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Scarperation:

An Empirical Inquiry into The Role of Scarcity in Fostering Cooperation Between International River Riparians

Shlomi Dinar
Ariel Dinar
Pradeep Kurukulasuriya

The World Bank
Development Research Group
Sustainable Rural and Urban Development Team
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Abstract

The environment and security literature has argued that freshwater scarcity often leads to inter-state conflict, and possibly acute violence. The contention, however, ignores the long history of hydro-political cooperation exemplified by hundreds of documented agreements. Building on a theory that considers the relationship between scarcity and hydro-political cooperation, this paper empirically investigates why treaties are negotiated for some rivers and between some riparians, and not others. The paper suggests that long-term water scarcity has a significant influence on levels of cooperation. Additional variables considered include trade, level of governance among the riparian states, and the geography of the river. Findings confirm that cooperation and scarcity embody a concave (inverted U curve) relationship. Governance has a positive impact on cooperation. In addition, riparians may either arrange the use of their scarce water resources via a treaty or trade (and indirectly exchange [virtual] water). Scarcity, governance, and trade were found to be most salient in explaining levels of cooperation while geography is significant in some of the estimates.

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AN EMPIRICAL INQUIRY INTO THE ROLE OF SCARCITY IN FOSTERING COOPERATION BETWEEN INTERNATIONAL RIVER RIPARIANS

Shlomi Dinar* Ariel Dinar** and Pradeep Kurukulasuriya***

*Corresponding author. Florida International University, Department of International Relations and Geography, 3000 NE 151st Street, Academic 1 Building, 323A, North Miami, FL 33181 (o) 305-919-4839, (em) dinars@fiu.edu. **World Bank, Development Research Group and Johns Hopkins University School of Advanced International Studies, Washington DC. ***Yale University School of Forestry and Environmental Sciences. Earlier versions of this paper were presented at the 2005 International Study Association Convention, Honolulu, Hawaii and in an AERE session at the 2007 ASSA winter meeting, Chicago, Illinois. We would like to thank Tony Allan, Barbara Connolly, Mark Giordano, Solomon Polachek, Rafael Reuveny, and Aaron Wolf for their invaluable comments. The views expressed in this paper are those of the authors and should not be attributed to the Word Bank.

INTRODUCTION

Among the trans-boundary environmental problems that can be empirically analyzed, freshwater is unique in that like problems occur throughout the world. Similarly, there are a large number of river basins that can be studied. To be sure, the details are unique to each river basin problem yet similarities are sufficient to make comparisons. When rivers and other bodies of water transverse or divide countries, transboundary externalities often culminate in inter-state conflict. However, conflict almost always provides the impetus for cooperation and cooperation is most regularly codified in international treaties (Wolf and Hamner 2000:66; Deudney 1999:207). Therefore, commons regimes, corresponding to the many freshwater problems, can be analyzed and compared empirically. The aim of this paper is to answer one fundamental question: Why are agreements negotiated between some states,[i] or river riparians, and not others, and what affects the level of cooperation measured by these agreements?

The motivation for the above query, and the empirical investigation, stem from the common claim that water scarcity is likely to lead to inter-state conflict, and possibly violence.[ii] More importantly, building on a theory that considers the relationship between scarcity and cooperation, this investigation strives to show that it is the 'critical need' for a given transboundary resource, and the dispute that may ensue, that provides the impetus for inter-state cooperation codified in international water agreements.

The history of hydro-political cooperation is rich in documented international water agreements. The empirical investigation proposed here considers 271 treaties negotiated between riparian states between the years 1850 and 2002 (Dinar S. 2007). The agreement texts are obtained from various depositories.[iii] In total 226 rivers shared by two states are investigated[iv] Thus, the available sample pertaining to an extensive number of international rivers, some governed by treaties while others are not, makes the inference of various hypotheses, across a large number of observations, possible. The bilateral focus of this paper facilitates a methodologically simpler analysis, compared to, say, a multilateral focus, at least as a first attempt in understanding this complex issue. Future research will build on this model and investigate rivers shared by more than two riparians.

Several past works are relevant for this particular study. Espey and Towfique (2004) and Song and Whittington (2004), for example, are also interested in the emergence of water agreements between riparians yet do not consider scarcity as an independent variable. Other empirical studies consider scarcity as a variable in their respective models, but do not use it to explain treaty formation *per se* or solely focus on conflict intensity between states.[v] Although our study continues in the empirical spirit of these works, it is different in the data it brings to bare, the methodology used, and most importantly the analytical framework and hypotheses developed to explain treaty formation and the extent of cooperation. Specifically, this study is not only interested in the emergence of international freshwater treaties (that is treaty/no treaty patterns) but also in the type of agreement (e.g., the issue area negotiated) and the level of cooperation that emerges. In addition, this paper directly tests the relationship between treaty formation and scarcity.

The following two sections develop the analytical framework. The main contention is that resource scarcity, while a source of conflict, is also the impetus for cooperation between states. Additional variables are also discussed for their importance in explaining cooperation. We build on the rich economic and international relations literature that introduces trade as a facilitator for further cooperation. In addition, we incorporate a measure of the river basin's governance level and the geography of the river as additional explanatory variables, as was suggested in several previous works (e.g., Kilgoer and Dinar 2001; Dinar S. 2006b). These sections are followed by an analytical framework applied to the treaty data. Section four presents the data and the empirical specifications of the various variables used in the analysis. While we develop a general analytical framework, only water quantity/allocation related agreements are considered in the empirical analysis. Other scarcity issues (e.g., hydropower, pollution and flood-control) will be investigated in later research. Section five presents the results while section six concludes with policy implications and thoughts for further research.

THE THEORETICAL MODEL

Scarcity, Conflict and Cooperation

The environment and security literature largely contends that water scarcity is the basic motivation for conflict and ultimately violence between states. Given that water is crucial for basic survival, irreplaceable, transcends international borders, and scarce, it follows that states will conflict over the resource or even take up arms to defend access to the shared river (Homer-Dixon 1999:80; Falkenmark 1992:279-293). Hensel, Mitchell, and Sowers further argue that resource poor areas, as opposed to resource rich areas, create environments where the creation of institutions to manage conflict will be lacking and/or ineffective (2006:3, 6 and 26-27). While the relationship between scarcity and conflict is often described as linear, Giordano, Giordano, and Wolf (2005) have modified this association. Arguing in terms of degree of resource abundance and conflict in general, the authors claim that conflict is least likely when the resources do not exist or exist in low quantities. Likewise when the resource is overly abundant the probability of conflict is reduced. As resource availability rises, the potential payoff from conflict rises and with it the probability of conflict. Reframed, the authors would contend that inter-state conflict is most likely when the resource is moderately scarce. [vi]

The above inventory describing why water scarcity is a likely source of conflict and may depress the formation of cooperative institutions, however, can likewise be associated with cooperation and the formation of international agreements. As Elhance contends, the hydrology of an international river basin links all the riparian states sharing it in a complex network of environmental, economic, political and security interdependencies. As such, it creates the potential for interstate conflict as well as opportunities for cooperation (Elhance 1999:13). In our empirical investigation, the cooperative side of the hydro-political coin is empirically scrutinized.

Since water is crucial for the economic and political well-being of a state, has no substitute, places parties in a web of security interdependencies, and is sparse, it follows that parties will attempt to cooperate and eventually negotiate an agreement so as to efficiently exploit this indispensable resource (Deudney 1991:10; Brock 1992:99; Dokken 1997). Scarcity, therefore, also provides the basic impetus for cooperation between states. In an attempt to empirically explain the patterns of cooperation and international water agreements, scarcity must be considered as the necessary independent variable. Dinar, S. (2006a) has coined such a relationship *scarperation.*

Dinar S. (2006a) has argued that the *scarperation* relationship is concave. That is, cooperation levels are low when scarcity is low, or non-existent. The likelihood of cooperation, in turn, increases with rising scarcity levels, but as scarcity increases beyond a certain level, the incentive for cooperation diminishes. For example, if two states have similar levels of 'water quantity' scarcity, either very low or high, then they are less likely to cooperate because the main impetus for cooperation is lacking (both enjoy an abundance of water) or the countries simply can't help each other (both suffer from a high level of water scarcity), respectively.[vii]

The above assumes that scarcity is experienced by both parties. However, cooperation may ensue when only one party experiences relative water scarcity while the other party does not experience scarcity for any other issue, for that point in time. Cooperation takes place when the interested riparian provides some sort of incentive, such as side-payments or linking of an issue unrelated to the water issue, to the other riparian to foster cooperation (LeMaquand 1977:10 and 119; Dinar S. 2006b)

While scarcity is a necessary condition for cooperation it is not a sufficient condition for explaining the emergence of treaties. Take, for example, river basins, which exhibit scarcity but evince no formal cooperation at all.[viii] Additional explanations, therefore, become relevant. We consider several variables, based on previous work on international cooperation.

