

Climate Change, Conflict, and Cooperation

Global Analysis of the Resilience of International River Treaties to Increased Water Variability

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June 2014



Abstract

Although water variability has already been observed across river basins, climate change is predicted to increase variability. Such environmental changes may aggravate political tensions, especially in regions that are not equipped with an appropriate institutional apparatus. Increased variability is also likely to challenge regions with existing institutional capacity. This paper argues that the best attempts to assess the ability of states to deal with variability in the future rest with considering how agreements have fared in the past. The paper investigates to what extent particular mechanisms and institutional designs help mitigate inter-country tensions over shared water. The analysis specifically focuses on identifying which water allocation mechanisms and institutional features provide better opportunities for mitigating conflict given that water allocation issues tend to be most

salient among riparians. Water-related events from the Basins at Risk events database are used as the dependent variable to test hypotheses regarding the viability, or resilience, of treaties over time. Climatic, geographic, political, and economic variables are used as controls. The analysis is conducted for the years 1948–2001 with the country dyad as the level of observation. Findings pertaining to the primary explanatory variables suggest that country dyads governed by treaties with water allocation mechanisms exhibiting both flexibility and specificity evince more cooperative behavior. Country dyads governed by treaties with a larger sum of institutional mechanisms likewise evince a higher level of cooperation, although certain institutional mechanisms are more important than others.

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Climate Change, Conflict, and Cooperation: Global Analysis of the Resilience of International River Treaties to Increased Water Variability*

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JEL Classification: Q 25, Q 28, Q 54,

Key Words: Water variability, climate change, international water treaties, water allocation mechanisms, institutional mechanisms, conflict, cooperation

* This paper received support from the Research Support Budget of the World Bank.

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1. INTRODUCTION

Annual and seasonal variability in river flow is well known and well documented by riparian communities, scientists, engineers and policy makers (Milly et al., 2005; Milliman et al., 2008). Yet, the projected effects of climate change may render future river flow variability outside the bounds of previously observed runoff events (IPCC, 2007: 31; Milly et al., 2008). These effects may be particularly salient in international river basins where several riparians are affected. For example, rivers such the Jordan and Tigris-Euphrates in the Middle East are expected to experience reductions in stream flow. Meanwhile, other basins such as the Congo in equatorial Africa and the La Plata in South America will experience increases in flow, adding to the salience of issues such as floods and inundation (Arnell, 1999 and 2004; Milly et al., 2005).

Climate change and water variability are also expected to intensify security concerns within or between countries or within river basins (Brown, 1989; Gleick, 1989; Nordås and Gleditsch, 2007). A report titled *National Security and the Threat of Climate Change* attests that one of the most destabilizing impacts from climate change will be in the form of reduced access to freshwater (CAN, 2007: 13-16). Despite the often cited claim that ‘water is a source of cooperation, rather than violent conflict’ (Wolf and Hamner, 2000), some observers have revived ‘water wars’ prognostications given the effects of climatic change (Working Group II, n.d; Schwartz and Randall, 2003). Whether in the form of heightened political tensions or the more extreme violent exchange, climate change and the projected increase in water variability may further complicate existing shared water management strategies.

Given the links between climate change, water variability, and inter-state tensions, the role of institutions in assuaging potential conflicts between states seems paramount (Salehyan, 2008: 317). Such allocational and institutional mechanisms may confer resilience allowing states to successfully deal with hydrologic changes that may have economic, social, environmental, and political consequences (Adger et al., 2005; Walker et al., 2006). In other words, while the mere existence of institutions may bestow resilience, this research is primarily interested in investigating how particular regime designs fare in the face of variability. Consequently, this research is interested in examining those river basins governed by treaties.

Guided by recent research exploring the utility of particular water allocation mechanism designs as well as various institutional mechanism designs in international water agreements

(e.g. Drieschova, Giordano, and Fishhendler, 2008; Stinnet and Tir, 2009; De Stefano et al., 2012; Drieschova and Fishhendler, 2011), we empirically examine the impact of these allocation mechanisms and treaty institutions on conflict and cooperation under conditions of water variability. When negotiating an agreement, parties must come to some sort of an agreement on which allocation mechanisms and institutional designs they will adopt. It is the efficacy of these allocation and institutional mechanisms, that we examine ex post.

In the following section we examine in more detail the relationship between climate change, water variability, and security. We then discuss the various allocation mechanisms and institutional designs that may promote resilience in river basins in the face of water variability in Section 3. In Section 4 we explain our methodology and describe our dataset and choice of variables, including climatic, geographic, and socio-economic variables that may also be important in evaluating treaty resilience. The latter are used as control variables in our empirical study. We describe the data utilized and propose hypotheses regarding the effect of the different mechanisms and institutional arrangements on conflict and cooperation. Section 5 provides regression results and finally, Section 6 provides conclusions with policy implications from our study.

2. CLIMATE CHANGE, WATER VARIABILITY, AND SECURITY

One of the most forceful links made between climate change and water variability came out of a 2008 Technical Report of the Intergovernmental Panel on Climate Change claiming that increased precipitation intensity and variability is projected to increase the risks of flooding and drought in many areas, affecting food stability as well as affecting water quality and exacerbating many forms of water pollution (Bates et al., 2008: 3-4). These hydrological changes will in turn increase the vulnerability of certain regions and communities and present substantial challenges to water infrastructure and services (Vörösmarty et. al., 2000: 287; Kabat et al., 2002: vii; IPCC, 2007: 49). According to Barnett, climate change may have indirect negative effects that can undermine the legitimacy of governments, undermine individual and collective economic livelihood, and affect human health (2003: 9). Regions comprised of developing countries, which may lack the capacity to deal with and adapt to climate change impacts and are more reliant on climate sensitive resources, may fare even worse (Barnett and Adger 2007: 648).

