable pressure on supplies for consumptive use and of environmental deterioration. The health of the river system has been compromised, particularly with respect to increasing water salinity and the frequency of algal blooms, declining biodiversity in riverine ecosystems, and a decrease in the frequency of beneficial flooding and wetland replenishment (Witter and Dixon 2011).

Reforms have been initiated to tackle the water scarcity and environmental problems in the basin. They include regulatory reform, increased charges for water, and development of an effective market-based property rights system for resource allocation and trade. According to these reforms, the water industry is required to take the following steps, among others (a) pay more for water; (b) allocate increasing amounts of water to the environment; (c) explore opportunities for more flexible water use; (d) achieve higher-use efficiencies through the adoption of best practices in management; (e) conform to more demanding environmental regulations; and (f) fund infrastructure maintenance and replacement costs.

Incentives to change traditional courses of action require a clear understanding of the benefits involved. For instance, in the Murray-Darling Basin, a new management plan involved a reduction in water security for the many communities dependent on the Murray River. The communities were involved in the negotiation process because they needed to understand the benefits to be gained by taking on that risk so that the new arrangements would be robust and sustainable in the long term.

These reform agendas are often supported by rigorous economic assessment. For instance, the economic costs and benefits of reallocating water from agriculture to environment have been assessed. In this analysis, the value of foregone agricultural outputs are compared to the estimated economic benefits of cooperation with regard to increased annual tourism expenditures and increases in consumer and producer surplus for recreational and commercial fishing, in addition to the benefits to recreational boating, avoided costs of rising salinity, and the reduced risk of black-water events, cyanobacterial blooms, acid sulphate soils, and riverbank collapse (Chambers and Adamson 2009). Though much remains to be achieved, the basin continues to provide an example of productive, cooperative federalism in river basin management.

11. Ganges River Basin

The Ganges River Basin covers an area of almost 1.2 million km^2 and traverses three countries: 85 percent of the basin lies in India, 12 percent in Nepal, and 3 percent in Bangladesh. All of Nepal and over one-quarter of Bangladesh lie within the basin. The Ganges is characterized by extreme seasonality and climate variability, with approximately 80 percent of annual rainfall received in just three months. Thus, the climate and hydrology of the Ganges are largely defined by the South Asian monsoon. On average, about 1,200 billion m^3 of precipitation falls in the basin in a year, of which around 500 billion m^3 becomes stream flow. Glaciers and snow contribute only a small fraction of the total flow, but represent important storage that contributes to the perennial flow, particularly in Nepal. Sedimentation, declining dry season flows, floods, droughts, and declining water quality are enduring challenges in the basin. Floods in particular cause frequent and considerable damage with huge losses of lives and livelihoods.

The Ganges is the world's most populous river basin, home to more than 655 million people. Population density is high, with an average of 551 people per km^2 (more than 10 times the global average) and as many as 1,285 people per km^2 in Bangladesh. Poverty is widespread and higher in the states and districts in the Ganges Basin than elsewhere, particularly in India and Bangladesh.

The basin provides significant economic opportunities for the riparian countries. Agriculture dominates water use, with irrigation currently representing about 90 percent of the basin's combined surface water and groundwater use. Currently, there is little capacity to regulate the system, either for flood mitigation or for water supply, and despite extensive irrigation development, many development opportunities remain. Although many of the required investments and policy reforms can be undertaken at the national level, all would be better informed by a basin-level approach to understanding and managing the dynamics, challenges, and solutions of the Ganges Basin. Yet, despite half a century of incremental bilateral treaties and several bilateral mechanisms, there are no basin-wide treaties or organizations with a clear mandate to facilitate cooperation in transboundary waters. Thus, cooperation among the basin countries has long been the subject of political and professional discussions on harnessing the water of the Ganges for the socioeconomic advancement of the people. Unilateral withdrawal of the Ganges water may cause economic losses and environmental damage to one or more of the basin countries. For instance, the withdrawal of water by India caused problems in southwestern parts of Bangladesh, such as reduced flow during the dry season, salinity intrusion, groundwater depletion, and economic losses in agriculture, industry, navigation, and forestry sectors. Bangladesh has formally voiced its concern to India on this subject.

