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The Politics of International Freshwater Resources

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Introduction

Freshwater systems offer unique opportunities for addressing key questions of international conflict and cooperation. In practical terms, freshwater is one of humanity's most valuable and vulnerable natural resources. Surface waters, such as rivers and lakes, which are the most accessible sources for human consumption and use, constitute only a tiny fraction of the water on earth. The world's $35 \times 10^6 \text{ km}^3$ of freshwater constitutes only 2.5% of its total water ($1,365 \times 10^6 \text{ km}^3$). Only 0.3% of all freshwater is stored in rivers and lakes; 30.8% is stored in groundwater, and 68.9% in glaciers and permanent snow cover (most of it in inaccessible places, such as Antarctica). Around $42,000 \text{ km}^3$ of the approximately $110,000 \text{ km}^3$ of precipitation over land is river runoff (UNEP, at www.unep.org/dewa/assessments/ecosystems/water/vitalwater/freshwater.htm).

While the *global* freshwater supply is constant, increasing population density, economic activity, and unsustainable water management practices have led to over-exploitation of many of the more easily accessible freshwater resources at *local and regional* levels. Many of these resources cross international boundaries. Notably, more than 260 river basins covering around 45% of the earth's continental landmasses span two or more countries. Some areas of the world suffer primarily from acute water scarcity. Others suffer more from pollution. All of these problems have direct implications for human health, ecosystems, and socioeconomic development more generally (Gleick et al. 2006).

Escaping the Malthusian trap of constant supply and increasing demand is feasible if societies can put in place appropriate institutions and technologies (Dinar et al. 2007). Social science research has contributed in important ways to identifying sources of conflict and cooperation as well as water management options and institutional solutions that can facilitate sustainable international water management.

From an academic perspective, international freshwater systems are interesting objects of study because they lend themselves to systematic comparison. They are shared by relatively small groups of countries (around two to ten). The natural resource and the problems associated with it are, in most cases, clearly circumscribed, and there are many such freshwater systems around the globe that can be compared. The large literature on international water conflict and cooperation, to which political scientists and researchers from related disciplines have been contributing to a growing degree, is testimony to the importance of the issue.

We review key contributions to this literature, beginning with a general description of important issues and questions in international water management, and then working our way through the main questions addressed by the existing literature:

- 1 Is there sufficient evidence for the "water wars" claim, arguably the most sensational hypothesis in this literature? That is, do water-related factors influence the

probability of armed conflict? Or, if the water wars claim turns out to be exaggerated, what are the factors that increase (or reduce) the probability of water-related conflicts short of war?

- 2 What are the determinants of international river basin cooperation, in terms of policy output and policy outcome or impact?
- 3 How are cooperative efforts to solve river basin conflicts designed? What are the determinants of particular institutional design principles?
- 4 How can we assess whether international water management efforts are successful in terms of solving problems that motivate cooperation?
- 5 To what extent does the literature offer insights into institutional design options that are effective in terms of problem solving?

A literature review of moderate length requires inconvenient tradeoffs. We could have covered a very large number of publications from different disciplines of the social sciences and humanities. But this would have come at the expense of specificity. We opted for greater depth rather than maximum scope. As a result, many (but hopefully not too many) interesting publications must go unnamed. Moreover, we focus largely on contributions by political scientists, leaving out a large body of international water management literature produced by scholars in law, economics, anthropology, and related disciplines.

The Issue

The obstacles to sustainable management of *domestic* water resources are often formidable. But water allocation, pollution, and other problems on *international* rivers appear to be particularly daunting. The sovereignty of states, the key organizing principle in international politics, means that there is no political unit above and beyond the state that could impose solutions (e.g. allocation rules, prohibitions, pollution thresholds) on unwilling nations.

Legal norms, through which victims of water scarcity, water pollution, or other water-related problems might seek remedy, are generally weaker at the international than the domestic level (e.g. Conca 2006; Dinar 2006). The same holds for international bodies that are authorized to adjudicate in cases of conflict (e.g. the International Court of Justice). In regard to international waters, basic principles of international law exist, but in practice they provide only very general guidance for resolving specific transboundary water problems (e.g. Marty 1997; Salman and Boisson-de-Chazournes 1998). Marty (1997:17) notes that "the golden rule of water law [. . .] says that there is no golden rule." In other words, institutional structures for reconciling conflicting interests at the international level tend to be less sophisticated and less resilient to opportunistic behavior than their domestic counterparts. Solutions need to be achieved through negotiations among riparian countries under conditions that, in many parts of the world, resemble a self-help system.

Motivated by the practical importance of the issue (see, e.g., Gleick 1998), research on international freshwater issues carried out by natural scientists and engineers has produced an enormous body of literature. Although many of these contributions are very important, they cannot provide conclusive explanations of success and failure in international freshwater management. New technology is obviously important for escaping the Malthusian predicament; but in most cases, the most serious obstacles to successful international freshwater management are not primarily technical, but rather political and economic. Answers to when and why international water management efforts succeed or fail must then, to a large extent, be found through the study of conflict and cooperation, which are social rather than technological phenomena.

The UN Food and Agricultural Organization (FAO) has counted several thousand treaties on international water issues since the eighth century. Wolf (1997; for updates see the Transboundary Freshwater Disputes Database (TFDD)) has identified around 450 international treaties on non-navigational issues of water management, flood control, hydroelectric projects, and allocations for consumptive and nonconsumptive uses of international rivers since 1945. These "real world experiments" offer great opportunities for observational studies that seek to test theory-derived explanations of water-related conflict and cooperation. Though the criteria for measuring performance (or effectiveness) of cooperative efforts remain disputed (see below), a large number of case studies on individual international rivers and lake management indicate that some institutions work quite well and problems are in fact solved, whereas others appear to fail (e.g., Le Marquand 1977; Marty 1997; Dinar and Dinar 2003).

Until the end of the 1990s the literature on international water management was mainly of the "lessons learned," prescriptive, or pure theory type (cf. Chapman 1963; United Nations 1975; Fox and Le Marquand 1978; Vlachos et al. 1986; Frey 1993; World Bank 1993; Barrett 1994; Rangeley 1994; Kilgour and Dinar 1995; Ganoulis et al. 1996; Nakayama 1997; Elhance 1999; Holtrup 1999; Shmueli 1999; Beach 2000). Recent work has focused on developing more coherent and theory-driven explanatory models. The vast majority of observational studies designed to empirically assess an explicit set of theory-based hypotheses are single case studies. However, an increasing amount of large-N research on the subject has appeared since the turn of the century. This new large-N literature is important in that it helps in assessing the external validity of many of the claims made in the qualitative case study work.