Domestic Institutions-Governance

When considering international cooperation, in general, and international water treaties, in particular, domestic institutions may play a major role in either facilitating or inhibiting cooperation when scarcity is evinced. Political, legal, and economic institutions often sustain the functioning of the state both domestically and internationally. They reflect not only on the state's concern for the environment but also its ability to enter into, and honor, an agreement, which may require financial investments and costs (Congleton 1992:412-413). The political stability of a given state is, therefore, one principal mode in which to judge the viability of its domestic institutions, its general inclination to negotiate an agreement and its capacity to honor that treaty.

Unstable countries have less institutional capacity to honor agreements and other countries, more politically stable, may in turn have little interest in cooperative ventures with such countries. Similarly, investments are not secure and property rights poorly defined in unstable countries characterized by political turmoil (Deacon 1994). Participating in an agreement requires both competence and stability inherent in a particular polity, which will in turn be able to honor the signed accord (Young 1989:365; Young 1982:287). Similarly, international water agreements that entail investment in large projects require that the infrastructure envisioned is secured. In both cases, a state characterized by weaker institutions may be unable to go forward with a water agreement that requires action on its part. Neither will another riparian, more stable perhaps, trust it with the responsibility entailed.

Overall State Relations: Trade and Diplomatic Relations

The extent of trade between states, the scope of their diplomatic relations and other engaging activities (e.g. cultural and academic exchanges) between countries provide an appropriate measure of their overall relations. Such variables may also indicate a history of inter-state conflict or cooperation, diminishing or enhancing prospects for treaty likelihood.[ix] This paper only considers the extent of inter-state trade given the availability of robust historical trade data.

In an effort to assess the link between trade, conflict and cooperation, the literature has been quite mixed. On the one hand, has been the general claim that increased trade between states should reduce incidents of militarized conflict between them and promote peace (Kant {1795} 1970; Polachek 1980; Arad and Hirsch 1981, 1983; Russett and Oneal 2001). The fear of losing gains from trade deters conflict. Along the same lines it has been argued that nations with cooperative political relations will engage in more trade, while conflictive nations are expected to trade less (Savage and Deutsch 1960; Nagy 1983; Pollins 1989). On the other hand has been the conjecture that high inter-state trade, interdependence, and conflict are positively related (Waltz 1979). Higher interdependence increases frictions among the countries, and therefore may lead to conflict. Barbieri (2002:121), for example, finds that the higher the interdependence, and trade, between states the higher the likelihood of militarized conflict.

In the context of their general corollaries, both the trade-conflict and trade–peace camps have also provided useful conjectures that are quite analogous. Specifically, authors have asserted that increased inter-state trade indicates not only a history of cooperation between states (and interest in maintaining good relations) but also aids states in achieving negotiated settlements (Polachek 1980; Polachek 1997; Stein 2003; Polachek, Seiglie, and Xiang 2005; Pollins 1989; Barbieri 2002:121). Trade, it seems, also acts as a contract enforcing mechanism. Stein (2003), who argues that trade increases the likelihood of disputes between states, also claims that it provides states with an opportunity to resolve them at a lower level of interstate conflict. In essence, the coercive potential of trade reduces conflict, the occurrence of political crisis, and the need for militarized actions.

The above examination of the literature leads us to suppose that overall inter-state relations, measured by the extent of trade among them, is an appropriate measure for assessing the likelihood of environmental treaty negotiations (Neumayer 2002). Specifically, treaty likelihood will be enhanced, in the case of good, or strong, relations among states, or will be diminished in the case of poor, or weak, relations among states (Sigman 2004).

In the particular case of freshwater, another argument may be introduced regarding the relationship between trade and treaty formation—that of virtual water (Allan 1993, 1998, 2000, 2002; Hoekstra and Hung 2005). 'Virtual water' is essentially the water used in the production process of goods and services, utilized by the riparian countries or imported/exported. For example, Hoekstra and Hung (2005:45) estimate that "…13% of the water used for crop production in the world is not used for domestic consumption but for export (in virtual form).". Similar findings exist for other water-using goods and services (electronics, cars). In particular, by trading (e.g., importing and exporting virtual water) countries may reduce the pressure on their scarce water resources.

Taking into consideration the aforementioned point, riparian states sharing scarce water resources may address their water scarcity problem by relying on import or export of virtual water via traded goods. It is likely that the greater the trade between the riparian states, or the higher the trade level with the world,[x] the less likely it is that scarcity in water resources will require a formal negotiated agreement over a shared river's water. Therefore, we also expect a negative sign for the trade variable with respect to the treaty variables. We do not rule out a-priori a concave or convex behavior. Our paper does not include specific quantification of virtual water in trade flows. This could be considered in future research.

Geography

While scarcity provides the main motivation for cooperation it may also be facilitated or impeded by geographical considerations. In fact, the physical geography of the river defines the possibilities for *where*, *how*, and *when* the multiple uses of its water can be developed and utilized by riparian states (Elhance 1999:15).

Several studies have hypothesized about the relationship between the geographical configuration of a river and the likelihood of conflict and cooperation. Using various case studies, LeMarquand has explained that conflict is more likely in upstream/downstream situations where the upstream country may use the river to the detriment of the downstream country. Conversely, there is significant incentive for cooperation when the river creates the border between the riparians—the incentive to reach agreement is to avoid the "tragedy of the commons" (LeMarquand 1977:9 and 10). Toset et. al (2000) have come to a similar conclusion based on three river types: an "upstream/downstream" relationship, a "mixed" relationship and "river boundary" relationship. Above all, they find that the "upstream/downstream" relationship is indeed the most conflict-prone type (2000:989-990).

Complementing the above studies, Dinar S. (2007) empirically considers how different geographical types of rivers help shape commons regimes (i.e. the substance and content of an agreement). While Dinar S. considers 13 geographical configurations, two extreme configurations constitute the main thrust of his theory, the "through-border" and the "border-creator". His main goal is to test the effects of these geographies at opposite extremes.

Using the geographical terminology introduced by Dinar S. it is likely that the asymmetrical relationship embedded in the "through-border" configuration implies not only a higher likelihood of conflict but also fewer treaties negotiated. By extension, the symmetry embedded in the "border-creator" configuration assumes that cooperation will be much easier to sustain and agreements are more likely to be negotiated. However, an opposite scenario may also result. Given the reciprocal nature of the "border-creator" configuration and given that the externality is at least partially internalized, states might voluntarily abate pollution, for example, and informal cooperation would replace formal cooperation, such as treaties. Similarly, agreements may be more likely in the "through-border" configuration precisely because conflict is probable and conflict is costly to both riparians. In this case, states will have greater need to constrain each other's actions through agreements. Plainly, whether a treaty is more likely for one configuration than another is an empirical question, which we examine below.

Additional variables

While our model identifies a number of key variables for explaining cooperation and the emergence of international water agreements, additional variables have been cited by other studies. Nonetheless, we exclude them from our model as explained below.

Some authors, for example, have argued that the type of political regime of a given country should also be a factor in explaining cooperation. Based on the democratic peace theory (Russet 1993), scholars have argued that competition for resources between democracies often leads to increased cooperation rather than armed conflict (Gleditsch 1997:91). Yet water agreements have clearly been negotiated between democratic pairs, non-democratic pairs, and dyads including a democracy and non-democracy[xi]. Therefore the ability of the government to enter into and follow through with an agreement seems more suitable to explain the emergence of international water agreements.