Therefore, the increase in future water variability forecasted by most climate change scenarios is one form of change that may alter current hydropolitical balances and already observed changes in mean water flows (Dai et al., 2009). As explained by the IPCC, the beneficial impacts of increased annual runoff in some areas are likely to be tempered by negative effects of increased precipitation variability and seasonal runoff shifts on water supply, water quality and flood risk (2007: 49). According to Buhaug, Gleditsch, and Thiesen (2008: 6), climate-induced events such as floods and droughts are expected to constitute a large threat to human security and the prospects of sustained peace. Consequently, inter-state tensions may rise as water variability increases (Bernauer and Siegfried, 2012). Evidence already suggests that the likelihood of political tensions is related to the interaction between variability, or rates of change within a basin, and the institutional capacity to absorb that change (Wolf, Stahl, and Macomber, 2003; Stahl, 2005). In this context, climate change may further act as a ‘threat multiplier’ exacerbating existing economic, social, and political problems (CAN, 2007: 43).

3. CLIMATE CHANGE, WATER VARIABILITY, AND TREATY CAPACITY

Given the potential security implications of climate change in international river basins, the sheer existence of water treaties may prove pivotal for hydro-political related stability (De Stefano et al., 2012). However, even in regions already governed by an institutional apparatus, such as a water treaty, climate change and variability could nonetheless affect the ability of basin states to meet their water agreement commitments and effectively manage transboundary waters (Ansink and Ruijs, 2008; Drieschova, Giordano, and Fischhendler, 2008; Goulden, Conway, and Persechino, 2009). This may be particularly salient for agreements that are not properly designed to deal with environmental changes and similar forms of uncertainty. Increased variability may thus raise serious questions about the adequacy of many existing transboundary arrangements even in areas that have exemplified cooperation in the past (Cooley et al., 2009: 28). As such, administrative instruments for transboundary basins, such as treaties and agreements, should be assessed for the potential impacts of climate change (Alavian et al., 2009: 24; WDR, 2011: 230).

A large spectrum of empirical research has already investigated several important factors associated with treaty formation (Espey and Towfique, 2004, Tir and Ackerman, 2009, Dinar et al., 2011, Brochmann and Hensel, 2011, Zawahri and Mitchell, 2011). In addition, there has been

a growing body of literature investigating the importance of treaties in fostering cooperation and mitigating conflict between river riparians. Brochmann and Hensel (2009), for example, find that although agreements may not necessarily prevent the emergence of country grievances, such claims are often resolved peacefully when treaties already exist. In a related article, Brochmann (2012) considers post-treaty hydro-political relations among the treaty signatories and finds that treaties distinctly contribute to cooperative behavior.

As the existing qualitative literature points out, the presence (absence) of particular allocation and institutional mechanisms may impact upon the resilience of treaties given water variability and climatic change (Odom and Wolf, 2008: 14; Gleick, 2010). In other words, such mechanisms and stipulations can potentially mitigate grievances and enhance cooperation over water (Cooley et al., 2009; Fischhendler, 2004). Focusing on the Jordan River, Fischhendler (2004; 2008) claims that ambiguity in terms of allocation mechanisms allowed parties to reach an agreement, but led to controversy in later years when the basin was facing drought. Assessing the Ganges Water Treaty, Salman and Uprety (2000) find that the 1996 Ganges River Treaty incorporated institutional mechanisms to address important issues such as water allocation, yet ignored others, including water augmentation and flood mitigation. The lack of recourse to deal with water variability contributed to political tensions between India and Bangladesh.

This study seeks to contribute to existing empirical literature on treaty design (Tir and Stinnett, 2012; De Stefano et al., 2012) by assessing the effects of water variability on conflict and cooperation over water, examining an array of important water allocation and institutional treaty mechanisms. We discuss these treaty instruments below in the context of the extant literature and offer a number of hypotheses regarding their impact on cooperation and conflict.

3.1. Allocation Mechanism Design

Examining the relationship between allocation mechanisms and water variability, Drieschova, Giordano, and Fischhendler (2008) concluded that a treaty's *flexibility* determines its resilience to climate change and increased water variability. Such a characteristic becomes particularly relevant when considering treaties that are distributive in nature, allocating water between the parties. If the allocation mechanism codified in the agreement is rigid and inflexible the parties are less able to honor their treaty commitments once water availability changes due to

environmental conditions. The authors enumerate several allocation mechanisms, which are echoed in a number of other studies (e.g. Gleick 1992; 139; Wolf and Hamner, 2000; Drieschova, Fischhendler, and Giordano, 2011).