The scope of the following literature review is limited primarily to two areas. First, we put somewhat more emphasis on large-N comparisons than on qualitative case studies because the movement towards large-N studies has been the most visible innovation in this literature in recent years. Moreover, reviews by Dinar et al. (2007), Dinar and Dinar (2003), Bernauer (2002), and Marty (1997) have already summarized the findings from the qualitative case studies literature quite extensively. Second, we concentrate on international rivers because they have attracted far more attention in the political science literature than international lakes or groundwater resources.

Water-Related Conflict

The literature on international water issues reflects the major themes that also appear in other areas of the International Relations literature. One part of the water literature deals with the causes of conflict at varying scales of intensity, the most radical version being the claim that water problems can be a cause of armed conflict. We discuss this area of research at this point. The next section looks at studies focusing on the causes of international cooperation. Some recent work suggests that conflict and cooperation should be studied jointly rather than separately (Zawahri and Gerlak 2009:218) because both might occur simultaneously in the same river basin. Nonetheless, because only very few authors have so far followed this path (examples include Wolf et al. 2003b; Brochmann and Hensel 2009; Warner and van Buuren 2009; Zawahri 2009) we discuss studies on conflict and cooperation separately.

Many case studies analyze the conditions that lead to water-related conflict in individual river basins. For example, Kibaroglu (2002) examines the Euphrates-Tigris basin, Lowi (1993) and Wolf (1995) the Jordan River, and Howell and Allan (1994) the Nile. Other work, for example by Wolf (2006; 2008), Marty (2001), Allan (2001), Amery and Wolf (2000), and Blatter and Ingram (2001), is comparative and uses sets of case studies. An extensive survey by Dinar and Dinar (2003; see also Dinar et al.

2007) summarizes findings from many of these case studies. We agree with them that these studies are very valuable. Many of them offer highly interesting accounts of economic, social, political, and physical conditions that lead to the overexploitation of river systems and conflict among riparian countries. Even though there are of course always case-specific, idiosyncratic causes at work, the general picture that emerges from these studies is that conflict is more likely when:

- due to anthropogenic influences or natural processes water becomes more scarce and/or more polluted (i.e., the costs of environmental degradation are felt more strongly by politically important constituencies in riparian countries);
- an upstream-downstream setting entices the upstream country to exploit its positional power and discriminate against downstream neighbors;
- non-water conflicts among the riparian countries exacerbate water-related conflicts;
- political and economic ties among the riparian countries are weak;
- the financial, institutional, or administrative capacity of key riparian countries is poor;
- water-related international institutions in the river basin are weak.

Factors such as these account quite well for why transboundary water management problems and associated conflicts are much harder to solve in cases such as the Nile, Jordan, Euphrates, Tigris, Amur, Syr Darya, or Mekong than in cases such as the Great Lakes and Rio Grande in North America and the Rhine, Danube, and Rhone in Europe.

When the Cold War ended many policy makers became more aware of potential nonmilitary threats to international peace and security. In this context, and in view of the UN's 1992 Rio summit on sustainable development, water issues began to attract considerable public attention. Statements such as "The wars of the next century will be over water" (Ismail Serageldin, former vice president for environmentally sustainable development of the World Bank, in a 1995 press release) started to make headlines (see also Cooley 1984; Bulloch and Darwish 1993). Some academics jumped on the bandwagon. Hughes Butts (1997), for example, states that "History is replete with examples of violent conflict over water, from competition for desert oases and water holes to the battles between the Mesopotamian cities of Lagash and Umma in 4500 B.C., to the fighting between Syria and Israel over Syria's attempts to appropriate the headwaters of the Jordan River in the 1960s." However, most of the academic community involved in case study work on international water issues were quick to recognize that such statements were hardly backed by empirical evidence. But at that point in time, there simply was no large-N data that could be used to expose the water wars claim to a serious test.

Gleick (1993), one of the pioneers in this field, identifies possible water conflict scenarios based on historical examples. He develops three categories of water-related conflict: water resources as military and political goals (Gleick 1993:84), water resource systems as instruments of war (Gleick 1993:87-8), and links between other conflicts and water developments, such as consequences of dam constructions (Gleick 1993:93). In most of Gleick's historical examples water scarcity does not appear to be at the core of the conflict but tends to figure as one of several elements of conflict. The same applies to Hughes Butts's (1997) work in this area. He contends that "water conflict is most likely when rivers are shared by multiple users and downstream users are vulnerable to decisions made by upstream states" (Hughes Butts 1997:70). But he does not offer a coherent theoretical explanation and empirical evidence for this claim. Similarly, Homer-Dixon (1994) regards depletion and pollution of fresh water supplies as a possible cause of violent conflict, but does not provide systematic empirical evidence.

One of the most important achievements of social sciences research in the international freshwater realm in recent years has been to establish large-N datasets and systematically test the water wars hypothesis. Such research started in the late 1990s (e.g., Mandel 1992 studies conflict in 14 river basins). It has materialized in two forms that can be distinguished by the type of dependent variable. The first introduces water-related factors into existing explanatory models of armed conflict. The second relies on events data that measures water-related conflicts more directly.

The first line of research initially concentrated on whether sharing an international river makes a difference in terms of increasing the probability of armed hostilities between countries. There are two reasons why sharing a river could play a role in determining a country dyad's (pair of countries') risk of experiencing interstate war, the most extreme type of conflict between states. First, upstream-downstream situations might induce conflicts related to resource scarcity (cf. Gleditsch et al. 2006). Second, due to natural processes, riverbeds can change over time. This might cause conflict if a river constitutes the border between two countries and this border becomes contested when the riverbed changes (Furlong et al. 2006). Gleditsch and his co-authors, as well as Furlong et al., call this problem "fuzzy boundaries" (Gleditsch et al. 2006; Furlong et al. 2006). Both Gleditsch et al. and Furlong et al. find empirical evidence in favor of the claim that, controlling for other determinants of war, sharing a river increases the risk of armed conflict, but they do not find robust support for the fuzzy-boundary hypothesis (Gleditsch et al. 2006:379).