Scholars have also contended that power asymmetries may also play a role in facilitating cooperation. Linking the prowess of a particular riparian with its geographical position, Lowi (1993), for example, has argued that cooperation is likely to take place only when the most powerful country is located in the downstream position (rather than the upstream location where it can operate essentially unilaterally) and if the hegemon's relationship to the water resources is one of critical need. The downstream hegemon, therefore, compels the weaker upstream state to agree to a basin wide regime. While the theory is compelling, it is important to note that studies have already questioned the utility of force in the realm of hydro-politics, making the use of power, often military in nature problematic and even irrelevant (Wolf 1998). Nonetheless, even when the downstream riparian is the hegemon examples can be cited where that hegemon acts in a rather benign nature and cooperation is not coerced as implied by Lowi's theory. In addition, cases where the upstream state is also the hegemon and cooperates willingly with an otherwise weaker downstream state can likewise be cited. Finally, cases where the riparians are considered symmetric can also be referenced.[xii] Since riparians of different power capabilities negotiate environmental regimes (Barrett 2003; Young 1989:353), overall power asymmetry does not seem to be an important variable explaining the emergence of international water agreements.

SPECIFICATIONS, EMPIRICAL FRAMEWORK, AND TESTABLE HYPOTHESES

The underlying empirical assumption in our analytical framework is that scarcity issues are not short-term phenomena. For example, although in some cases disasters caused by floods or droughts may encourage states to engage in joint efforts, we claim that it is the long-term scarcities that lead to enduring cooperation, codified in an agreement, between river riparians.

We should also note that scarcity at the national level and scarcity at the basin level may very well constitute different measures. However, some scarcity issues such as water quantity may be related to national scarcity measures, given that water may be transferred via canals and pipelines to regions, outside the particular basin, suffering from scarcity.[xiii] Thus, water scarcity at the national level may also affect a particular river basin.

Introducing notation, we assume that long-term cooperation among riparian states is expressed through treaties. Therefore, the general way of presenting our analytical framework is by the following relationship:

[1] $C = f(\underline{S}; \underline{X})$.

That is, cooperation, measured through treaty relations, is a function of a vector of resource scarcity levels ($\underline{S}$) and of other variables ($\underline{X}$), some of which are of mutual interest to the two riparian states and can be linked to the variables in $\underline{S}$. The vector $\underline{X}$ includes state governance, the states' overall relations, and physical geographical considerations.

The general presentation of the inverted U curve *scarperation* hypothesis requires $\frac{\partial C}{\partial S} \geq 0$ and $\frac{\partial^2 C}{\partial S^2} \leq 0$, where *S* is scarcity. In the next section we provide several alternative empirical specifications for *C* and *S*.

Applying the Framework

For the case of a bilateral river, let *j* be the index representing the river, with $j = 1,..., J$; *i* be the index representing riparian state, with $i = 1,2$; and k_i^j be the index representing the issue of concern to state *i*, in river *j*, $k_i^j = 1,..., K_i^j$. For a given river, *j*, for each state *i*=1,2 there could be several scarcity issues of concern.

Some scarcity issues could be more severe than others. Therefore, we hypothesize that all else being equal, the higher the level of scarcity of issue k_i^j state *i* may more likely be interested in signing a treaty with the other riparian state in order to solve that issue, and vice versa, subject to the inverted U curve scarcity-cooperation hypothesis.

The unit of observation in our analytical framework is the river. Cooperation between the two riparian states takes place if a treaty (or treaties) exist(s).[xiv] A treaty in our framework is defined as a set of rules and arrangements through which the riparian states cope with the scarcity issue(s) of concern and allocate costs and benefits among themselves. Although the focus of the empirical investigation in this paper is only on water quantity scarcity, we present an analytical framework that allows more than one scarcity issue to be considered. As will be explained later, scarcity issues are interrelated and their resolution may affect each other.

The notation that describes a treaty is:

$$T_t^j = \left\{ \ R(k_i^j),\ k_i^j = 1,..., K_i^j,\ i = 1,2 \ \right\}$$

where T_t^j is the treaty that was signed in year *t* between the riparian states to river *j*, and *R* is the set of rules agreed upon in addressing scarcity issue k_i^j.

Measuring Treaty Cooperation

Several proposed expressions for *C* will be based on a cooperation relationship explaining treaty formation. Our first cooperation expression, $P(C_j)$ in [2], assesses the likelihood of a treaty on any of the scarcity issues in the basin, regardless of the issue, of the riparian state that faces scarcity, or of the period that the treaty was signed.

$$[2]\quad P(C_j) = \begin{cases} 1 \ \textit{if at least one treaty exists on any scarcity issue } k_i^j, & k_i^j = 1,...,K_i^j \\ 0 \ \textit{if no treaty exist on any scarcity issue } k_i^j, & k_i^j = 1,...,K_i^j \end{cases} \quad i = 1,2 \ \forall j = 1,...,J$$

A second cooperation expression, $N(C_j)$ in [3], is a simple arithmetic count of the number of treaties signed between the two riparian states on any scarcity issue over the years.

$$[3]\quad N(C_j) = \sum_t T_t^j \quad \forall j = 1,...,J$$

Finally, $A(C_j)$ in [4], distinguishes among the scarcity issues by assigning weights to each issue, using a principal component procedure. Based on the weighted value of cooperation, which is the result of the principal component analysis, a value is attached to the level of cooperation. In fact, $A(C_j)$ is estimated in a two stage procedure. First, the principal component analysis is performed on the 'number of issues addressed in each treaty' matrix to produce the weights, and then, the weights are used to calculate one value, $A(C_j)$, for each river. In this paper, however, we focus on water allocation issues only.

$$[4]\quad A(C_j) = \alpha_k^j \sum_t k_i^{j,t} \quad \forall j = 1,...,J$$

where α_k^j is the coefficient estimated in the principal component analysis. Note that we use the index *t* only in expression [4], since we did not distinguish between years of treaty signature in expressions [2] and [3].

We continue with the empirical specifications of the scarcity issues. Several relationships are suggested, following the discussion in the analytical framework section. We start with a definition of the vector $\underline{S}$.

$$[5]\ \underline{S}^{A} = \left\{ S^{j1}_{k_1^j=1}, S^{j1}_{k_1^j=2}, \ldots, S^{j1}_{k_1^j=K_1^j}, S^{j2}_{k_2^j=1}, S^{j2}_{k_2^j=2}, \ldots, S^{j2}_{k_2^j=K_2^j} \right\}$$

where $S^{ji}_{k_1^j}$ is the scarcity level of issue k_i^j in river *j* of state *i*. The values of $S^{ji}_{k_1}$ will be specified in the next section. The definition of $\underline{S}^A$ uses the actual values of each individual scarcity issue in each state on each river.

According to [5] when both countries face high scarcity in a particular issue the likelihood for cooperation will be higher than when only one state faces high scarcity, but that likelihood diminishes as scarcity levels increase, as was indicated in the Theory of Scarperation section.

$$\frac{\partial C}{\partial S^{ji}_{k_i^j=h}} \geq 0, \quad \frac{\partial^2 C}{\partial \left(S^{ji}_{k_i^j=h}\right)^2} \leq 0 \quad j = 1,\ldots, J \quad i = 1,2 .$$

Another way to express the scarcity levels in the basin is by calculating the absolute difference in the scarcity level of a particular issue between the two riparian states. The expression of $\underline{S}^D$ in [6] is the set of all absolute differences in scarcity levels for the river riparian countries.

$$[6]\ \underline{S}^{D} = \left\{ \left|S^{j1}_{k_1^j=1} - S^{j2}_{k_2^j=1}\right|, \left|S^{j1}_{k_1^j=2} - S^{j2}_{k_2^j=2}\right|, \ldots, \left|S^{j1}_{k_1^j=K_1^j} - S^{j2}_{k_2^j=K_2^j}\right| \right\}.$$

According to [6] the higher the difference in scarcity value between the two countries for a particular issue the higher the likelihood of cooperation will be, but that likelihood diminishes as scarcity levels increase.

$$\frac{\partial C}{\partial \left|S^{j1}_{k_1^j=h} - S^{j2}_{k_2^j=h}\right|} \geq 0, \quad \frac{\partial^2 C}{\partial \left(\left|S^{j1}_{k_1^j=h} - S^{j2}_{k_2^j=h}\right| \right)^2} \leq 0 \quad j = 1,\ldots, J \quad h = 1,\ldots, K_i^j .$$

The empirical specification of the relationship to be estimated will include combinations of [2], [3], [4] and [5], [6], and additional variables to be included in $\underline{X}$.