First, the authors consider direct allocation mechanisms which clearly stipulate how the water is to be divided. A ‘direct flexible’ allocation mechanism is one that divides the resource by percentages. Such flexible mechanisms may also include provisions that allow countries to average a particular allocation over a given set of time or make-up transfers of water which they owe their fellow riparian from a previous period in a following period (McCaffrey, 2003: 160). Mechanisms that recognize that water allocations may have to be reduced due to water availability are also considered to bode well for flexibility, as are mechanisms that specify that an upstream riparian deliver a minimum flow to a downstream riparian (Cooley et al., 2009: 15-16). A ‘direct fixed’ allocation mechanism, on the other hand, divides resources by absolute volumes and effectively ignores the uncertainty that may arise given climatic change (Dreischova and Fishhendler, 2011: 12). The former stipulation is preferable in situations of high water variability since it is not clear if the same stock amounts of water that were available, say when the treaty was negotiated, will be available uniformly throughout time.¹ The authors also consider indirect allocation mechanisms and general principles such as ‘consultations between the parties’ and ‘prioritization of uses’ and ‘equitable utilization’ and ‘needs-based’ approaches, respectively. While these indirect stipulations and general principles exhibit flexibility they are also open-ended. Open-ended characteristics to a water allocation mechanism may be problematic in the context of climate change when more clear direction is required. According to the authors, it is specific, or direct, mechanisms that “ensure credibility and action, which appear to have a number of advantages for variability management” (2008: 7).

3.2. Institutional Mechanisms

Beyond the specific allocation mechanism pertinent for examining water quantity treaties, the type or design of institutional arrangements codified in the agreement may also be relevant to treaty resilience and stability (Barrett, 2003). Tir and Stinnett (2011), for example, have

¹ This distinction is likewise echoed in the Third Assessment Report. It was argued that “one major implication of climate change for agreements between competing users (within a region or upstream versus downstream) is that allocating rights in absolute terms may lead to further disputes in years to come when the total absolute amount of water available may be different” (IPCC 2001: 225).

demonstrated that treaties governing highly contentious issues, such as water quantity, tend to include such institutional provisions.

3.2.1. Enforcement, monitoring, conflict resolution, and joint commission

Both the various studies cited above as well as the so called institutionalist literature, enumerate a number of institutional mechanisms that likely add to the robustness of treaties. The TFDD identifies a number of such institutional mechanisms including enforcement, monitoring, conflict resolution, and a joint commission or organization. Enforcement mechanisms are imperative as they provide states, or other relevant parties, the power to punish defectors (Susskind, 1994: 99-121). The agreement is consequently more robust, effective, and credible. Enforcement may be facilitated by the presence of a monitoring mechanism since states often fear that fellow states to an agreement may cheat or free-ride (Keohane and Martin, 1995). A monitoring mechanism potentially provides a means through which the parties can scrutinize each other's behavior or simply a medium for investigating the hydrological environment of the river basin. The presence of a conflict resolution mechanism could also prove invaluable. To the extent that the treaty stipulates how disputes are to be resolved among the parties or provides a forum for discussing resource and environmental changes not envisioned in the treaty, the more confident parties may feel that their concerns will be met in an amicable fashion (Drieschova, Giordano, and Fishhendler, 2008). Another mechanism that further signals that the treaty is more institutionalized and may overcome challenges across time is the existence of an international joint commission or committee. Such a joint body enables treaty signatories to confront environmental uncertainties as they arise or handle particularly technical information (Allan and Cosgrove, 2002: 66; McCaffrey, 2003: 160-161). In addition to being mandated with proposing plans and projects for implementation, the commission may also have a monitoring and conflict resolution mandate (Dombrowski, 2007: 113; Gerlak and Grant, 2009). In her study of the Indus Basin, for example, Zawahri (2009) finds that the Permanent Indus Commission (PIC) has essentially played an invaluable role in the treaty's implementation since 1960. In essence, to "manage the questions and issues that continuously arise as they develop their shared river and insure compliance with the [Indus Water Treaty], India and Pakistan have relied on the PIC" (Zawahri, 2009). She attributes a large part of stable cooperation over water that has existed

between the two riparians since the treaty's inception to the success of the PIC to negotiate, monitor, and manage. However, the mandate and strength of such international joint bodies may vary from an institution with "shallow cooperation with very loose institutional cooperation to a bureaucratic organization with formal meetings up to formal intergovernmental organizations" (Gerlak and Grant, 2009: 119-120; Drieschova and Fishhendler, 2011: 21).

3.2.2. Variability adaptation mechanisms

De Stefano et al. (2012) argue that variability management mechanisms create a means for dealing with climatic extremes such as droughts and floods or other specific variations and thus increase a river basin's resilience to water variability. Pertaining to water allocation treaties, in particular, adaptation mechanisms to drought may be highly pertinent. The literature points to a number of specific mechanisms treaties may employ to enhance resilience to drought. Combined with some of the allocation mechanisms discussed above, authors have pointed to: 'immediate consultations between the respective states', 'stricter irrigation procedures', 'water allocation adjustments', 'specific reservoir releases', and 'data sharing' (McCaffrey, 2003; Turton, 2003). Examples of treaties that have stipulated these mechanisms in some form, include the 1996 Ganges River Agreement, the 1997 Cuareim River Agreement, the 1970 Lake Lanoux Agreement, and 1989 Vuoksi River/Lake Saimaa Agreement, respectively. Arrangements such as desalination, wastewater reclamation and increased storage capacity have also been touted as important steps to augment supplies of water in times of drought (Dziegielewski, 2003: 324; Iglesias, Garrote, and Flores, 2007).