The main difficulty with the work by Gleditsch, Furlong, and their co-authors is that it remains silent on whether conflicts experienced by countries that share a river were actually linked to freshwater issues. The dependent variable in these studies is the "onset of militarized interstate disputes (MID) with a minimum of one fatality," based on data from the Correlates of War project (Gleditsch et al. 2006:367). This data does not include any information on whether conflicts are directly linked to freshwater issues or merely happen to occur between river-sharing countries. The link to transboundary water issues as a cause is made through statistical inference, that is, by using geography (sharing a river) as the main explanatory variable while controlling for other determinants of armed conflict.

Arguably, sharing a river and plain geographical contiguity (having a common border) are highly correlated. In fact, most countries that have a common border share at least one river, but countries might share a river without bordering each other if the river flows through intermediary countries. Consequently, the conflict-enhancing effect of sharing a river might reduce to an artifact of contiguity. To exclude this possibility, Toset et al. (2000) explicitly take contiguity into account when examining whether sharing a river increases the probability of interstate armed conflict. They find an independent, albeit very small effect of river sharing. Moreover, contiguity has a bigger effect on the risk of interstate conflict than sharing a river. This work offers some support for the earlier results on the relationship between transboundary rivers and interstate conflict. However, the particular definition of the dependent variable can provide only very indirect evidence on whether water is actually the cause of any armed conflict observed, and genuine river-sharing effects remain very difficult to separate from simple gravity effects (geographic proximity, common border).

The "Issue Correlates of War Project" (ICOW) has produced more direct evidence on whether or not conflicts are water-related. The ICOW data captures all reported events including "evidence of contention involving official representatives of two or more nation-states" (Hensel 2005). That is, it tells us whether an official of either country in a dyad makes an explicit claim regarding the use of an international river by expressing demands concerning the quality or quantity of river water.

Hensel et al. (2006) and Brochmann and Hensel (2009) use this data to explore the causes of river claims, their aggravation (becoming militarized) and resolution,

and the success rate of negotiations over river claims. They find that water scarcity and asymmetry of capabilities in a country dyad aggravate conflict and reduce the probability of successful negotiations, whereas freshwater treaties are conducive to resolving river claims. Furthermore, greater water demand and a generally cooperative relationship between riparians are associated with successful negotiations over river claims, notably in case of current rather than future river-related concerns (Brochmann and Hensel 2009). These results are consistent with findings by Mitchell and Hensel (2007) and Hensel et al. (2008), who study the circumstances of conflict settlement agreements in more general terms (territorial, maritime, and river claims) based on the ICOW dataset. Surprisingly, recent militarized conflict appears to have a positive effect on the probability of ending a river claim. Moreover, the value of a river to a country (navigational or irrigational value, presence of hydroelectric projects, river passes by major population centers) is positively correlated with attempts at peacefully settling a river claim (Hensel et al. 2006). But it also increases the likelihood of militarized settlement attempts (Hensel et al. 2008:137).

As of mid 2009, the ICOW river data was still being collected and existing studies were based on data for the Americas, northern and western Europe, and the Middle East. Whether the early findings reported above are supported within a global dataset remains to be seen. In any event, the work by Brochmann, Hensel, Mitchell, and coauthors is very insightful in that it uses a very sophisticated dependent variable, systematically relates it to a wide range of determinants of conflict, and considers conflict and cooperation jointly.

The second line of research, as mentioned above, concentrates on events data that was collected (coded) by Wolf et al. (2005) in the Transboundary Freshwater Disputes Database (TFDD) project. This data captures "reported events of either conflict or cooperation between nations over water resources during the last 50 years" (Wolf et al. 2003b:29). Yoffe et al. (2003; 2004), Wolf et al. (2003a; 2000b) and other authors have used this data as a dependent variable. One of their main goals has been to identify "basins at risk," i.e., international river basins likely to experience political stress in the near future (Wolf et al. 2003b).

The conclusions of this work are (1) that cooperative events by far outweigh conflictive events over shared water, and (2) that "The likelihood and intensity of a dispute rises as the rate of change within a basin exceeds the institutional capacity to absorb that change" (Wolf et al. 2003b:51; see also Wolf et al. 2005). More specifically, the likelihood and intensity of disputes rise when population density is high, income is low, overall relations between countries are unfriendly, there are politically active minority groups, large dams or other water development projects are planned, and there are limited or no freshwater treaties. Yoffe et al. (2004) find, furthermore, that, at least in the Middle East, South Asia, and Southern Africa, both water conflict and cooperation at the international level correspond to similar events at the domestic level. Giordano (2002) arrives at similar results, concluding that "water-related events at the national level are related to both water and nonwater events at the international scale" (Giordano 2002:79). According to this work, the majority of basins at risk are located in southern Asia and central and southern Africa. They include the following freshwater systems: Ganges-Brahmaputra, Han, Incomati, Kunene, Kura-Araks, Lake Chad, La Plata, Lempa, Limpopo, Mekong, Ob (Ertis), Okavango, Orange, Salween, Senegal, Tumen, and Zambezi.

The *ex post* evidence discussed so far disconfirms the water wars hypothesis. However, as noted by Wolf (1998), this result should not mislead us into thinking that conflicts over freshwater are *de facto* irrelevant: "while water wars may be a myth, the connection between water and political stability certainly is not. The lack of a clean freshwater supply clearly does lead to instability which, in turn, can create an environment more conducive to political or even military conflict." The nature of these relationships

and the extent to which they are present, however, appear to vary considerably by country and region. This result highlights not only the intricacies of hydro-political dynamics and their variation across geographic space, but also the need to consider the often distinct historical and political conditions within a region or basin if water relations are to be well understood."

In other words, international water war predictions turn out to be largely political rhetoric. But serious non-militarized international disputes over water issues exist and may well increase in frequency in future, particularly in areas hard hit by climate change and population growth. Water scarcity and pollution are not primary causes of domestic wars/conflicts. Rather, societies that are vulnerable in multiple ways (e.g., due to ethnic tensions, poverty, weak institutions, a history of violent conflict, resource (water) scarcity) can be thrown into violent conflicts through triggers not related to water. Such conflict, in turn, can exacerbate preexisting resource scarcity problems. Darfur is a good example.