DATA AND EMPIRICAL SPECIFICATIONS

In this section we provide the empirical specification of the variables we use and explain how they were collected and constructed. We also justify the functional forms of the equations used for estimating the hypothesized relationship.

Treaty Data

As mentioned earlier, the treaty dataset is based on Dinar S. (2007) and includes 226 country dyad observations. Eighty-six of the corresponding rivers are not governed by treaties while 140 are, providing a diverse pool of observations to examine the *scarperation* contention. Three hundred and eleven treaties were identified and analyzed for their content. Of these, 40 provide only periodical re-affirmation of previous treaties and do not introduce new agreements. These treaties were removed from the analysis, leaving the dataset with 271 treaties.

Treaty cooperation variables are described in our analysis as: (1) *Treaty/no-treaty* (a dichotomous variable indicating whether or not there is (are) an existing treaty (treaties)—1, or not—0); (2) *Number of treaties* signed between the river riparians (an integer ranging between 0-N that measures the number of treaties on that river); and (3) *Share of water allocation issues* in treaties (while each treaty may address several scarcity issues--water allocation, hydropower generation, pollution control, flood protection, and general issues--in this paper we measure the share that the water allocation issue commands among the sum of issues addressed in all the treaties).[xv]

Water Scarcity

As explained earlier, our empirical application utilizes physical water scarcity measures based on national level data.[xvi] We use the index of water per capita as the basis for calculating water scarcity. In this index we capture both the actual scarcity and the perceived scarcity. Decision makers in a particular state consider not only the level of water availability per capita at present, but also future values, calculated based on population growth predictions. We estimate a hyperbolic water scarcity function for the period 1955-2050. Using data on water availability per capita from Population Action International (1993, 1995, 2004), for 1955, 1975, 1990, 2000, and predictions based on medium population growth rates (United Nations 2000) for 2025 and 2050.[xvii] For each state we estimated the following water scarcity function:

$$W = \alpha \cdot t^{\beta}$$

where W is the available annual water per capita (cubic meters/year), α is an estimated intercept, t is year, and β is an estimated coefficient of decrease in water per capita over time. We argue that $\beta < 0$, means that the function W decreases over time (mainly due to population growth), and that the larger the $|\beta|$ the higher the scarcity level the state faces. To demonstrate the possible severity in water scarcity across countries, Figure 1 presents the reduction in water per capita for Angola and for Austria (estimated β values are –49.12 and –2.49, respectively). Since our data on population includes both actual population for $t \leq 2000$ and forecasted levels of population for $2000 < t \leq 2050$ the estimated scarcity level is both actual and perceived.

Values of α for countries sharing the same river are highly correlated and the same is true for the β values of river riparians. Therefore, we created principal component variables for various dataset specifications that include the information on the intercept (α)—*Water scarcity intercept* and on the slope (β)—*Water scarcity slope*. These variables incorporate the values of the intercept and the slope, respectively, of the two river riparians (Table 1). The hill shape behavior of the scarcity variables is captured via positive and negative signs for the linear and quadratic terms of *Water scarcity intercept* and negatives signs for the linear and quadratic terms of *Water scarcity slope*.

Governance

We include variables in the analysis that measures the viability of institutions and governance in the countries that share the river so as to obtain a measure of domestic stability. We use a 7-year (1998-2004) average of the Corruption Perception Index (Transparency International, 2004). The notable features of this variable is that it is based on perceptional data in each of the river riparians, and uses a long-term average of each governance level measured as governance of country 1 and governance of country 2. A similar approach has been suggested in Kaufmann et al., (1999). We used two specifications for the governance variable. The first, *River riparians governance*, is a simple summation of the value assigned to each riparian, country 1 governance and country 2 governance. Since both of these variables range from 1 to 10, the values of *River riparians governance* range between 1 and 20, with higher values indicating better governance. The second governance variable introduces in the equation each country's governance, *Country 1 governance*, *Country 2 governance*, and includes also an interaction term, *Country 1 governance*×*Country 2 governance* (appears as *Country 1*×*Country 2*).

Trade

We obtained two separate trade datasets. The first is the Direction of Trade Statistics (DOTS) Database IMFDOT that includes trade information for 184 countries for the period 1950-2004, in current US$. The second dataset is the United Nations Statistics Department (UNSD) dataset COMTRADE that includes information for 207 countries for the period 1962-2004 in current US$.

Sources of data feeding into the IMFDOT and into the COMTRADE datasets are different and as such, differences in annual trade values can be expected. Such differences have been observed (IMF, 1999: Table 2), although differences do not exceed 10%. We constructed separate trade variables based on both the IMF and UN datasets. We converted the trade values in these two datasets into constant US$ of 1999 (for IMFDOT) and of 2002 (for COMTRADE). We then used annual country-level GDP data from the GGDC&CB (2005) dataset, which is expressed in 1999 and 2002 US$ to construct our trade variables. Missing trade values in particular years were ignored because our trade variables are calculated as long-term averages.

The following definitions apply for the two trade variables we constructed: Let *i*=1 and *i*=2 be two riparian states sharing a river. Let IMP_{12t} be import of 1 from 2 in year *t*, [= EXP_{21t}]; EXP_{12t} be export of 1 to 2 in year *t*. [= IMP_{21t}]; IMP_{1wt} be import of 1 from w in year *t*; IMP_{2wt} be import of 2 from *w* in year *t*; EXP_{1wt} be export of 1 to *w* in year *t*; EXP_{2wt} be export of 2 to *w* in year *t*; GDP_{1t} be gross domestic product of country 1 in year *t*, GDP_{2t} be gross domestic product of country 2 in year *t*; and *w* be rest of the world (not including 1 and 2).

We first constructed two annual trade variables for each trade dataset. The first variable (*TRD*1) expresses total trade between 1 and 2 as a fraction of the countries' GDP, expressing the economic importance of trade to the riparians (Sigman 2004). The second variable (*TRD*2) measures trade between 1 and 2 as a fraction of their trade with the rest of the world, expressing their dependence on each other (Reuveny and Kang 1996).

In this framework, we adopt the significant finding by Arora and Athanasios (2005) that the relatively important trading partners tend not to change much over time. This finding is very important in the case of international water treaty formation because long-term impact variables such as scarcity, governance, and trade play in the relationship between the riparian countries, justifying use of long-term values.

The two trade variables that we apply to the two trade data sets are presented in equations [7] and [8].

$$[7]\quad TRD1^{12} = \frac{\sum_{t=1}^{T}\left(IMP_{12t} + EXP_{12t}\right)}{\sum_{t=1}^{T}\left(GDP_{1t} + GDP_{2t}\right)}$$

$$[8]\ \ TRD2^{12} = \frac{\sum_{t=1}^{T}\left(IMP_{12t} + EXP_{12t}\right)}{\sum_{t=1}^{T}\left(IMP_{1wt} + IMP_{2wt} + EXP_{1wt} + EXP_{2wt}\right)}$$

where, $IMP_{12t} + EXP_{12t}$ is the total annual volume of trade between every two countries 1 and 2. Both $TRD1$ and $TRD2$ are fractions, with $0 \le TRD1, TRD2 < 1$. We will refer to TRD1 as *Trade importance* and to TRD2 as *Trade dependency*. The data sets will be identified in parentheses to the right of the name of the variable.