3.2.3. Self-enforcement mechanisms: Side-payments, benefit-sharing, and issue-linkage

Additional institutional mechanisms important for treaty resiliency are expressed through the so-called notion of 'self-enforcement' (Barrett 2003). To the extent that the treaty itself restructures the incentives of the parties towards cooperation, makes it more effective. While self-enforcement can take on a variety of forms, a number of identifiable strategies include: a) the use of financial transfers/side-payments and cost-sharing arrangements (Bernauer 1996; Weinthal 2000; Dinar 2006), b) the use of benefit-sharing schemes (Phillips et. al. 2006), and c) issue-

linkage (Wolf and Hamner 2000; Katz and Fischhendler 2011). All three strategies may be used to further bind the parties to the agreement's tenants by making it costlier to defect so long as benefits accrue from cooperation. Examples of treaties codifying such strategies include the 1973 Helmand River Agreement between Iran and Afghanistan, 1986 Orange River Agreement between South Africa and Lesotho, and 1998 Framework Agreement among various Central Asian countries.

4. METHODOLOGY

In this study, we seek to assess the efficacy of various allocation and institutional mechanisms designs under conditions of resource variability by evaluating their impact on instances of transboundary cooperation and conflict over time. Specifically, we seek to discern what types of allocation mechanisms – flexible vs. rigid, specific vs. non-specific – seem to promote cooperation more effectively. Similarly, we evaluate the importance of a series of institutional mechanisms, which, as detailed above, are expected to reduce conflict and promote cooperation. We present a description of the database and variables used to conduct these evaluations, and grounded in the theoretical discussion above include hypotheses regarding their expected impact. In terms of explanatory variables, we have two overall types: those representing type of allocation mechanism and those representing types of institutional mechanisms. A number of control variables are included representing climate variability as well as a variety of other factors that may impact conflict or cooperation between riparians. We explain each below and offer hypotheses as to their expected effects. We then follow with a description of the regression models used in this assessment.

4.1. Description of Dataset and Variables

We assembled a database of all treaties ratified between 1948 and 2001 and taking riparian signatory country pairs (dyads) as our unit of observation. Our analytical framework considers long-term trends and long range mean values for these variables and their effects on treaty resilience. A similar cross-sectional approach used to investigate environmental treaty formation or examine international water treaties has been adopted by Neumayer (2002a), Dinar et al. (2010), Dinar et al. (2011), and De Stefano et al. (2012).

In order to examine the resilience of treaties, we needed a measure of conflict and cooperation to use as a dependent variable. We developed such an indicator based on the water events stored in Oregon State University's (OSU)'s International Water Events Database, created under the framework of the Basins at Risk project (BAR) (Yoffe et al., 2003), which was recently updated (De Stefano et al, 2010), to consider water events in international river basins worldwide (for the period 1948-2008). Each event includes a brief summary and source of information, and is coded by date, country pair (dyad), basin, issue area, and intensity of conflict/cooperation. Each event is coded also according to the type of event (conflictive or cooperative) and its intensity using the BAR scale, which ranges from -7, the most conflictive (war), through 0 (neutral events), and up to +7, the most cooperative (voluntary merging of countries).

To extract the events relevant to treaties examined in this study we first re-coded the events by country-basin dyad so that we could relate the events for a specific international basin with the treaties signed by each pair of countries. Secondly, for each treaty, we identified which events had occurred after the signature of the agreement and, among those, which were relevant to water quantity or allocation. In cases where a treaty was replacing a preexisting agreement, the relevant events were assigned accordingly. Moreover, in cases where a treaty affected a specific sub-basin within a wider transboundary basin, we identified, based on the content of the event summary, countries' interactions relative to that specific sub-basin and assigned those to the corresponding agreement. The data processing produced a database listing the number and intensity (BAR values) of all the events relevant to each country-basin dyad and treaty issue. In order to treat the categorical BAR values as ordinal values, we use the anti-logged equivalent for each event intensity level. This is in line with previous studies using BAR events data (e.g. Yoffe and Larson 2001; Brochmann 2012).

4.1.1. Allocation mechanisms

Based on a review of all available international water allocation treaties housed in the Transboundary Freshwater Dispute Database (TFDD) treaty databank and a joint TFDD-International Water Management Institute (IWMI) categorization, a set of allocation mechanisms were identified.² These mechanisms were then further assessed as to their flexibility and

² The list includes allocation mechanisms such as "fixed quantities," "fixed quantities which vary according to water availability," "fixed quantities recouped in the following period," "percentage," "prior approval," "consultation," "prioritization of uses."

specificity based on the typology inferred from Drieschova, Giordano, and Fischhendler (2008).³ While these mechanisms may not be substitutable (as different contexts may warrant different mechanisms), we expect those countries governed by treaty mechanisms that display both flexibility and a more specific, or direct, allocation regime to exhibit more cooperation in their hydro-relations.

4.1.2. Institutional mechanisms

As elaborated in the previous section, treaties contain a range of institutional arrangements that are expected to facilitate cooperation, by reducing uncertainty, providing monitoring and enforcement, introducing conflict resolution mechanisms, allowing side-payments, etc. In this study we document the absence or presence of a number of such institutions, including whether or not the treaty covering the particular dyad contains an enforcement mechanism, a self-enforcement mechanism, provision for monitoring, a conflict resolution procedure or mechanism, a river commission or some sort of standing body to oversee and manage riparian relations, and some arrangement for adaptive management.

We assess both the total number of such institutions as well as the presence or absence of each individual type. In all cases, theory predicts that, *ceteris paribus*, the more such institutions the greater the level of cooperation (and lower level of conflict). We include both a count variable (number of institutional mechanisms), as well as a binary variable indicating the presence or absence of each type of institutional arrangement, in order to isolate the impact of each one.