Diagnostic research has made considerable progress in identifying key drivers of international river basin conflict. These results facilitate "risk profiling." Events data is particularly useful in this respect. A corollary of this research is that well-designed international river basin institutions may not prevent conflict altogether, but they impose "bounded competition"; i.e., they constrain processes of escalation and thus help in mitigating conflict. This leads us to research on water-related cooperation.

Water-Related Cooperation

Cooperation cannot be fully explained by simply focusing on the inverse values of explanatory variables that account for conflict, even though many case studies and some large-N data discussed in the previous section offer important insights also into the causes of cooperation. As in the preceding section we begin with a review of key results from the comparative case studies literature and then move to a review of recent large-N work.

The pioneer in this area of research is Le Marquand (1977). Using a unified analytical framework he studied the Colorado salinity issue, the High Ross Dam controversy, the development of the Columbia River, and Rhine water quality problems. His list of explanatory variables is rather long and only loosely connected to political science and economic theories. Similarly, the empirical testing of propositions is, from a methodological viewpoint, rather cursory, but still, the conclusions rest on more systematic empirical analysis than conclusions offered by previous research.

Le Marquand's findings are: (1) Riparians are better able to solve their problem if they have common perceptions of the problem, if win-win solutions are created, and if national leadership is committed to solving the problem. (2) Economic optimization is less important for cooperation than non-economic factors. (3) Cooperation is more successful when social concerns and objectives are evaluated and defined in the planning process, and when consequences and costs of alternative strategies are assessed in detail. (4) Cooperation is more successful when agreements are flexible enough to adapt to changing values, technologies, and market conditions. (5) Reciprocal interests in cooperation are most conducive to problem solving, whereas upstream-downstream problems are the most difficult ones to deal with. Third parties, such as international organizations and donor countries, can be instrumental in overcoming the latter type of problems.

Subsequent comparative case study research has by and large confirmed these conclusions, though it has also produced a lot of additional insights (cf. Wolf 1997; 1998; 2007). Durth (1996) and Marty (2001), for example, have revisited the hypothesis that cooperation is less likely in upstream-downstream situations than in situations

characterized by more symmetrically distributed environmental damages. Their and other authors' work shows that even under the more adverse upstream-downstream condition cooperation is still possible if specific socioeconomic conditions are present and particular policy tools are applied. Waterbury (1997:280) indeed notes that "International relations theory, as well as a good deal of economic theory, would warn us of the difficulties of achieving cooperative solutions to multi-player games in which the actors are sovereign and the pay-offs to cooperation asymmetrical. Asymmetrical rewards always characterize the potential outcomes of cooperation in international river basins. [. . .] those with the least to gain will retain veto power over cooperative solutions. They must be compensated by those who stand to gain the most, and it is no easy task to arrive at compensatory schemes when the beneficiaries of cooperation are not sure of what they will gain nor the losers of the extent of their potential losses. The indifferent may prefer the familiarity of the status quo to the uncertainties of binding cooperation."

Durth (1996) offers a very systematic argument on when and why riparian countries are likely to overcome upstream-downstream asymmetries and engage in cooperation. His principal hypothesis is that such problems are easier to solve when riparian countries are more "integrated," i.e., when the density of political, economic, and social ties among countries is greater. He claims that efficient cooperation is more likely in more integrated settings because: (1) compensation of upstream countries, which is needed to motivate the latter to cooperate, is easier; (2) integrated settings enable riparian countries to make more credible commitments to one another because they interact in a larger number of policy areas; (3) information is likely to be more complete and evenly distributed; (4) notions of equity or justice are more likely to be congruent; (5) unequal bargaining leverage is mitigated by transboundary institutions, which also allow for more clearly defined, transferable property rights and lower transaction costs; and (6) opportunities for nongovernmental (including private) actors to influence outcomes are greater. Using descriptive statistics for a sample of 127 agreements (involving a total of 35 countries plus the EU) from 1852 to 1992, Durth concludes that the evidence, especially for upstream-downstream cases, confirms his principal hypothesis.

In contrast to Durth, Marty (2001) finds that concerns over equity (or fairness) may be as intense in more integrated as in less integrated settings; moreover, he shows that such concerns can arise and stall international efforts even when there is no substantial cost-benefit asymmetry in the material (economic) sense. This finding receives support from a book by Blatter and Ingram (2001; see also Ingram and Blatter 2000), in which the authors explore the range of subjective meanings and values that water has in different social contexts. They claim that, in many places, water is essential for the existence and identity of social actors and serves as a focal point for community building. They postulate that when riparian actors' connection to water is "essentialist" or even fundamentalist, policy processes "cannot be captured by game theory based on the assumption of strategic action. Neither perceived threats to national security nor fundamental value conflicts allow for 'rational' solutions like side payments or package-deals" (Blatter and Ingram 2001). Blatter and Ingram do not systematically test this hypothesis. The empirical evidence produced by Durth and Marty suggests, however, that fairness concerns of riparians that are unrelated to material (economic) costs or benefits can indeed complicate international efforts to resolve upstream-downstream problems through compensation, issue linkage, or other policy instruments.

Marty concludes that joint research, joint development and implementation of solutions, jointly owned infrastructure, and third party input of know-how can help in overcoming obstacles to cooperation. Another of his important findings is that cost-benefit asymmetries often exist at the local level, rather than at the national

level, in riparian countries. One of the key questions, then, concerns the conditions under which local interest groups are able to engage their respective national governments in international negotiations on the issue. The analysis of the Alpine Rhine flood control, the Colorado salinity, and the Tijuana sanitation cases demonstrates that transforming an issue from an inter-local to an international problem can foster progress in two ways: first, a wider set of possible issue linkages for changing the incentives of uncooperative actors is available at the international level; second, national governments' capacity to fund projects is bigger. The Colorado case illustrates both these mechanisms. Hardest to solve are, in Marty's view, problems plagued by a "double asymmetry," i.e., strong differences of interest between riparian countries and, within those countries, between local actors and their national governments. The Tijuana case comes closest to the "double trouble" situation, followed by the Alpine Rhine case in some phases. In contrast to Durth, Marty finds that compensation of the more unwilling participants – by either national governments, other riparians, or third parties (e.g., non-riparian countries or international financial institutions such as the World Bank) – is crucial to cooperation in many cases.