The potential benefits of basin-wide cooperation include flood control, low-flow augmentation, hydropower generation, and the creation and improvement of navigation. The Ganges Economic Optimization Model was developed to explore the following strategic questions:

- What are the relative magnitudes of the economic benefits from hydropower, flood control and low-flow augmentation from water resource development in the Ganges?
- Are there significant economic trade-offs from hydropower, flood control, and low-flow augmentation resulting from water resource development in the Ganges?
- How sensitive are the sizes of hydropower, flood control, and low-flow augmentation outcomes to varying assumptions about their relative economic values and what are the trade-offs between them?

The results of the model indicate that constructing large dams on the upstream tributaries of the Ganges may in fact have less of an impact regarding controlling downstream floods than is thought and that the benefits of low-flow augmentation delivered by storage infrastructures are currently low. The potential gross economic benefits of new hydropower generation from developing the full suite of new hydropower investments was estimated at US$7 billion to US$8 billion annually, which is significantly greater than the current hydropower benefits produced in the basin (about US$2.5 billion).

Regarding the trade-off between irrigation in the Ganges plain and low-flow augmentation in

Bangladesh, the model showed that the optimal allocation between these two uses is highly sensitive to their relative economic value—when the economic value of low flows in Bangladesh is high, the model allocates less water to India for irrigation and vice versa. In conclusion, the model results suggest that Nepal and India may concentrate on jointly developing dams for hydropower generation instead of seeking elusive deals designed to take full account of multipurpose benefits since construction of large dams upstream in Nepal would have a limited effect on flood control, low-flow augmentation, and irrigated agriculture downstream (Wu et al. 2013).

Evidence from African Basins

1. Zambezi Basin

The Zambezi is the largest river basin in southern Africa, covering some 1.37 million km^2 across eight countries: Angola, Botswana, Malawi, Mozambique, Namibia, Tanzania, Zambia, and Zimbabwe. The Zambezi River Basin is home to about 40 million people who rely on the river for domestic water supply, fisheries, irrigation, hydropower generation, mining, and industry, ecosystem maintenance, and other uses. Only about 10 percent of the total hydropower potential has been developed. However, hydropower is by far the largest water use in the basin since evaporation from the hydropower reservoirs is estimated to be 17 km^3. Victoria Falls and wildlife living along the river banks are the major sources of tourism, which supports local economies and brings much-needed foreign currency into the basin countries.

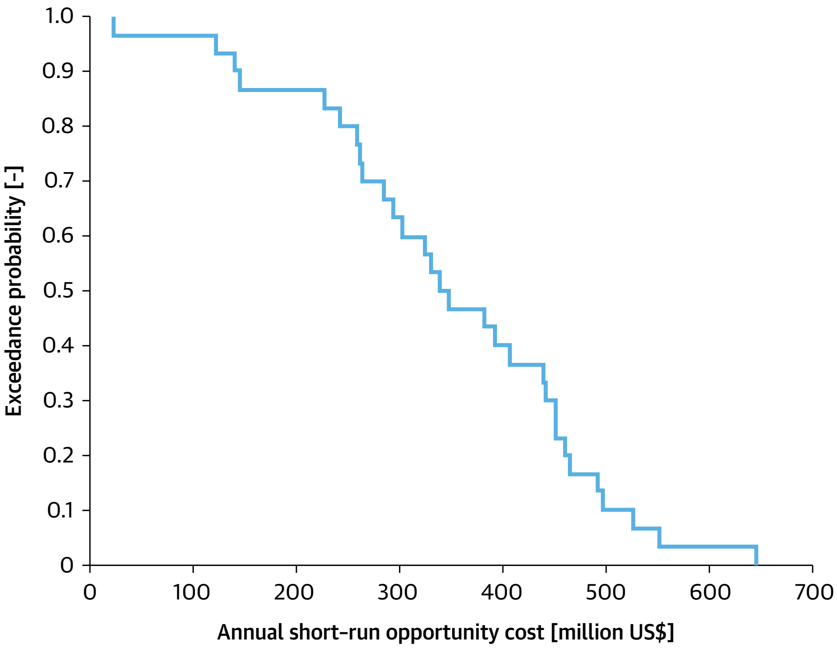
Due to the lack of an integrated flood warning system in the basin, floods have been and continue to be a threat to the lives and property of floodplain residents. There are two large dams, the Kariba and Cahora Bassa Dams, in the basin. Water releases from these dams can aggravate flooding in downstream communities, especially when intense rainfalls or tropical cyclone events coincide with above-normal inflows to the reservoirs. Protecting and managing the sustainable use and development of the Zambezi is extremely important to the people living in the region.