³ For example, the “fixed quantities” allocation mechanism is not flexible yet specific. On the other hand, the “percentage” allocation mechanism is both flexible and specific. While not as flexible as the “percentage” allocation mechanism, the “fixed quantities which vary according to water variability” allocation mechanism does evince a level of flexibility (as the allocation is based on available water) as well as specificity. The “prior approval” allocation mechanism, like the “consultation” and “prioritization of uses” allocation mechanisms, is flexible but relatively ambiguous and open ended in specifying actual allocations since the agreement itself stipulates no direct allocation amounts.

4.1.3. Control variables

4.1.3.1. Water variability

While water variability is an inherent characteristic across river basins, climate change is predicted to intensify such variability. All else being equal, higher water variability has been shown to lead to political tensions between states sharing river basins (Yoffe et al. 2004; Stahl 2005: 277).⁴ Results presented in Wolf, Stahl and Macomber (2003: 1), for example, demonstrate that “extreme events of conflict were more frequent in marginal climates with highly variable hydrologic conditions, while the riparians of rivers with less extreme natural conditions have been more moderate in their conflict/cooperation relationship.”

For the most part, empirical studies investigating international conflict and cooperation over water and have utilized static measures of water availability. Given that this study aims to look at the effects of water variability on treaty resilience over time, we use a measure of past hydrological variability. In particular, we use the coefficient of variation (CV) for precipitation in each basin and sub-basin. Precipitation data from the Climate Research Unit (Mitchell and Jones, 2005) downloaded at the CGIAR website⁵ are the input values for the precipitation CV. The CV is calculated to measure inter-annual precipitation over all monthly observations for the time period (1901-2001). Our rationale for calculating the CV based on this extended time period is based on our empirical assumption that water variability is embedded in the basin’s history and that it is long-term water variability that affects conflict and cooperation over time in a given basin. The variability measure proposed here is, therefore, not year specific. We likewise follow precedent set by previous studies using a CV as well as other measures of water availability (Dinar et al. 2010; Dinar et al. 2011; De Stefano et al. 2012).

All things being equal, we expect basins that exhibit higher variability to exhibit less cooperative behavior, though some research in the hydropolitics literature related to water scarcity and cooperation (Dinar 2009; Tir and Ackerman 2009; Dinar et al. 2011) and variability and cooperation (Dinar et al. 2010) suggest that higher levels of variability may actually

⁴ According to the National Intelligence Assessment (2008) “climate change could threaten domestic stability in some states, potentially contributing to intra- or, less likely, inter-state conflict, particularly over access to increasingly scarce water resources.

⁵ <http://cru.csi.cgiar.org/>

encourage cooperative behavior as countries attempt to deal with such environmental changes through coordination.

4.1.3.2. Geography

The physical attributes of shared rivers have long been recognized as important to understanding conflict and cooperation over transboundary water (e.g. Le Marquand 1977; Toset et al. 2000; Brochmann and Hensel 2009; Brochmann and Gleditsch 2012). In particular, empirical studies considering the river basin as the unit of analysis find that the greater the significance of the particular basin to the respective countries the higher the cooperation evinced. In addition, the more control a country has over a given river basin the less cooperation (or more conflict) is evinced because that country perceives more benefits from unilateral action. (Espey and Towfique 2004; see also Gleditsch et al. 2006: 369).

Since we consider the river basin as the main unit of analysis, we adopt a rationale and methodology similar to Espey and Toufique (2004). We expect less cooperative behavior in cases where the percentage of the basin within the boundaries of one country is higher compared to the other country. On the other hand, we expect more cooperative behavior in cases where the river basin comprises a larger percentage of the countries' territory.

We derive two geographic measures to proxy for the level of control a given country in the dyad and the entire country dyad has over the basin as well as two similar measures proxying for the importance of the basin to the individual country as well as the country dyad. The proxy for control is derived by calculating the percentage of the total river basin within the boundaries of each country while the proxy for importance is derived by calculating the size of the river basin within the country as a percentage of the total area of the country. Two numbers are then derived for that dyad, a ratio derived value and a sum derived value, so as to gauge asymmetry and country dyad-wide nuances. The variables are derived and calculated based on OSU's International River Basin Register.

4.1.3.3. Governance and democracy

Based on the Democratic Peace Theory, scholars have claimed that regime type should also matter for explaining conflict and cooperation over the environment. Neumayer (2002a), for example,

finds that democracies tend to exhibit higher environmental commitment. Pertaining to international rivers, Gleditsch (1998: 389) suggests that democratic countries (as opposed to non-democratic countries), which share a river basin, should be more peaceful in their hydropolitical relations. Brochmann and Hensel (2009) who consider conflictual river claims and their subsequent settlement, find that river claims are less likely to begin, and more likely to experience peaceful settlement attempts (when those claims do begin), between two democracies than between other pairs of states with less democratic forms of government. Tir and Ackerman (2009) make a similar conjecture and find that dyads with joint democracies, are more likely to engage in international hydropolitical cooperation (measured by treaty signature).

We follow a similar rationale and expect that, all things being equal, country dyads which comprise of two democracies as opposed to two non-democracies or a mixed dyad (democratic state and non-democratic state), should exhibit more cooperative behavior. We calculate a combined democracy score based on the Polity IV database (Marshall, Gurr, and Jaggers 2013). Polity IV is time variant but our combined democracy score is based on an average value.

4.1.3.4. Overall relations: Militarized history and trade

Overall political and economic relations between countries should also affect countries' hydropolitical relations (Yoffe, Wolf, and Giordano 2003: 1117; Brochmann and Hensel 2009: 415). We use measures of a history of militarized disputes and trade to proxy for overall relations between states sharing a river.