Since our unit of observation is the river, we construct the trade variable for the entire dyad (the two riparians). As was indicated in our analytical framework, one riparian may be more interested in signing a treaty than the other. However, the outcome (as we measure it) does not reveal which riparian initiated the water treaty and, thus, our trade variables measure the dyadic trade volume rather than that of each riparian state.

Geography

The 13 geography configurations were re-categorized into three groups, capturing the rivers that fall under the through-border geography and the rivers that fall under the border-creator geography. The remaining rivers that fall under the other 11 configurations were included under *other* geography, whereby this category served as a benchmark. The reasons for this regrouping are as follows: (1) the distorted distribution of the 13 categories doesn't allow the estimated regression model to be fully ranked, and (2) we are mostly interested in the impact of the two extreme geographies that have been identified by Dinar S. (2007, 2006b) and their ability to explain interactions between riparian states. The two dummies that are included in the regressions are *Through-border*, and *Border-creator* , for the through-border and border-creator configurations, respectively.

FUNCTIONAL FORMS AND ESTIMATION ISSUES

The empirical specifications of the various expressions to be estimated[xviii] are as follows:

Treaty/no-treaty =f1(.)

Number of treaties =f2(.)

Share of water allocation issues =f3(.)

The expression (.) includes a subset of the following independent variables: *Water scarcity intercept*, *Water scarcity slope*, *River riparians governance*, *Through-border dummy*, *Border-creator dummy*, *Trade importance* (UN), *Trade importance* (IMF), *Trade dependency* (UN), *Trade dependency* (IMF).

In addition, several of the estimated relationships were regressed over different data subsets. Three subsets were identified: the full dataset, the subset that includes rivers with treaties only, and the subset that includes rivers with treaties with water allocation issues only. Different estimation procedures were applied to different combinations of dependent variables and the data set used for the estimation.[xix] The rationale for the various regressions and estimation procedures are as follows. In cases where the dependent variable is a dichotomous choice (1/0) we employ a maximum-likelihood logit model. The function guarantees probabilities in the (0,1) range. The logit form also gives a plausible shape for the marginal effects. That is, for a continuous variable X_k, at relatively high values, a marginal change will create a relatively smaller change in the probability of success (Y=1). In some cases, we also rely on a generalized linear model (GLM) procedure, which fits models, using Newton-Raphson (maximum likelihood) optimization. The GLM procedure is preferred over a conventional Ordinary Least Squares (OLS) approach when the dependent variable of interest may have a non-continuous distribution, and thus, the predicted values should also follow the respective distribution. Any other predicted values are not logically possible, as the effect of the predictors on the dependent variable may not be linear. The generalized linear model is used to predict responses both for dependent variables with discrete distributions and for dependent variables which are nonlinearly related to the predictors. We also use a POISSON procedure in the case of the full data set to capture the non-continuous distribution of the dependent variable. The results are presented with indication of the data sets to which they refer.

To sum, our general basin-level treaty cooperation model takes the form:

[9] $$Water\ \ Treaty\ \ Cooperation = h(Scarcity, Governance, Gegraphy, Trade) + \varepsilon ,$$

where ε is the error term and each variable is represented by the various measurements discussed above.

We cannot avoid addressing possible endogeneity related to modeling the relationship between trade and cooperation (Timpone 2003). One concern is that both trade and cooperation, among the river basin riparians, might be endogenously determined in an interdependent relationship and thus, if specified in a single equation, may lead to a biased estimation. By taking trade as a long-term activity among the riparians, our theory suggests that trade is determined outside of the model and is uncorrelated with the error term of the equation. Therefore, we can use trade as an independent variable in our single model estimates.

RESULTS

We start with the principal component analysis followed by some general trends and distribution patterns. We then move to reporting on the econometric results.

Principal Component Analysis Results

The results of the principal component analysis are presented in Table 1. Several dependent and independent variables were created, using (1) the entire dataset, (2) observations with a treaty only, and (3) observations with a water allocation treaty only. The eigenvectors of the first principal components, used in the creation of the principal component variables, are presented in the table.[xx] These eigenvectors explain between 0.84 and 0.89 percent of the standardized variance among the variables. The *Water scarcity intercept* and *Water scarcity slope* variables are used in our econometric estimates to measure water scarcity at the river level.

General Descriptive Results

There are 13 geographical configurations representing the set of 226 rivers (based on Dinar S. 2007).[xxi] The 226 bilateral rivers in the dataset were categorized, for the purpose of our analysis, into three geography types: through-border, border-creator, and others, comprising 44, 7, and 49 percent of the observations, respectively (Table 2).

Simple analyses of treaty distribution provide compelling results. As Table 3 indicates, the number of treaties per river varies between 1 and 10. Records of treaty signature dates provide very useful information regarding the distribution of the treaties over time. Table 4 reveals that between 25 and 75 percent of the treaties in the dataset were signed between 1850-1950 and 1951-2002, respectively. Using our notion of treaty as a measure of cooperation, these results suggest that more cooperation is apparent in recent years.[xxii]

The treaty content descriptive analysis, vis-à-vis water allocation, hydropower, pollution control, flood protection, and general issues (such as statements reconfirming the good intent of the riparians, setting a basin committee, etc…) also provides useful lessons. While treaties could address a multiple set of issues, we find that 67 percent of the treaties are single-issue ones. Table 5 presents the distribution of these issues in the dataset. However, it is also apparent that more treaties address multiple issues in recent years (since 1951).

The distribution of the issues agreed in the treaties by year also provides useful information. As noted in Table 6, more pollution control and flood protection issues are addressed in treaties in the past 25 years while more water allocation and hydropower production issues were addressed in treaties in the first 50 years covered by our dataset.

Results of the Econometric Analyses

The descriptive statistics of the various variables is presented in the Appendix. In general, cooperation, measured both by the number of treaties signed among the two riparian states, and by the principal component variable that integrates the shares of issues in the treaties is well explained by water scarcity, trade and governance regimes of the riparian states. Our estimates of likelihood of treaty formation (*Treaty/no-treaty*) did not yield compelling results and therefore are not presented.

The geography variables, *Through-border* and *Border-creator*, were not always significant, so that they cannot robustly support the hypothesis that river geographies lead to different levels of cooperation. This is in line with our claim that the effects of geography on treaty cooperation may be ambiguous. However, as explained in Dinar S. (2006b, 2007), geography may not explain the level of cooperation but rather it is essential to understanding cooperation patterns and, most importantly, the allocation of costs and benefits among the riparian states.

The statistical results are robust in the sense that various estimation procedures applied to different datasets suggest similar value ranges, significance levels, and signs for the coefficients. The results are stable for all three subsets of the basins (all basins, basins with treaties only, and basins with water allocation treaties only). They are especially similar in terms of values, signs and significance for the governance variables and the trade variables. The results are also quite alike for trade variables derived from the IMF and UN datasets, with slightly better performance for those based on the IMF dataset. In addition, the results are comparable for the two scarcity variables, both in terms of signs and level of significance of the estimated coefficients in the various estimated equations. Finally, the results are quite analogous in terms of significance and signs for the various functional forms used. Our estimates explain 13-40 percent of the variation in cooperation levels and all have significant fit or pseudo fit test values.

Table 7 presents results from a set of regressions based on application of the GLM and POISSON procedures that examine the relationship between the number of treaties in a river and the several independent variables identified in our empirical specification section. Observations used for this analysis include rivers with and without treaties. In this case a GLM and Poisson regression procedures are applied as the dependent variable (*Number of treaties*) assumes a discrete values 0, 1,…, 10 of treaties (Maddala 1983). The results strongly suggest that the relationship between scarcity and cooperation takes the shape of an inverted U curve, that governance in the basin countries is an important factor, that trade and treaty cooperation are complementary, and that geography is not conclusive in explaining differences in level of cooperation, as only the *Through-border* geography has several significant coefficients. Since the IMF-based and the UN-based trade variables provide similar results, we present selected regressions for various specifications of IMF and for UN trade variables.

Table 8 presents results from a set of regressions based on application of the OLS procedure that examines the relationship between the number of treaties in a river and the several independent variables identified in our empirical specification section. Observations used for this analysis include rivers with treaties only. All variables are with expected signs, and among the geography variables the *Through-border* is significant in only one equation.