Transboundary management of shared water resources has been a challenge in the Zambezi River Basin because countries have multiple and competing economic interests. The situation is exacerbated by inadequate hydrological and economic data. Countries' needs differ depending on whether they are upstream or downstream and the adequacy of water resources. Zambia and Zimbabwe have the lion's share of the watershed within their borders and engage in bilateral management of the river. In addition, both countries share the Kariba Dam and Victoria Falls.

Recently, Zambezi Watercourse Commission has been established to promote equitable and reasonable utilization of the water resources of the Zambezi water course. Water-rich countries like Angola, Mozambique, and Zambia are less reliant on surface water for irrigation, while Namibia receives scant rainfall and relies on groundwater for irrigation. The specific development challenges of the basin are (a) inadequate water infrastructure for achieving regional energy security; (b) insufficient water infrastructure for agricultural development to achieve regional food security; (c) non-optimal use of the major dams, which were mainly constructed for a single purpose; and (d) low access to water supply and sanitation.

The economic cost of noncooperation in the development and management of Zambezi water resources is estimated to be quite substantial (Tilmant and Kinzelbach 2012). The economic loss of noncooperation was evaluated based on the difference in value between unilateral development of the basin's water resources by respective countries and the value of collaborative development. This valuation exercise revealed that the yearly average cost of noncooperation would reach US$350 million, which corresponds to 10 percent of the average annual benefits (US$3.5 billion per year) derived from the development of the basin's water systems. Figure A4.1 shows

FIGURE A4.1. Annual Opportunity Cost of Noncooperation on Development of the Zambezi Basin



that the opportunity cost increases in tandem with the exceedance probabilities, meaning that during wet years, the cost is negligible and as the system gets drier, the opportunity cost increases. During dry years, with low exceedance probabilities, the opportunity cost can be as high as US$600 million per year.

It should be noted that the distribution of economic gains and losses varies from country to country. In general, with cooperation and economically efficient allocation, upstream countries see their irrigation entitlements reduced, while the production of energy increases throughout the basin from the upstream country to the outlet. Upstream countries also tend to face inter-sectoral trade-offs. For instance, Zambia would have to forgo two-thirds of its irrigation projects for a 12.5 percent gain in energy, while at the same time contributing much of the 8.5 percent increase in energy benefits observed in downstream Mozambique. Angola, and Namibia would have to forgo about 40 percent of their irrigation projects should downstream countries choose to exploit their hydropower potential. Without some form of compensation or benefit-sharing mechanism, upstream countries will have little incentive to move toward a cooperative framework.

Multi-sector Investment Opportunity Analysis also underlined the benefits of cooperative development of the basin's water resources for hydropower generation, irrigation, and restoration of natural flooding for beneficial uses in the Delta of the Lower Zambezi (World Bank 2010). The analysis reveals that with cooperation and coordinated operation of the existing hydropower facilities found in the basin, firm energy generation can potentially increase by 7 percent, adding a value of US$585 million over a 30-year period with no major infrastructure investment. Development of the hydropower sector according to the generation plan of the southern Africa Power Pool would result in estimated firm energy production of approximately 35,300 GWh per year, thereby meeting all or most of the estimated energy demand of the riparian countries. The coordinated operation of the new system of hydropower facilities can provide an additional 23 percent generation over uncoordinated or unilateral operation.