Pertaining to militarized disputes, Hensel et al. (2008: 133-135) and Brochmann and Hensel (2011, 867-868) hypothesize that countries with overall unfriendly relations (due to a history of militarized conflict) may be less likely to cooperate over such contentious issues as water. Consequently, we hypothesize that a dyad with a more robust history of militarized disputes will be more likely to elicit conflictive events and their intensity shall be higher. A history of militarized disputes will likewise affect the incidence of cooperation. Furthermore, inclusion of a history of militarized conflict is an important control in terms of understanding the presence of certain types of institutional mechanisms. For instance, existence of a conflict dispute resolution mechanism may be more prevalent among dyads with a history of military conflict.

To measure the history of militarized disputes, we use the Correlates of War (COW) dataset (Militarized Interstate Disputes (v3.1)). We created a dyadic count of the river riparians involved in militarized disputes (disputes could be bilateral or multilateral). The total number of recorded disputes is used for each river dyad.

Based on the claim that increased interdependence in the form of trade decreases the likelihood of militarized conflict among countries and enhances cooperative political relations (Mansfield and Pollins 2003), studies have shown that heightened trade facilitates environmental treaty formation and acts as a contract enforcing mechanism (Neumayer 2002b; Stein 2003). Studies examining international water treaty formation have likewise found a significant relationship between cooperation and trade (Espey and Towfique 2004; Brochmann and Hensel 2009, Tir and Ackermann 2009; Dinar et al. 2011). We follow the same rational expecting high trade relations to increase the likelihood of cooperative behavior.

To measure trade relations, we obtained two separate trade datasets. In this framework, we adopt the significant finding by Arora and Vamvakidis (2005) that relatively important trading partners tend not to change much over time, further justifying the use of long-term values. Using average annual country-level data from the Gleditsch (2004) dataset, we constructed an annual trade variable for each dyad that expresses total trade (imports + exports) between Country 1 and Country 2 as a fraction of their combined GDP, describing the economic importance of trade to the riparians (Sigman 2004).⁶

4.1.3.5. Power and wealth

The literature has provided a variety of views relating to the role of power in international hydropolitics. Some authors have claimed that an asymmetric inter-riparian power relationship impedes international cooperation over shared rivers (Hijri and Gray 1998; Just and Netanyahu 1998:9). Other scholars (particularly those echoing neorealist assumptions) have argued that hegemony, or power asymmetry, actually facilitates cooperation especially when the stronger party is downstream and initiates and imposes a cooperative regime (Lowi 1993:10). Empirical

⁶ Given that exports from Country 1 to Country 2 were not always equal to imports by Country 2 from Country 1, due to discrepancies in national accounting, we took the average of the two for each dyad.

studies have likewise found evidence for the links between power asymmetry, cooperation, and reduced conflict (Toset et al 2000; Song and Whittington 2004; Tir and Ackerman 2009).⁷

Authors associated with the neo-liberal institutionalist school of international relations have seconded the importance of hegemony for international cooperation, but have likewise argued that such asymmetry is not a necessary prerequisite for cooperation as the demand for cooperation often produces its supply (Keohane 1982; Keohane 1984; Young 1989: 353; Barrett 2003). This argument has also been confirmed in empirical works on international water treaty formation and negotiation onset suggesting that even countries of equal power cooperate (Espey and Towfique 2004; Brochmann and Hensel 2009; Dinar et al. 2011).

Further challenging neorealist claims, examples may be cited when even the hegemonic downstream riparian acts in a rather benign nature whereby cooperation is not coerced or enforced, but rather encouraged and sustained using incentives (e.g. India-Bhutan hydropolitical relations). In addition, cases where the upstream state is also the hegemon and cooperates willingly with an otherwise weaker downstream state can likewise be cited (e.g. 1973 Colorado River Agreement between the United States and Mexico). As Linerooth writes in the context of pollution control in this latter scenario, “the more developed upper riparian nations may wish to create ‘good will’ with their neighbors by contributing more to pollution control while [themselves] benefiting less” (1990: 643; see also Shmueli 1999: 439). Finally, and based on this latter argument regarding power asymmetry, studies have claimed that cooperation in the environmental realm may be better encouraged and sustained using soft-power and incentives by able states rather than coercion (Young 1994:135; Barkin and Shambaugh 1999).

Given the varied conjectures and inconsistent empirical results regarding power asymmetry, conflict, and cooperation over water, we do not expect power asymmetry to be an important explanatory variable. Our expectation is further supported by the argument that brute power has been largely inefficient in the realm of hydropolitics (Wolf 1998: 258-261; Barnett 2000: 278). However, and in line with some of the neo-liberal institutionalist literature cited above, we expect differences in wealth to matter given the wealthier state’s ability to provide

⁷ It is important to note that these results and arguments could also be supporting the ‘hydro-hegemony’ school of thought which argues that the most powerful state in the basin is able to determine the outcome of basin interactions, including cooperation, assuming the most powerful state will benefit from such a policy (Zeitoun and Warner, 2006).

incentives and inclination to create ‘good will’ with the less developed riparian. Consequently we expect more cooperative behavior in economically asymmetric dyads.