Recent case studies challenge the realist view that cooperation is more likely when the downstream country is the hegemon and less likely if the upstream country is the strongest riparian (Daoudy 2009; Dinar 2009). Dinar argues that rather than power in a realist sense (military and economic capabilities), "issue specific structural power in asymmetric contexts highlights how otherwise weaker parties are able to extract concessions from more powerful states" (Dinar 2009:330). Basing his argument on in-depth study of several treaties over international river basins with an upstream and others with a downstream hegemon, he concludes that issue linkage, reciprocity, and side-payments are key to achieving collaborative solutions in asymmetric contexts. Similarly, Daoudy (2009:382) concludes that "power asymmetries have paradoxically favored upstream/downstream interactions towards bilateral if not basin-wide agreements" in negotiations on the Euphrates and Tigris basin. Both authors claim that a weaker downstream state may constrain the basin-dominant riparian's alternatives by acting in the latter's interests and thus invert situations of power asymmetries.

Using a "hydropolitical" framework of analysis proposed by Dinar (2000), Kempkey et al. (2009) analyze treaty formation in the La Plata river basin in terms of "(1) power relations, interdependencies, and regional politics; (2) protracted conflicts and domestic politics, and; (3) likely benefits from cooperation" (Kempkey et al. 2009:256). Comparing the successful negotiation in the La Plata case with the situation in other transboundary basins (Aral Sea, Nile), the authors conclude that the following features of negotiation in the La Plata basin might explain their relative success: (1) no external mediation, which sometimes increases transaction costs (time, lack of breakthrough, (2) establishment of institutions as a very first step, (3) focus on development projects rather than water allocation, and (4) vague language in terms of the form of cooperation agreed upon (Kempkey et al. 2009:274–5).

Large-N datasets developed since the late 1990s have allowed researchers to explore the extent to which some important insights from case studies on individual rivers are relevant to a larger number of international water systems. As noted in the section on water-related conflicts, events data collected by Wolf et al. (Wolf 1998; Wolf et al. 2003a; 2003b) demonstrates that cooperative events outnumber conflictive events by far. This evidence is very much in line with many case studies, including those on basins with particularly high conflict potential, such as the Nile and the Euphrates/Tigris (e.g. Stroh 2004; Stucki 2005).

In view of such compelling evidence, supporters of the water war hypothesis have retreated to the claim that water-related wars may still occur in some river basins at some point in the future (a claim that is impossible to test), or they have noted that water-related conflicts take place at the domestic rather than the international level

(cf. Homer-Dixon 1994:19). Stucki (2005) asks "why, in the face of a clear epistemic consensus in academia in favour of the 'water peace' hypothesis, the public discourse retains its belief in the threat of interstate conflict over water" (2005:5). He concludes that there are two main reasons. First, the water peace hypothesis is more complex and thus more difficult to communicate than the water war hypothesis (2005:67). Second, water war is likely to gain more attention than water peace, which is why the media can gain more by reporting on the former (2005:67). This latter point may also be a source of bias in the academic literature, where case studies cluster strongly on the "hottest basins," such as the Jordan, the Nile, and other particularly conflictual cases (see also Wolf 2003b:32).

While the large-N data on water events and treaties tells us that cooperation is the rule rather than the exception, inferential statistical research on the causes of cooperation is still at an early stage. Some of this research focuses on international river treaties as the dependent variable. Other research looks at the flipside of the conflict hypotheses discussed in the section "Water-Related Conflict" above and combines events and treaty data.

Using data from the Transboundary Freshwater Disputes Database (TFDD) project, Espey and Towfique (2004) estimate the probability that two countries sharing a river will conclude a water-related bilateral treaty. The sample includes 118 bilateral water treaties from 1944 to 1998 and also covers 157 international river basins where no bilateral treaty exists. The biggest effects emanate from geography. The larger a river basin as a share of the country's territory, the more likely is this country to join a bilateral agreement. The opposite effect dominates if a country controls a larger share of the basin than the other country in a dyad. Whereas income and income differences between countries have no significant effect, trade ties have a small, positive effect on the probability of treaty formation. Similarities in culture, government, and language have only weak effects.

Song and Whittington (2004) concentrate on international river treaty formation as well, using TFDD and data from the Food and Agriculture Organization of the United Nations (FAOLEX). Their sample includes 200 international rivers and 122 treaties since 1950. The explanatory variables pertain to geography (location on particular continents, river geography), types of civilizations, and similarities/differences in economic size, income, and population. The authors observe more treaty formation in basins with states that differ more in terms of their GDP and population size. Basins with multiple "civilizations" are no less likely to have treaties, though rivers in the "Western civilization" are more likely to have treaties. Upstream-downstream geography makes treaty formation less likely.

A somewhat similar study by Tir and Ackerman (2009) analyzes the conditions under which riparian countries enter into treaties dealing with water quantity and quality. They find that both joint democracy and riparian interdependence increase the likelihood of treaty formation. This study is very sophisticated in illuminating the effects of country characteristics on cooperation. However, it aggregates the data up to the country dyad level (rather than the river basin country dyad). This prevents the analysis of river basin-specific effects. In contrast to Tir and Ackermann (2009), Gerlak and Grant (2009) use the river basin (implicitly defined by its riparian countries) as the unit of analysis. They examine 63 institutional arrangements in 245 international river basins between 1975 and 2000. They find that institutional arrangements are more likely to be established in basins shared by multiple countries (more than two) and between predominantly democratic riparians with asymmetrical military capabilities (Gerlak and Grant 2009:29). The depth of institutional arrangement is best explained by existing formalized organizational structures and strong economic capabilities.

Brochmann and Gleditsch (2006b) examine whether sharing a river induces cooperation between states. They find that country dyads sharing a river basin cooperate

more than other dyads. Cooperation is measured by joint membership in international organizations and bilateral trade volume. Joint membership in international organizations and trade are obviously rather crude proxies for cooperation and do not inform us whether cooperation is related to shared rivers. In another paper, Brochmann and Gleditsch (2006a) refine their concept of cooperation by analyzing the determinants of freshwater treaty participation. They focus on the relationship between water events (using data from the TFDD) and the signing of freshwater treaties to study whether previous water events lead to treaty signing and whether dyads that have signed a freshwater treaty are more prone to engage in cooperative events after the signing of a freshwater treaty. The empirical results show that water-related events stimulate the signing of freshwater treaties and that the number of water-related events between countries increases once a treaty has been signed. Surprisingly, this effect appears to be independent of whether the events are of a cooperative or conflictive nature.