According to this study there is substantial trade-off between energy generation, irrigation development, and restoration of natural flooding, which can be attenuated through coordinated planning and development of the basin's water resources. Implementation of all identified national irrigation projects would expand equipped area by 184 percent but this would reduce hydropower generation of firm energy by 21 percent. If identified irrigation projects and regional hydropower plans are developed cooperatively, the resulting reduction in generated firm energy would be only about 8 percent. Restoration of natural flooding for beneficial uses in the Delta including fisheries, agriculture, environmental uses, and flood protection could cause significant reduction in hydropower production.

2. Nile Basin

Eleven countries share the Nile Basin: Burundi, Egypt, Eritrea, Ethiopia, Kenya, Rwanda, South Sudan, the Sudan, Tanzania, Uganda, and the Democratic Republic of Congo. The Nile is one of the world's longest rivers, traversing 6,695 km, and the 3.2 million km^2 of the basin cover about 10 percent of the African continent. Despite the length of the river and its expansive basin area, the flow in the Nile is a small fraction of the flow in other large rivers of the world due to the low runoff coefficient of the Nile (below 5 percent) and the fact that about two-fifths of the basin area contributes little or no runoff as it is comprised of arid and hyper-arid dry lands (Nile Basin Initiative 2012).

Approximately 300 million people live in the basin countries, which may double within the next 25 years, adding to the demand for water, and around 160 million people depend on the Nile River for their livelihoods. Most of the basin countries are among the world's 50 poorest nations, and many commentators have opined that competition over the Nile River may lead to wars.

The Nile is one of the least-developed rivers in the world and offers tremendous opportunities for growth. It has significant potential for cooperative management and development of the common water resources as well as for hydropower development, agricultural development, domestic and industrial water supply, ecotourism, fisheries development, and navigation. The Nile Basin is endowed with rich cultural history and environmental assets, and the river can serve as a catalyst for broader regional economic integration and the promotion of regional peace and security.

Despite this potential, however, the basin is facing ever-increasing challenges and pressures. Climate change is expected to adversely affect the food, water, and energy security of the riparian countries, which may be compounded by high demographic growth rates and faster economic growth. Furthermore, the Nile is a relatively water-scarce river compared to major rivers of the world, and the basin faces land and wetland degradation, seawater intrusion, soil salinization, and loss of biodiversity.

These opportunities and challenges call for cooperative action. Unilateral actions not only have limited efficacy in addressing the challenges, but also entail significant opportunity costs (Blackmore and Whittington 2008; Whittington et al. 2005). Whittington et al. (2005) developed the first economic model designed to optimize the water resources of the entire Nile Basin. The model showed that total potential annual direct gross economic benefits of Nile water utilization in irrigation and hydroelectric power generation stand at about US$7 billion to US$11 billion. The economic value of cooperation, taking the status quo and full cooperation scenarios into account, was also compared (Table A4.1). Table A4.1 shows that the economic value of cooperation is US$4.943 billion per year.

Application of a real options approach to the dam development in Blue Nile Basin clearly demonstrated the benefits of a system- or basin-wide cooperative dam planning approach as compared to designing and building dams in a piecemeal fashion without careful consideration of system-wide consequences (Jeuland and Whittington 2014). Jeuland and Whittington (2014) defined 350 unique planning alternatives based on (a) configurations of the five dams for which pre-feasibilities have been completed, namely Karadobi, Beko Abo, Mabil, Mendaya, and Border; (b) sequencing of building of the five dams; (c) slower or faster timing of successions of the projects; (d) size of the dams; and (e) two

TABLE A4.1. The Economic Value of Cooperation: Status Quo versus Full Cooperation