To reflect the economic and welfare asymmetry discussed above, we use annual country-level real GDP and per capita GDP data from Gleditsch (2004). Taking annual GDP and GDP per capita as units of analysis, average values were calculated for each of the dyad countries for the period of time data was available for both parties, such that an identical time period was used for both to ensure comparability. Ratios of these average values were then calculated for each dyad, with the larger value country serving as the numerator and the lesser value the denominator, such that larger values always indicate greater asymmetry. The ratio of total GDPs is a measure of overall power asymmetry, or economic power, while the ratio of the per capita GDP is a measure of wealth asymmetry, or welfare power.

4.2. Regression Models

In order to evaluate the above hypotheses we ran a series of ordinary least squares regressions on cross-sectional data, using riparian treaty member dyads as the units of observation. The basic regression model used was of the form:

$$Eq. (1) \quad \mathbf{AvgBAR} = B_0 + B_1\mathbf{Allocation} + B_2\mathbf{Institutions} + B_3\mathbf{Controls} + e$$

Where:

AvgBAR is a measure of the mean of the antilogged values of conflictive and cooperative relations between the dyad in question since treaty signature based on the event rankings in the Basins at Risk database.

B_i = coefficient parameters to be estimated

Allocation = types of allocation mechanism

Different specifications of the variable were used in separate regression runs.

- **Allocation** - a binary dummy variable indicating whether or not an allocation method was specified in the treaty.

- *Specific, Flexible, and Specific*Flexible*: each of which were binary dummy variables indicating type of allocation method based on the TFDD-IWMI/ Drieschova, Giordano, and Fischhendler (2008) categorization described above.

Institutions = a set of variables indicating the presence of particular institutional mechanisms in a given treaty. In some regression runs a count variable of total number of mechanisms was used, while in more detailed models, binary dummies indicating the presence or absence of individual institutional mechanisms were used. The institutional mechanism variables included were:

- *Number of Institutional Mechanisms* - a count variable representing the total number of the below-listed variables present in a given treaty
- *Enforcement* - a mechanism that enables enforcement of treaty obligations
- *Self-enforcement* - a mechanism which includes side-payments, issue-linkage, or benefit-sharing provisions
- *Monitoring* - a mechanism requiring monitoring
- *Conflict Resolution* - an established conflict resolution mechanism
- *Commission* - an established body for oversight of treaty implementation
- *Adaptability* - a mechanism allowing for adaptation to variability

Controls = vector of control variables, covering a range of issues including

- Climatic (coefficient of variation of basin precipitation; Variables for both CV and the CV squared were included in different regression models to allow flexibility in functional form and test for non-linear responses to variations in natural supply)
- Geographic (percent of the basin within a country(ies)—“Control” [ratio and sum measures per the country dyad]; size of the river basin within the country as a percentage of the total area of the country(ies)—“Importance” [ratio and sum measures per the country dyad])
- Political/Economic (democracy, history of militarized conflict, trade importance, GDP ratio, and GDP per capita ratio)

e = error term

5. RESULTS

Descriptive statistics of the dataset are provided in Table I and II. Of the 221 country dyads in the dataset, 141 had at least one event with a BAR score and were included in the regressions. Under half (48%) of the dyads evaluated contained a water allocation method (either specific, flexible or both) (Table I in the Appendix). The average number of institutional mechanisms per dyad was 3.4. Few extreme events took place (Figure 1 in the Appendix). In fact, no instances of war (BAR = -7), and only an isolated number of instances of events more extreme than "Political-military hostile actions" (BAR = -4) were recorded during the studied time frame. "Minor official exchanges" (BAR = 1) were the single most common type of event.

Additional descriptive information and statistics depict the treaties and country dyads according to World Bank regions and other non-World Bank regions. Of the 221 dyads examined:

- 137 (62.0%) were between states falling within one World Bank region (as defined in 2013)
- 39 (17.6%) were between a state in a World Bank region and a state not in a World Bank region (primarily High-Income states)
- 30 (13.6%) were between two states that do not fall into a World Bank region
- 6 (2.7%) were between states in two different World Bank regions
- 5 (2.3%) were between a state in a World Bank region and either the former USSR or the former Yugoslavia
- 4 (1.8%) were between a state not in a World Bank region and either the former USSR or the former Yugoslavia

The distribution of the treaties by region is provided in Table II (in the Appendix).

Table III (in the Appendix) presents the results of six regression models run to evaluate factors affecting cooperation and conflict. Starting with Model 1, which evaluated the mere presence of an allocation mechanism and the number of institutional mechanisms, counter to our expectations, we find the average BAR score to be negatively affected by the presence of an allocation mechanism. Our general expectation was that basins governed by treaties with an allocation mechanism should reflect a level of resilience as opposed to a basin governed by a more generic treaty without an allocation mechanism (De Stefano et al. 2012). A number of reasons may explain this outcome. First, treaties that do not anticipate problems over water allocation are less likely to include an allocation mechanism. In other words, there may be an

endogeneity problem in that treaties that include an allocation mechanism are often treaties that are negotiated between countries that anticipate allocation problems to arise. However, based on a broader assessment of our results pertaining to the various allocation measures we believe another, more plausible, explanation may also be in order. In particular, the generic allocation variable does not distinguish between the various allocation mechanisms we are examining, which could further impact conflict and cooperation.