Whereas the large majority of studies concentrate on policy output (treaties, events) a few authors have also addressed policy outcomes, i.e. the factors that determine how much countries in international river basins harm each other environmentally. Sigman (2001; 2004) is among the very few scholars who have looked at the effect of trade relations on externalities in international water systems (measured by organic pollution in this study). She argues and finds some evidence that states do free-ride on their neighbors. But she also finds that trade promotes environmental cooperation among states in several ways: by providing opportunities for implicit side-payments, thus allowing for linkages between environmental and trade concessions; by providing direct leverage over other countries' production; and by installing a perception of shared goals.

Similarly, Bernauer and Kuhn (2009) explore whether there is an environmental version of the Kantian peace in international river basins. That is, they examine whether democracies that trade and are bound by international treaties are less likely to harm each other environmentally. To that end, they focus on five factors that are likely to help in reducing beggar-thy-neighbor behavior in terms of transboundary pollution: democracy, supranational institutions, trade relations, stringency of domestic environmental policy, and international environmental commitment. Their dataset includes observations on upstream-downstream water pollution in Europe from 1970 to 2003. The observed effects of the five variables differ across forms of pollution and definitions of beggar-thy-neighbor behavior. Some of the explanatory variables contribute to reducing beggar-thy-neighbor behavior. Hence there is some empirical support for the environmental Kantian argument. The authors conclude, however, that "state behavior in this area remains characterized by free-riding incentives; the forces of democracy, trade, and national and international regulation and institutions do not easily produce decent international behavior." By and large, this finding lines up well with previous case study work. The latter demonstrates that cleaning up transboundary upstream-downstream pollution is usually a long and cumbersome process, even among rich and democratic countries. Examples include the Rhine, Oder, Elbe, Colorado, Rhone and many other transboundary rivers in Europe and North America.

Design Principles of International Freshwater Management Institutions

As suggested by studies on transboundary water pollution (see above), "real" progress in sustainably managing international rivers requires more than the mere existence of treaties, international organizations, or other political events or structures. Not surprisingly then, policy makers are often interested primarily in how cooperative arrangements should be designed so that they have a positive (problem-solving) effect

on riparian behavior and the environment. We start by discussing some findings that have emerged from qualitative case studies and then move to recent large-N research on institutional design in international water cooperation.

Marty's (2001) book contains one of the most extensive analysis of institutional design features and their effect on success/failure in international river management. The finding likely to spark the most debate among policy makers and ecologists is Marty's conclusion that integrated river basin management, though desirable in ecological terms, has in practice failed. He argues that international river basin institutions that focus on a small number of core issues and detailed and operational regulations tend to be more effective. This conclusion is vulnerable to criticism because it may suffer from selection bias: all cases studied by Marty are cases of specific (functional) river management. His claim would have been more defensible had he also explicitly studied attempts at integrated river management. The available evidence in fact suggests that many if not most attempts at integrated river management have failed (e.g., Gambia River Development Agency, Niger Basin Authority, Lake Chad Basin Commission, Kagera Basin Organization, Zambezi Action Plan; see Lee and Dinar 1995; Dinar and Dinar 2003; Dinar et al. 2007). Though the population of integrated international river management efforts remains unknown, it appears that failure is most common in sub-Saharan Africa. A more sophisticated analysis of this proposition would need to take into account the level of development of riparian countries, their geographic region, political stability, and other variables.

Other design features that Marty (2001) and other authors (e.g., Dinar and Dinar 2003) associate with successful river management include: "feasibility," i.e. match between objectives and available resources and know-how; "flexibility," i.e. adaptive capacity of cooperative arrangements in view of changing interests of riparians and changing scientific knowledge and environmental problems (Drieschova et al. 2008); effective organizational structures, notably well-run professional international river commissions (Zawahri 2009) and effective inter-administrative relations; close ties between international river commissions and national-level authorities; and "openness," i.e. involvement of nongovernmental stakeholders and subnational political units.

The principal difficulty with these findings is empirical, that is, to disentangle the effects of institutional features, such as specificity, from the effects of antecedent cooperation problems (e.g. upstream-downstream vs. common pool resources). Most research designs in fact operate with two assumptions that are not explicitly discussed. The first assumption is that the problem structure (e.g. upstream-downstream), as well as political efforts (negotiations among riparians) to deal with it, result in a non-empty "win set," the latter denoting the range of possible bargaining outcomes that each of the participants regards as preferable to the status quo (non-agreement). The second assumption is that policy makers can make better or worse choices within this win set. This analytical distinction is rarely congruent with the real world of politics. For example, the lack of specificity that is associated with failure of the problem-solving effort may simply be the result of riparian countries' inability to come to terms with a difficult upstream-downstream situation in the first place, rather than inability of policy makers to get the institutional design right. For example, existing studies do not clearly tell us whether or not, in the Colorado salinity case, it was the upstream-downstream problem or the attempt of some policy makers to broaden the range of issues to be tackled that produced delays in solving the problem.

Though very narrow in terms of their empirical focus, Verweij (1999; 2000a; 2000b; 2000c) and Tschanz (2001) offer interesting insights into one specific institutional design feature: voluntary vs. government-imposed pollution reduction rules. That is, both authors focus on the effect of variation over time in one regime design principle on environmental outcomes in one international river management case (Rhine).

While this approach does not permit generalizations beyond the case studied, it is commendable for its methodological rigor; it enables the authors to focus on a single and important hypothesis while holding conditions exogenous to the explanation (e.g., the nature of the environmental problem, the number and level of development of riparians, the institutional setting) constant.

Verweij and Tschanz examine whether voluntary pollution reduction measures (notably in regard to heavy metals), adopted by industry along the Rhine, have been more effective than government-imposed national and international measures (notably, the Rhine Action Program and earlier agreements). Verweij (2000a; 2000b; 2000c) claims that industry made large-scale voluntary investments in water protection and thus reduced water pollution before the imposition of reduction measures by governments and the Rhine Commission. Voluntary measures implemented by industry (in addition to domestic political measures) are, in his view, primarily responsible for the dramatic reductions in heavy metal and other pollution of the Rhine. Verweij's conclusion rests primarily on data demonstrating the industry's overcompliance with international pollution control standards. Tschanz argues that Verweij's interpretation of the available data is, in part, incorrect. Correcting for such errors, he arrives at the opposite conclusion: that government-imposed measures (national and international) have contributed more to reducing heavy metal pollution of the Rhine than voluntary measures. Further analysis will be required to determine whose conclusions are, in light of the available evidence, more accurate. Findings of this nature are interesting not only from an academic but also from a policy perspective.