Riparian country	Gross economic benefit	
	Status Quo	Full Cooperation
Ethiopia	50	3,010
Sudan	723	513
Egypt	3,204	4,313
Others	186	1,272
Total	4,164	9,107
Economic Value of Cooperation (US$ billion, annually)	4,943	

Source: Whittington et al. 2005.
Note: The status quo scenario assumes that proposed infrastructure is not built and that water is allocated to individual riparian countries in approximately the current allocation pattern.

operational rules (that is, hydropower-based rule and downstream coordination rule. The hydropower-based rule focuses on the optimization of energy generation ignoring the effect on downstream riparians. In contrast downstream coordination operating rule sets a trigger to force minimum releases from Blue Nile dams if storage in the downstream High Aswan Dam in Egypt drops below 60 billion m^3. Each of the 350 unique planning alternatives were evaluated for seven hydrological run-off scenarios and three assumptions about water withdrawals by Egypt, Sudan, and Ethiopia.

The results of these analyses provide important insights into the economics of infrastructure investments on the Blue Nile. The best alternatives, which include three dams, do not include the Renaissance Dam, which is currently under development. The results consistently show that the Renaissance Dam has significant disadvantages across all model conditions relative to the best-performing three-dam alternatives. Assuming that the Renaissance Dam will be completed, a two-dam combination with Beko Abo as a second project is likely the best alternative for a Blue Nile cascade. The lost expected value for the best two-dam alternative that includes the Renaissance Dam, relative to the more economically attractive three-dam cascade with Beko Abo, Mendaya, and a smaller dam at the border, ranges from US$3 billion to US$7 billion across model conditions.

3. Lesotho Highlands Water Project: Bilateral Cooperation on Orange-Senqu River Basin

The Lesotho Highlands Water Project is a project developed in partnership between the Governments of Lesotho and South Africa comprising a system of several large dams and tunnels. In Lesotho, it involves the rivers Malibamatso, Matsoku, Senqunyane, and Senqu. These rivers are part of the Orange-Senqu River Basin, which covers an area of about 900,000 km^2. In South Africa, the project involves the Vaal River. This binational collaborative project exemplifies the economic benefits of cooperation on international waters and is Africa's largest water transfer scheme (Lawrence et al. 2010).

Lesotho is a small, landlocked country completely surrounded by South Africa and covering about 30,300 km^2. Two-thirds of its land area comprises mountains and small valleys, with less than 10 percent suitable for crop cultivation. Water is the only natural resource in relative abundance in Lesotho, providing a unique development opportunity. The energy resources of Lesotho were extremely limited and the country was reliant on South Africa for nearly 90 percent of its commercial energy supply. Primary fuel needs were met by vegetation and agricultural residues and supplemented by imported wood, coal, petroleum, and electricity. The development of hydropower was the only promising possibility to secure the energy needs of the country.

South Africa is a chronically water-scarce country due to the poor rainfall received over much of the surface area of the country and high evaporation rates. The problem becomes worse on the western Atlantic Ocean coast, particularly in the industrial heartland of the Gauteng region, which accounts for almost 60 percent of the national gross domestic product (GDP) and 42 percent of the urban population. In this region, the water supply was not sufficient to meet the large and growing demand and water had to be imported to bridge the growing supply-demand gap. The relative abundance of water in Lesotho and the enormous water demands in South Africa created the impetus for cooperation.

The Lesotho Highland Water Project was initiated to (a) provide revenue to Lesotho from water transfers, (b) generate hydropower for Lesotho, (c) provide the opportunity to undertake ancillary developments in both countries, and (d) promote the general development of the remote and underdeveloped mountain regions of Lesotho.