Table 9 presents results from an analysis of those observations where only rivers with water allocation treaties are included. We used two sets of dependent variables: *Number of treaties*, and *Share of water allocation issues*. A GLM estimation procedure was applied to regressions with *Number of treaties* as a dependent variable, and an OLS estimation procedure was applied to regressions with *Share of water allocation issues* as a dependent variable. The estimated coefficients are significant, and all the variables of interest had the expected signs. The results suggest that water scarcity and trade are the major explanatory variables of cooperation between basin riparian states. In the case of regression (3) the *Through-border* was found to be significant in explaining lower levels of cooperation compared to the other geographies. However it is significant only in the OLS equation. Although this paper argued that the results stemming from the geography variable may be ambiguous, the findings here may indicate that given the reciprocal nature of the *Border-creator* configuration, states might voluntarily abate pollution and informal cooperation would replace formal cooperation.

The two scarcity variables that were used— *Water scarcity intercept* and *Water scarcity slope* (with the variations related to the various data sets), support our hypotheses regarding the *scarperation* relationship. The first relates scarcity to the intercept of the water availability per capita of river riparians. Hence, higher values express lower scarcity levels. The second relates scarcity to the reduction in annual water availability as measured by the slope of the water scarcity of river riparians. Hence, higher absolute values indicate higher levels of scarcity. We calculated the level of maximum cooperation, using the results in Tables 7 and 8. In the case of *Water scarcity slope*, maximum cooperation occurs where the value of annual reduction in available water per capita is around –22. In the case of *Water scarcity intercept*, maximum cooperation occurs where the value of the intercept of available water per capita is around 190. These results suggest some policy implications discussed in the conclusion. The estimated coefficients of equations with the *Water scarcity slope* are not presented due to space considerations.

The trade variables are consistently stable in the majority of the estimates. For example, the linear estimates of *Trade dependency* and *Trade dependency* (IMF) suggests a reduction range of between 0.12 to 1.8 treaties per river, on average, with increase in trade share within the ranges observed in the sample. The quadratic estimates of *Trade dependency* (UN) and *Trade dependency* (IMF) are quite similar. Maximum treaty cooperation is observed for both trade variables at around 0.10-0.12 and then declines as trade share increases. Observing the range of the trade variables in the Appendix suggests that the negative tradeoff between trade and treaty substitution holds for between 30-60 percent of the range of the trade variables (beyond the value of 0.10-0.12), which again supports our model of substitution between the two types of cooperation—treaty-based cooperation and trade-based cooperation. Schneider and Schulze (2003:12) define a linear relationship as "unconditional impact" and a quadratic relationship as "conditional impact" of interdependency level (e.g., trade) on conflict level among two nations.

CONCLUSION

Water scarcity has been argued and shown to be a major factor explaining cooperation among two riparian states sharing a river. Our proposed models, applying the theory of *scarperation* to the overall dataset of documented international rivers and various bilateral treaty datasets explain up to 40 percent of the variation in cooperation among the basin riparian states, depending on the way cooperation is measured. The scarcity variables are significant and their signs support our hypotheses regarding the inverted U curve scarcity-cooperation relationship.

Trade is an important determinant of cooperation. Riparians, facing scarcity, may either arrange the use of their scarce water resources via a treaty or trade (and indirectly exchange [virtual] water). The trade variables turned out to be among the most significant ones in our analyses.

Governance levels in the basin are also significant in explaining levels of cooperation. The conclusion from our research is that better overall governance levels and domestic institutional stability for the two riparian states increases cooperation levels.

The role of geography is either insignificant or ambiguous in most estimated relationships. Geography may, therefore, not be important in explaining the level of cooperation. However, as Dinar S. (2006b, 2007) has shown, geography may be important in explaining treaty design and the allocation of costs and benefits.

Some of the descriptive results also provide useful information for international bodies dealing with water-related conflicts. We found that there is a trend of an increased number of treaties signed in recent years. This is contrary to the popular and alarmist belief that water scarcity is likely to lead to conflict and even wars. Moreover, trends in treaty composition over time suggest that the treaties in recent years are more likely to address more issues than the treaties that have been signed in earlier years of the dataset. These scarcity issues include hydropower, pollution control, and flood protection.

Another important trend we observed in the treaty content is a change from a focus on water allocation and hydropower to issues of pollution and flood control. Does this mean a change in the nature of scarcity, or change in values riparian states assign to different scarcity issues? Understanding these trends will be the subject of future research.

Finally, and as can be ascertained from the Appendix, it is apparent that the mean levels of scarcity in our basin sample are already beyond the values leading to maximum cooperation. These results suggest that states, regional and international institutions need to be able to foster new ideas for initiating cooperation. Such initiatives may include: issue-linkage, side-payment transfers, and attractive investment arrangements.

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Figure 1: Water availability (m^3 per capita) in Angola and Austria between 1955-2050.

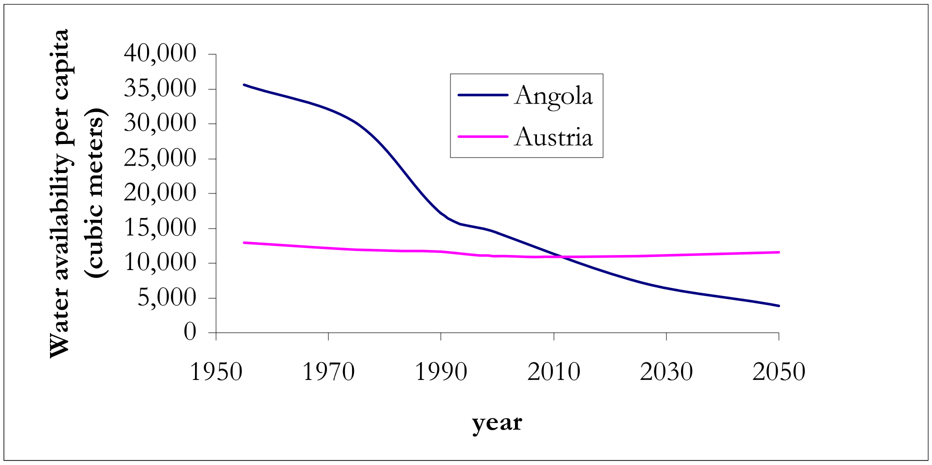

Table 1: Principal Component Variables

PC Variable	*Water scarcity intercept*	*Water scarcity slope*	*Water scarcity intercept*	*Water scarcity slope*	*Water scarcity intercept*	*Water scarcity slope*	treaty issues (full set)	treaty issues (subset with treaties only)	treaty issues (subset with treaties only)
Dataset	Full dataset		Treaties only		Water allocation treaties only		Full dataset	Treaties only	Water allocation treaties only
Eigenvector									
CNTRY1_INT	0.7071		0.7071		0.7071				
CNTRY2_INT	0.7071		0.7071		0.7071				
CNTRY1_SLP		0.7071		0.7071		0.7071			
CNTRY2_SLP		0.7071		0.7071		0.7071			
SHARE_WTR							0.6239	0.5883	-0.6220
SHARE_HDR							0.4884	0.4261	0.1235
SHARE_PLT							-0.6024	-0.6572	0.5249
SHARE_FLD							-0.0408	-0.2145	0.5314
SHARE_GEN							-0.0876	-0.0476	-0.2001
Percent of explained Standardized Variance	0.891	0.891	0.848	0.848	0.852	0.853	0.893	0.875	0.858

Table 2: Distribution of the river geographies in the data set (treaty and non treaty rivers)

Geography	Frequency	Percent	Dummy Variable
1	100	44.2	Through Border
2	16	7.1	Border Creator
3	32	14.2	Other
4	33	15.0	
5	9	4.0	
6	2	0.9	
7	14	6.1	
8	11	4.9	
9	3	1.3	
10	1	0.4	
11	1	0.4	
12	1	0.4	
13	3	1.3	
Total	226	≅100.0	

Table 3: Distribution of the treaties per river in the data set

Treaties per River	**Frequency**
1	66
2	90
3	42
4	12
5	35
7	7
9	9
10	10
Total	271

Note: 86 rivers do not have treaties and were not included in this table.