A recent study by Zawahri (2009) emphasizes the important role that third party mediators can play in resolving international river disputes and establishing stable institutions. She argues that mediators can contribute by assisting in implementing (and monitoring) a treaty, coordinating riparians and the donor community and establishing an effective joint river commission. Successful mediation is illustrated by a case study on the Indus River.

Studies by Dombrowsky (2007), Dinar (2006), and Conca et al. (2006) are the first to use large-N approaches to study institutional design principles in international water management. Dombrowsky (2007) draws on a wide range of (mainly political economy) theories to study institutional design issues in international water management. The empirical analysis is based on information for several hundred international river treaties and several qualitative case studies. Dombrowsky's work is very useful because it systematically connects theoretical discussion of problem structures to institutional solutions.

She observes that international agreements exist in around 40% of all international river basins, and that international river basin organizations have been set up in 60% of the basins where an agreement exists, or around 25% of all basins. Interestingly, she notes that side-payments and issue linkages, which one would expect to be used quite frequently when unidirectional externalities in upstream-downstream settings exist, are rare. Only 9% of the 506 agreements analyzed include financial transfers and only 6% include non-water issue linkages. She notes, however, that intra-water issue linkages materialize more frequently. Dombrowsky also shows that of 86 international river basin organizations in the sample, 50% have neither monitoring nor enforcement provisions, and that only 10% have some kind of enforcement provisions in place.

The authority of existing river management organizations is, on average, very much constrained. That is, the character of river basin cooperation remains strongly in the intergovernmental rather than the transnational or supranational realm. Moreover, in the case of some existing organizations that are equipped with a rather broad range of functions, such as the Organisation pour la mise en valeur du Sénégal, their *de facto* authority and effectiveness are very much in doubt. Finally, the majority of agreements

deal with more than one water-related issue area, but the concept of integrated water resources management (IWRM), which postulates a basin-wide approach that covers all relevant problems simultaneously, is very rarely applied in practice.

A more recent study by Stinnett and Tir (2009) examines why some river treaties are more institutionalized than others. Their main argument is that institutionalization is most valuable when river issues are complex. In such cases, member states are willing to bear the cost of greater institutionalization (vs. more flexibility), because they benefit from higher problem-solving potential. Their empirical study, focusing on three major aspects of institutionalization, namely monitoring, enforcement, and conflict resolution mechanisms, provides support for this claim.

Shlomi Dinar (2006) concentrates on one particular institutional design issue that is also covered (albeit in less depth) by Dombrowsky: side-payments and cost sharing. Assuming that states are rational utility maximizers, we should expect such institutional design principles to be used particularly in upstream-downstream settings in order to motivate the upstream country to cooperate.

Using data for 91 international freshwater treaties from 1906 to 2000, S. Dinar finds evidence that side-payments occur more often in upstream-downstream settings. He also finds that in geographically more symmetric settings costs are more equally shared. However, the supporting evidence pertains largely to water quality issues and river development agreements and is not supported for water quantity issues. The author also observes that when economic (income) differences are taken into account, the direction of side-payments is reversed (the upstream pays the downstream country); or, in geographically more symmetric settings, the richer state bears most of the burden. An extended version of Dinar's research, which contains a lot of very useful data, was published in book form in 2008.

The fact that Dombrowsky and S. Dinar arrive at different empirical findings with respect to side-payment (or compensation) is striking and raises important questions for further research. The two authors use different empirical definitions of side-payments, somewhat different datasets, and different approaches in their data analysis. An important task will be, therefore, to clarify to what extent these differences are driving the results. Besides the question whether one or the other conclusion is more convincing, it will be necessary to establish empirically whether side-payments, to the extent they in fact occur in particular geographic and economic settings, can offer effective solutions to transboundary water problems. In a case study on the river Rhine published ten years earlier, Bernauer (1996) found that it took several decades of acrimonious bargaining to set up a side-payment (compensation) scheme in that case. Moreover, this scheme contributed close to nothing in terms of solving the transboundary problem (salination). Given that this solution was implemented by and among rich, democratic, and politically and economically quite strongly integrated countries, Bernauer concluded that there was rather little hope that side-payment strategies would work better in less fortunate regions of the world. This claim is supported also by a more recent case examined by Siegfried and Bernauer (2007), the Syr Darya. In that case third party support enabled the riparian countries of that river to establish side-payments more quickly than in the Rhine case. Nonetheless, an in-depth analysis based on quantitative methods shows that the effectiveness of this arrangement has been virtually nil.

Problems of water allocation are becoming increasingly important in view of climatic changes. In this context, Drieschova et al. (2008) study how water flow variability is dealt with in water treaties. They provide descriptive statistics on flow variability rules in 50 treaties signed between 1980 and 2002, concluding that "open-ended governance mechanisms may provide a means for addressing variability while at the same time accommodating the sovereignty and power concerns that are still a corner stone of water negotiations" (Drieschova et al. 2008:293).

Like Dombrowsky and S. Dinar, Conca, Wu, and Mei (2006) examine international water treaties. However, they do not focus on specific institutional design characteristics, but rather on the emergence of fundamental, globally accepted principles of international water law (such as basin-wide participation in agreements, equitable use, territorial integrity and sovereign equality, avoiding significant harm, information exchange and consultation, and peaceful dispute resolution). Using information from the TFDD and FAOLEX databases they code the contents of 62 international treaties from 1980 to 2000. Conca et al. show that some principles emanating from global efforts have experienced growth, diffusion, and deepening at the river basin level, notably principles of environmental protection, consultation, and peaceful dispute resolution. And yet, the rate of growth of international water agreements has been very modest in the 1990–2000 period, with most new agreements concluded in basins where there was already a history of cooperation. Few agreements include all riparian countries, and several important principles (e.g. the principle of avoiding significant harm) show no significant signs of deepening and diffusion. The authors observe, moreover, that convergence on two partly conflicting normative frameworks has taken place, one emphasizing joint protection/management of transboundary rivers, the other emphasizing countries' national rights. By and large, Conca, Wu, and Mei conclude that there is only weak evidence for the emergence of a "global rivers regime." Their important achievement is that their work links developments at the global to the regional level and that it offers a more nuanced view on the evolution of international freshwater cooperation than studies focusing merely on water treaties as a binary dependent variable.