Lesotho and South Africa recognized that there are real benefits to cooperation and explicitly defined the mechanisms for sharing the cooperation benefits from joint development in a mutually agreed treaty. The treaty covers the rights and obligations of each party and stipulates the quantities of water to be delivered, the cost-sharing provisions, and the scope and calculation of payments for the water. It also sets forth the principles for financing, constructing, operating, and maintaining the system (Food and Agriculture Organization 1997). The key provisions of the treaty include the following:

- South Africa is responsible for all costs of the Lesotho Highland Water Project related to the transfer of water, including construction, O&M, and social and environmental mitigation measures. Lesotho is responsible for any hydropower costs or ancillary development.
- South Africa will pay Lesotho royalties for water transferred.
- Lesotho will receive all hydroelectric power generated by the project.
- The net benefit will be shared as follows: 56 percent to Lesotho and 44 percent to South Africa.
- Each country will be allowed the opportunity to undertake ancillary developments, such as irrigation, domestic water supply, hydroelectric power, tourism, fisheries, and so on.

Ex post CBA of the treaty revealed positive net present values from the entire project for both Lesotho and South Africa. Lesotho received royalties, hydropower benefits, southern Africa Customs Union receipts, taxes, and economic multiplier benefits, while South Africa gained the consumer surplus and bulk sale benefits of the additional water and other indirect multiplier benefits.

Revenues from the joint project have had a substantial impact on the economy of Lesotho, contributing almost 5 percent to GDP growth. The GDP growth rate was estimated to be 6.2 percent, of which 4.8 percent growth was associated with project investments. Annual energy production has adequately met domestic needs and generated export revenues, and the economy has undergone a fundamental transformation due to an increase in foreign direct investment and export revenues. The contribution of the primary sectors to GDP has contracted, while the contributions of the secondary sectors have increased substantially. The project also had positive spillovers into utilities and local construction and spurred growth in services such as business, information technology, hotels, and tourism. Since implementation of the project, more than 80 percent of the gross national product (GNP) is produced domestically with less dependence on South Africa. Private investment has also emerged, primarily in the manufacturing sector.

Unfortunately, the record-setting growth in GDP did not translate into sufficient job creation or an increase in household income for the rural poor, the project's most fundamental objective (Lawrence 2010; World Bank 2010). In other words, despite the project's favorable contribution to economic development, the impact on poverty reduction has been limited, and poverty in terms of incidence, depth, and severity remained virtually unchanged. Insight from the application of the social accounting matrix (SAM) revealed the underlying reasons for the lack of a significant impact on poverty. The SAM results indicate that while GDP growth was sustained at 6.2 percent per year for a decade, it was neither accompanied by sufficient job creation nor a significant increase in household income due to (a) slow growth or a decline in the primary sector, which supports the bulk of the rural poor; (b) excessively capital-intensive growth; and (c) the fact that most of the jobs created were in manufacturing or in urban areas (World Bank 2005).

From the outset it was well understood that the project would contribute to economic growth, but not significantly to employment or to developing rural livelihoods (World Bank 2005). Thus, the Government of Lesotho established a dedicated fund to channel 75 percent of the revenues generated toward rural development. However, despite some initial success, the fund suffered from a number of weaknesses (World Bank 2010).

In summary, the project demonstrated that there can be benefits to cooperation and that these can be explicitly determined and shared between parties. However, translating the cooperative benefits into poverty reduction outcomes presents a challenge.

4. Senegal Basin

The Senegal River Basin covers a total area of approximately 300,000 km^2, with 11 percent of the area in Guinea, 53 percent in Mali, 26 percent in Mauritania, and 10 percent in Senegal.

Beginning in the late 1960s, the riparian countries realized that much could be achieved by developing the Senegal River Basin. However, inter-annual variability in the Senegal River hampered development opportunities, particularly in the area of agricultural development. The Senegal River flow could vary sixfold between wet and dry years, which increased the risks of both flood damage and drought. The effect of drought is particularly perilous for recession agriculture and fishing along the flooded banks of the Senegal River, whereas the arable land that could be effectively farmed after a flood could range from 15,000 hectares to 300,000 hectares depending on the size and timing of the flood. The flood plain also provided opportunities for fisheries production, with as many as 10,000 fishers catching 30,000 metric tons annually. During low-discharge periods, however, increased saltwater intrusion into coastal areas was common (Yu 2008).