Table 4: Distribution of Water Treaty signature years (1850-2002)

Treaty Year (25 year intervals)	Number	Percent	Cumulative
1850	8	2.9	2.9
1875	2	0.7	3.67
1900	20	7.4	11.1
1925	36	13.3	24.3
1950	103	38.0	62.4
1975	99	36.5	98.9
2000 (-2002)	3	1.1	≅100.0
Total	271	≅100.0	

Note: Number of treaties refers to the years after that indicated in the first column.

Table 5: Distribution of treaties with number of issues over time

Year	**1 Issue**	**2 Issues**	**3 Issues**	**4 Issues**
1850	8	0	0	0
1875	2	0	0	0
1900	18	1	0	0
1925	23	7	2	0
1950	62	27	6	7
1975	66	10	18	5
2000	3	0	0	0
TOTAL[a]	182	45	26	12

[a] The table includes a total of 265 treaties. However, 6 additional treaties are based on general issues only and are not included in this table.

Table 6: Distribution of Treaty/Issues over time.

Year	Water Allocation	Hydropower	Pollution Control	Flood Protection	General Issues
1850	8				
1875					2
1900	16	1			3
1925	19	8	4	7	5
1950	44	47	38	26	7
1975	39	20	65	27	9
2000	1				2
Total	127	76	107	60	28

Note: Number of treaties refers to the years after that indicated in the first column.

Table 7: Results of the cooperation estimates applied to the full data set (Poisson and Normal distributions)

Dataset Specifications	All rivers					
Dependent Variable	*Number of treaties*					
Estimation Procedure	POISSON (1)	POISSON (2)	GLM (3)	GLM (4)	GLM (5)	GLM (6)
Water scarcity intercept	4.59e-3** (2.17)	5.16e-3*** (2.93)	5.91e-3* (1.77)	6.03e-3* (1.79)	5.76e-3* (1.81)	5.28e-3** (1.81)
Water scarcity intercept squared	-1.05e-5*** (-2.62)	-1.25e-5*** (-3.51)	-1.35e-5*** (-2.34)	-1.34e-5** (-2.32)	-1.20e-5** (-2.21)	-1.05e-5*** (-2.35
Through-border	-0.286* (-1.72)	-0.275** (-2.07)	-0.274 (-1.07)	-0.263 (-1.01)	-0.429* (-1.72)	-0.285 (-1.44)
Border-creator	-0.446 (-1.06)	-0.250 (-0.60)	-0.728 (-1.30)	-0.724 (-1.30)	-0.763 (-1.29)	-0.405 (-0.97)
River riparians governance			0.109*** (2.78)	0.112*** (2.79)		
Country 1 governance	0.230*** (4.04)	0.204*** (4.98)			0.469*** (3.25)	0.320*** (3.71)
Country 2 governance	0.260*** (4.33)	0.214*** (4.27)			0.555*** (4.78)	0.324*** (4.26)
Country 1×Country 2	-0.041*** (-4.63)	-0.042*** (-5.13)			-0.092*** (-4.34)	-0.070*** (-4.84)
Trade importance (IMF)	10.79*** (2.64)				21.76** (1.87)	
Trade importance squared (IMF)	-44.49*** (-3.14)				-77.49** (-2.27)	
Trade importance (UN)			-6.707*** (-3.37)	-0.625*** (-3.24)		
Trade dependency (IMF)		22.22*** (6.47)				41.81*** (3.13)
Trade dependency squared (IMF)		-86.85*** (-5.13)				-159.14*** (-2.98)
Constant	-1.03*** (-2.88)	-1.17*** (-4.01)	0.625 (1.49)	-0.558 (1.29)	-1.11** (-1.73)	-0.813 (-1.36)
No. of Observations	170	217	173	170	170	217
Log Pseudo Likelihood	-259.91	-301.22	-328.45	-324.22	-335.01	-377.42
Maddala R^2			0.27	0.28	0.32	0.33
Wald chi^2	70.03	116.81				
Pseudo R^2	0.13	0.17				

In parentheses are t-values. *** (=0.01); ** (=0.05); * (=0.10).

Table 8: Results of the cooperation estimates applied to the only-treaty data set

Dataset Specifications	Rivers with Treaties Only	
Dependent Variable	*Number of treaties*	
Estimation Procedure	OLS (1)	OLS (2)
Water scarcity intercept	9.08e-3*** (2.45)	5.65e-3* (1.78)
Water scarcity intercept squared	-1.50e-5*** (-2.52)	-9.21e-6* (-1.75)
Through-border	-0.239 (-0.96)	-0.315* (-1.61)
Border-creator	0.542 (0.70)	0.448 (0.58)
River riparians governance	0.048 (1.25)	
Country 1 governance		0.339*** (3.21)
Country 2 governance		0.365*** (3.73)
Country 1×Country 2		-0.068*** (-4.12)
Tradedependency (UN)		38.74*** (2.98)
Trade dependency squared (UN)		-134.19*** (-2.82)
Trade dependency (IMF)	47.61*** (3.27)	
Trade dependency squared (IMF)	-192.57*** (-3.31)	
Constant	-0.017 (-0.03)	-0.723 (-1.11)
No. of Observations	137	138
F-test	4.34***	4.91***
Adjusted R^2	0.28	0.31

In parentheses are t-values; *** (=0.01); ** (=0.05); * (=0.10).

Table 9: Results of the cooperation estimates applied to the only water-issues treaties

Dataset Specifications	Rivers with (water allocation issues) Treaties Only		
Dependent Variable	*Number of treaties*	*Number of treaties*	*Share of water allocation issues*
Estimation Procedure	GLM (1)	GLM (2)	OLS (3)
Water scarcity intercept	10.0e-3** (2.05)	9.16e-3** (1.87)	5.04e-3* (1.59)
Water scarcity intercept squared	-1.81e-5** (-2.17)	-1.66e-5** (-2.02)	-1.10e-5** (-2.01)
Through-border	-0.061 (-0.19)	-0.111 (-0.36)	-0.393* (1.54)
Border-creator	0.212 (0.29)	0.231 (0.31)	-0.801 (-1.32)
River riparians governance	0.227*** (3.68)	0.217*** (3.55)	
Country 1 governance			0.535*** (3.66)
Country 2 governance			0.633*** (4.06)
Country 1×Country 2			-0.97*** (-3.74)
Trade importance (UN)			-3.84** (-1.83)
Trade dependency (UN)		30.36** (1.96)	
Trade dependency squared (UN)		-148.06** (-2.38)	
Trade dependency (IMF)	36.68** (2.19)		
Trade dependency squared (IMF)	-184.02*** (-2.58)		
Constant	-0.961 (-1.03)	-0.571 (-0.70)	-1.32* (-1.83)
No. of Observations	88	89	88
Log Pseudo Likelihood	-149.39	-152.04	
Maddala R^2	0.40	0.39	
F-test			5.30***
Adjusted R^2			0.22

In parentheses are t-values. *** (=0.01); ** (=0.05); * (=0.10).

Appendix: Descriptive statistics

Variable	Mean	Std. Dev.	Min	Max	Obs.
Country 1 governance	3.97	2.77	1.00	9.77	226
Country 2 governance	3.94	2.44	1.00	9.77	226
River riparians governance	19.46	22.77	0.00	86.27	226
Through-border	0.44	0.50	0.00	1.00	226
Border-creator	0.07	0.26	0.00	1.00	226
Treaty/no-treaty	0.62	0.48	0	1	226
Number of treaties	1.27	1.61	0.00	10.00	226
Water scarcity intercept	255.51	170.19	3.79	587.97	226
Water scarcity slope	-31.90	22.38	-75.82	1.27	226
treaty issues (full set)	0.68	0.32	-0.60	0.62	226
treaty issues (subset with treaties only)	0.03	0.33	-0.69	0.64	140
treaty issues (subset with water allocation treaties only)	-0.177	0.299	-0.625	0.355	90
Share of water allocation issues	0.21	0.31	0.20	1.00	90
Trade importance (IMF)	0.021	0.048	2.85e-06	0.173	169
Trade dependency (IMF)	0.038	0.085	8.20e-06	0.299	171
Trade importance (UN)	0.128	0.036	3.77e-06	0.284	215
Trade dependency (UN)	0.081	0.333	3.75e-05	0.201	208

Note: In *italics* are variables that were included in the econometric analysis.