A book by Conca, published in 2006, operates very much along the same lines as the journal article just discussed. He describes and explains the evolution of normative principles and practices in transboundary water management. He thus examines processes of institution building by focusing on changes in normative frameworks, the nodes, sites, networks, and platforms in the international systems where such frameworks are debated and developed, and the roles played by state and non-state actors in this realm. With two case studies, on Brazil and South Africa, he also explores how transnational processes are reaching into the domestic sphere.

Assessing the Effectiveness of International Water Management Efforts

As noted above, most large-N research on international water management focuses on policy-output variables (notably, treaties and events data). This focus is clearly justified, because policy output is usually a necessary condition for problem solving. However, most studies readily agree that these variables tell us rather little about the effectiveness of international efforts in terms of solving specific problems that motivate cooperation. Many qualitative case studies include some assessment of how substantive or effective international cooperation is. But the criteria against which the depth or substance of cooperation is measured differ very much across studies (Bernauer 2002; Dinar 2003). Moreover, most assessments rely on non-causal criteria. The most common approach in this respect is to describe, over time, the development of a particular problem targeted by a cooperative effort (e.g. pollution of a river) and to assess compliance with international obligations in this respect. This is usually done without systematic analysis of whether and how changes in the environmental outcome and in compliance levels have, *ceteris paribus*, been affected by international cooperation.

Substantial progress has been made in recent years with measurement concepts focusing primarily on policy outcomes or problem solving (e.g., environmental behavior, or ecological parameters) rather than policy output (i.e., international agreements

and their content). Work by Sprinz and Helm (2000), Hovi, Sprinz, and Underdal (2003a; 2003b), and Underdal (1992) on the effectiveness of international environmental regimes is particularly noteworthy in this regard.

Building on this work, Siegfried and Bernauer (2007) have developed a policy performance concept that relies on three parameters: the outcome that should ideally be reached (optimum), the performance of a given policy at the time of measurement (actual performance), and the outcome that would have occurred in the absence of this policy (counterfactual performance). To demonstrate that this measurement concept is empirically useful and can provide policy-relevant insights, the authors examine international water management in the Syr Darya basin, a major international river system in Central Asia. The study focuses on the Toktogul reservoir, the main reservoir in this basin, and its downstream effects. The principal policy challenge in this case has been to design and implement international tradeoffs between water releases for upstream hydropower production in winter and water releases for downstream irrigation in summer. The analysis reveals that the international arrangement in place since 1998 is characterized by high levels of compliance, but low average performance and high variability over time. The principal policy implication is that the management system in place for the Syr Darya is in need of repair. The more generic insight is that improved diagnostic tools that look beyond policy output and compliance can help in identifying management systems for international river basins that rest on "shallow" or unstable cooperation and thus require reforms. Riekermann et al. (2006) have applied a simpler version of this performance concept to Lake Titicaca.

The advantage of this approach to measuring policy performance is that it forces the analyst to make explicit assumptions (e.g., with respect to optimal performance). In addition, it focuses on causal effects and problem solving, and it produces quantitative assessments that are comparable across cases of river management. The main disadvantages are that some aspects of performance are difficult to quantify, and that carrying out such an assessment is quite labor-intensive. At least for the time being, the method appears more suitable for the analysis of individual river management cases. Large-N studies will probably have to continue relying on events and treaties, as well as on relatively simple types of policy outcome data (e.g., pollution).

Policy Implications

Existing research on international water management has produced a substantial amount of policy-relevant analytical concepts and empirical findings. For example, events data and methods for assessing policy performance can serve as diagnostic tools for identifying water systems at risk. Moreover, empirical research on water-related conflict has helped in debunking the water wars claim and has thus been instrumental in refocusing policy makers' attention on more relevant challenges to be dealt with.

The literature addressing institutional design issues is heavily dominated by qualitative case studies on individual rivers and comparative case studies guided by a "lessons learned" approach. This makes it difficult to extrapolate from research on past experience to the future, or from one river management case to others. Dinar et al. (2007:224) in fact note that "there is no one solution that fits all situations. There is also no clear recommendation on how to build a sustainable regime for a given basin. [...] River basin modeling has shown that there are a wide range of approaches for specifying a model for river basin planning, development, and management."

This caveat notwithstanding, several findings from the existing literature seem to be applicable across a rather wide range of political, economic, social, and geographic contexts.

First, cooperative arrangements are likely to be more successful when they involve strong and competent international river commissions, and if they systematically link such commissions and national level authorities, thereby ensuring financial and political support within riparian country bureaucracies (e.g. Marty 2001).

Second, fairness (equity) is one of the key concerns of all governments when they engage in international water cooperation. Joint investigations into scientific aspects of a problem and possible solutions, as well as joint projects for implementing agreed measures, can mitigate fairness concerns (e.g. Wolf 1997).

Third, political symbols and prestige effects can encourage cooperation. Such strategies can be particularly important where material incentive strategies fail to address concerns over fairness or in cases where countries are generally reluctant to cooperate (e.g. Durth 1996).

Fourth, great efforts should be made to systematically assess the problem and the range of possible solutions before deciding on and implementing policies. Quick fixes in international river management are virtually nonexistent. Successful cooperation evolves over decades rather than years. Additional time spent on fully investigating a problem and evaluating different possibilities for action will usually be compensated for by more effective implementation. Joint data gathering and analysis can help in avoiding data disputes later on, which frequently are a major component of overall water conflict. Most studies note, however, that technological fixes have rarely if ever played a decisive role in solving international river problems (e.g. Dinar et al. 2007).

Fifth, involvement of all principal stakeholders may delay agreement, but tends to prevent breakdowns in the implementation process. Nongovernmental participation may help in removing efficiency-reducing information asymmetries and forcing governments into more efficient cooperation and accountability. It also tends to open up more avenues for transnational (in addition to international) activity that generates innovative solutions (e.g. Durth 1996; Marty 2001).

Sixth, potentially the most controversial conclusion of several studies is that IWRM may look nice on paper but does usually not produce the desired results. The implication is to avoid complicated package deals (issue linkages) that risk creating a mismatch between tasks and resources, and to focus on clearly defined problems and specific, operational institutional arrangements.

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