This economic imperative motivated the riparian countries to jointly develop infrastructure on the Senegal River, which was preceded by the establishment of the Senegal River Basin Organization in 1972, comprising Mali, Mauritania, and Senegal. By controlling the flows along the river, the three riparian countries aimed to develop large areas of land for agriculture and generate hydroelectricity to solve the problem of a low supply and high cost of electricity in the region. Moreover, these structures would maintain a sufficient flow depth in the rivers to make navigation to the Atlantic Ocean possible. By 1987, two reservoirs—the Diama and Manantali Dams—were developed to prevent saltwater intrusion, generate power, expand irrigated agriculture, and enhance navigability.

The joint construction of the dams involved resolution of several issues related to ownership of the infrastructure, cost allocation for civil works, financing arrangements, and benefit-sharing mechanisms. These issues were addressed by signing conventions related to the legal status and financing mechanism of the jointly owned structures. The agreed conventions specified that (a) all structures are the joint, indivisible property of the member states throughout their life-span; (b) each co-owner state has an individual right to an indivisible share and a collective right to the use and administration of the joint property; (c) the investment costs and operating expenses are distributed between the co-owner states on the basis of benefits each co-owner draws from exploitation of the structures; and

(d) each co-owner state guarantees the repayment of loans extended for the construction of the structures.

Cooperative development of the Senegal River required rigorous quantification of the economic benefits and costs and an agreed framework for allocating the benefits and costs among all member states. In particular, a methodology was needed to allocate the joint costs across services (hydropower, navigation, and irrigation) and member states. Eventually, the member states adopted the adjusted separable costs-remaining benefit (SCRB) method. Following this method, 22.37 percent of the total costs is allocated to the irrigation service, 30.78 percent to the energy service, and 46.85 percent to the navigation service. The final allocation of costs across the member states was based on the estimated and agreed proportions of the project services used by each state, which is the area of land that could be developed for irrigation in each nation, the projected river transport use in terms of volume and distance, and the quantity of power consumed by potential consumers in each nation.

The final cost share among countries was 35.3 percent for Mali, 22.6 percent for Mauritania, and 42.1 percent for Senegal. With regard to benefits, Mauritania would receive 31 percent of the total irrigation potential, 15 percent of the energy generation, and 12 percent of the navigation benefits; Mali would receive 52 percent of the energy generated and most of the navigation benefits; and finally, Senegal would receive about 58 percent of the irrigated land and 33 percent of the energy generated. However, these envisioned economic benefits have not been fully realized as set forth in the plan as irrigated agriculture has developed at a slower pace than anticipated. Thus far, only about 130,000 hectares of the 375,000 hectare potential have been developed. With significant recent additional investments, energy production has begun to meet original expectations; however, 30 years after it was identified, navigation still does not exist in the valley.

Reassessment of the original benefit- and cost-quantification and benefit-sharing arrangements revealed some caveats. The assessment was limited to just three benefits (hydropower, irrigation, and navigation) despite the fact that the project could produce a wider range of benefits and costs beyond the direct investment costs. In addition, unexpected environmental and social costs emerged. The environmental impacts identified include alteration of the estuarine and freshwater system dynamics, the generation of invasive weeds and grasses, the disappearance of wetland areas, degradation of fish populations, a reduction of pasturelands, changes in forests, and increases in parasitic diseases. Moreover, social disruption and conflicts have occurred in the basin region (Finger and Teodoru 2003; Homer-Dixon 1998; Lahtela 2003).

To address many of these emerging challenges, a new water charter was introduced to fully realize the development potential and share the benefits of development with the broader population in the Senegal River Basin. The scope and purpose of the new water charter were broader than the previous conventions, and it embraces sectors such as fishing, domestic use, health, and the environment. The new charter also introduced the concepts of sustainability and environmental protection.

Note

1 Columbia River Treaty, Canada-U.S., September 16, 1964.

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