Notes

[i] The term used in international law to refer to a country or nation-state. We use state and country interchangeably.
[ii] While the popular 'water-wars' thesis has largely been discredited (Wolf 1998) certain authors have argued that violent conflict over water, if not war, is still possible (Homer-Dixon 1999 is one of the most recent examples). Scholarship is in agreement that 'conflicts of interest' over water are quite common.
[iii] Food and Agriculture Organization of the United Nations, Legislative Texts and Treaty Provisions Concerning the Utilization of International Rivers for Other Purposes than Navigation (1978, 1984); League of Nations Treaty Series (London: Harrison and Sons, 1920-1946); United Nations Treaty Series, (New York: United Nations, 1947-present); United States Department of State, Treaties in Force: A list of Treaties and Other International Agreements of the US, http://www.state.gov/s/l/treaties/; Transboundary Freshwater Dispute Database, International Freshwater Treaties Database, Oregon State University, http://www.transboundarywaters.orst.edu/projects/internationalDB.html; Food and Agriculture Organization Treaty Index (FAOLEX), http://faolex.fao.org/faolex/; Dinar, *International Water Treaties*; United Nations Treaty Collection Website, http://untreaty.un.org/; International Materials, International Water Law Research Institute, University of Dundee, http://www.dundee.ac.uk/iwlri/Research_Documents_International.php
[iv] Wolf, Natharius, Danielson, Ward and Pender (1999, 424) documented 261 international river basins, 176 of which are shared by just two states. They use the river basin as the observation unit rather than the river itself, as used by Dinar S. (2007)
[v] In their study, Wolf, Yoffe and Giordano (2003) and Yoffe, Wolf, and Giordano (2003) consider scarcity but they only use this type of measurement as a) both an indicator, among other variables, to assess which river basins are at risk of conflict among the respective riparian states in the coming 5-10 years by showing 'that the likelihood and intensity of dispute rises as the rate of change within the basin exceeds the institutional capacity to absorb that change', and b) to regress against their overall conflict/cooperation basins at risk event intensity scale (which ranges from events that prescribe to a 'formal declaration of war' to the 'voluntary unification of both countries into one nation'). In general they find that water stress is not a significant indicator of water conflict or cooperation; Hensel, Mitchell, and Sowers (2006) consider international agreements and scarcity, among several other variables to explain militarized disputes and conflict resolution, yet their model regards scarcity and institutions as distinct independent variables; Gleditsch, Furlong, Hegre, Lacina, and Owen (2006) consider the relationship between overall conflict intensity, geography and water scarcity.. A related earlier study by Toset, Gleditsch, and Hegre (2000) considers water scarcity, contiguous countries and joint rivers and their relationship to overall conflict behavior. Both the 2006 and 2000 works do not consider cooperation or international water agreements.
[vi] It is important to note that the authors' study was aimed at demonstrating the relevance of two opposing theories with regards to resources and conflict. The first theory is the common resource scarcity conflict contention. The latter theory is the resource curse theory contending that conflict is most likely where resources are abundant. Depending on the circumstances, the authors argue, both claims could be correct.
[vii] The theory also incorporates scarcity in hydropower, flood-control, and pollution issues. For example, if no, or very little, pollution exists in the river there is no incentive to negotiate a pollution abatement agreement. At the same time, very high pollution requires the riparians to exert sizeable costs and efforts to abate the pollution, which may be a deterrent to pollution abatement.
[viii] Before the early 1990s the Jordan River, for example, was not governed by any formal treaties.
[ix] Goldstein (1992) developed a scale that maps conflict and cooperation among states onto a scale that ranges between war, as the most conflictive status, to extending military assistance, as the most cooperative status. Trade agreements are ranked at the second highest cooperative status on that scale.
[x] A riparian state, facing water scarcity, may also trade with a partner outside the basin. This is addressed in our empirical analysis by one of the trade variables.
[xi] One example of a treaty negotiated between two non-democratic riparians is the 1959 Nile Rive Agreement signed between Egypt and Sudan. The 1994 Jordan River Agreement is an example of a treaty signed between a democracy and a non-democracy.
[xii] Several agreements signed between downstream India and upstream Bhutan demonstrate such a benign relationship. The 1973 Colorado River Agreement between upstream United States and downstream Mexico is one example of the latter scenario. If one was to consider GDP per capita (rather than GDP which has been used as a measure encompassing military might) as a means to compare riparians,the 1961 Columbia River Agreement signed between Canada and the United States could be one example of a treaty signed between symmetric countries.

[xiii] For example, the California water aqueduct transfers water from northern rivers such as the Sacramento, San Joaquin and others to southern California; Israel's National Water Carrier transfers water from Lake Kinneret, located in the north of the country, to the dry Negev; Egypt transfers Nile waters to the Western Desert; China transfers Yangtze River basin waters to the Hai River basin.

[xiv] Some of the earlier treaties in our database may no longer be in force for a variety of reasons. However, because our approach considers scarcity as a long-term phenomenon and since we argue that agreements are a response to such scarcity we are interested in all treaty observations throughout time.

[xv] For example, for a given river the *Share of water allocation issues* = number of treaties with water allocation issues / (number of treaties with water allocation issues + number of treaties with hydro issues + number of treaties with pollution issues + number of treaties with flood issues + number of treaties with general issues)

[xvi] Scarcity can be expressed in economic terms as well. Some suggest using value of water or price of water expecting that higher values express scarcier water situation. However, such information is not available at the basin level.

[xvii] As our data spans over an extensive time period, we encounter changes in state regimes, the break-up of states, and the formation of new states. Therefore, for several states, we may find gaps in data availability over time. We filled this gap by extrapolating forwards and backwards, based on specific year data availability.

[xviii] On a technical note, relationships based on [2] will be estimated using Logit procedures, while relationships based on [3] and [4] will be estimated using Probit, Poisson, or OLS procedures. For the reader needing more details please refer to Maddala (1983).

[xix] For equations with *Treaty/no-treaty*, values of the independent variable are 0/1 and a Logit procedure was used; for *Number of treaties* applied to the full data set, values are in the range of 0-10 and a Poisson and GLM procedures are used; for *Number of treaties* applied to the subset of treaties only, values are in the range of 1-10 and an OLS procedure is used; for *Share of water allocation issues* applied to the subset of treaties only, values are in the range of r_2-R_2 and an OLS procedure is used; for *Share of water allocation issues* applied to the subset of treaties with water allocation issues only, values are in the range of r_3-R_3 and an OLS procedure is used.

[xx] In the process of merging the basin dataset with the trade datasets, we lost several observations due to lack of GDP data for several countries. Principal component analyses were performed for each subset. While the appropriate principal component values were assigned in the regression analysis based on the data subset, we present in the table only the values for the full dataset distinguished by types of treaties.

[xxi] Through Border=1: upstream-downstream; Border Creator=2: State A-State B; Mixed=3: Upstream-Downstream; Through Border but Creates Border=4: Upstream-Downstream; Partial Border Creator=5; Upstream-Downstream; Partial Border Creator but Returns=6: Upstream Downstream; Through Border x2=7: Upstream-Downstream; Partial Border Creator x2=8: Upstream-Downstream; Border Creator but Enters States=9: State A-State B/downstream; Partial Border Creator x2 But Enters State Second=10: Upstream-Downstream; Partial Border-Creator but Returns and Then Enters Other State=11: Upstream-Downstream; Partial Border Creator x2 but Enters State First=12: Upstream-Downstream; Mixed Zig-Zag=13: Upstream-Downstream.

[xxii] This result supports the findings in Yoffe, Ward and Wolf (2000), which is based on an assessment of country positions and claims noted and tracked in the press. More importantly, these results contradict statements made by various experts that a war over water is imminent.

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