In fact, it is only when our models (models 4-6) distinguish between the categories of allocation mechanisms, that results reflect a more nuanced relationship between treaty design and conflict and cooperation over shared rivers. It appears that allocation mechanisms that are either only specific in nature (such as a stipulation that calls on the parties to divide/share a set or fixed amount of water) or only flexible in nature (such as a mechanism that directs the parties to set up ad hoc consultations in an effort to determine water allocations at a future date) bode negatively for cooperation between states. This is distinct from an allocation mechanism that exemplifies both flexibility and specificity (like those allocation mechanisms that call on the parties to divide available water by a percentage or ratio). Results suggest a strong positive effect on levels of cooperation. In other words, all else being equal, mechanisms that prescribe both specific and flexible water allocation features tend to increase the likelihood of cooperative behavior among river riparians, relative to treaties with only one type of allocation feature. This finding also complements work that has argued that ambiguity or vagueness (i.e. non-specificity) in water allocations may negatively affect hydro-political relations among states (Fischhendler 2008).

Our expectation that the assembly of institutional mechanisms will contribute to treaty resilience in the form of cooperation is supported and follows the findings of other scholars (Tir and Ackermann 2009). Specifically, the greater the number of such mechanisms in a treaty, the higher the expected level of cooperation. This finding is confirmed and is robust with a strongly and highly significant relationship found in Models 1-3. When considering the institutional mechanisms individually, self-enforcement, enforcement, and adaptability mechanisms appear to be most central for treaty resilience. Self-enforcement is of particular interest as the literature has claimed that for water allocation issues (which tend to be relatively divisive, salient, and conjure concerns about relative gains) such strategies as side-payments, issue-linkage, and/or benefit-sharing help make cooperation more viable and acceptable to the parties (Bennett, Ragland, and

Yolles 1998; Sadoff, Whittington, and Grey 2003: 43). The ability of the agreement to punish possible defectors, through enforcement stipulations, is also conducive for cooperation. The adaptability mechanism likewise yielded a positive and significant result suggesting that a stipulation specifically dealing with instances of water flow variations may be particularly important for the robustness of water allocation treaties given variability (Drieschova, Giordano, and Fishhenlder 2008). Interestingly, the conflict resolution mechanism is both negative and significant meaning that the existence of a conflict resolution variable by itself reduced the average BAR score. While this is counter to our expectations, it is possible that as in the case of the absence/presence of an allocation mechanism, there is an issue of endogeneity, in that dyads that include such a conflict resolution mechanism may be those that expect to be in conflictive situations. Inclusion of prior militarized history may have been insufficient as a control in this respect. The monitoring mechanism proved to be insignificant.

Among the control variables, most all performed as expected. Starting with the climatic variables, we find evidence that average BAR score increases as a function of water variability. While this may not be in line with common intuition regarding environmental change, international security, and conflict, it is in line with previous scholarship that has found a robust relationship between water variability and cooperation as well as water scarcity and cooperation (Tir and Ackerman 2009; Dinar et al. 2010). However, like Dinar et al. (2010) and other studies (e.g. Dinar 2009) the negative coefficient on the square CV term indicates a relationship resembling an inverted U-shaped curve. That is, beyond a certain point of increasing variability the incidence of cooperation begins to decrease and/or the incidence of conflict increases. Thus, the proposition that very high water variability may increase the likelihood of conflict (or at least lower instances of cooperation) is still entirely viable, as the high water variability makes it increasingly difficult for riparians to cooperate and honor their treaty commitments. As such, and per the relevant regression model, Table IV (in the Appendix) includes a calculation of the turning point beyond which the CV tends to reduce cooperation.

Per the geographical variables, our regression results suggest that when both states (in a given dyad) control a large portion of the basin, the level of cooperation evinced is negatively

affected.⁸ As the more general environmental politics literature suggests, both states may be more inclined to engage in unilateral behavior given their increased control of the resource and consequently diminishing reliance on the other state (Young 1989, 354). However, when proxying for the importance of the basin to the individual states, our results indicate that when one state deems the basin important (compared to the other state) the level of cooperation increases. It seems that the state which considers the river basin to be more important for its needs will work to foster cooperation with the other state, which is less dependent on the basin.⁹

Our various political and economic variables also provided interesting results. The democracy variable was insignificant across the models tested. While somewhat surprising given earlier theoretical research, the finding is not uncommon given other empirical work on international freshwater in which the democracy variable has exhibited insignificant results (Espey and Towfique 2004; Brochmann and Hensel 2011). Measures for political and economic relations did exhibit significant results. The higher the history of militarized encounters in a given dyad the more negative effects such a history has on the level of cooperation. This result was robust across all models tested and suggests that while a history of militarized conflict may not necessarily stifle the likelihood of treaty formation or peaceful settlements (Hensel et al. 2008, 136; Tir and Ackerman 2009, 631), hydro-relations, more broadly, may very well be vulnerable to a history of protracted conflict (Yoffe et al. 2003, 1117). The importance of trade between two countries as a percentage of their GDP also produced a positive and significant result, suggesting that increased trade is associated with cooperation on water-related issues. Complementing other empirical studies on international freshwater, we find that trade performs a kind of contract enforcing role even after a treaty has been signed (Brochmann 2012). Finally, our expectation that welfare asymmetry (which proxies for preponderance in financial capabilities and the capacity of a richer state to incentivize poorer states to cooperate) as opposed to sheer power asymmetry, was likewise supported. Preponderance in levels of wealth between two countries may thus be conducive to cooperation and follows not only arguments made in the environmental politics and negotiation literature but also results in other empirical studies on

⁸ Our variable measuring the percent of the basin within a country (i.e. ratio/proxying for one state that has comparative control of the basin) came out insignificant. Similarly it was highly correlated with another geographical variable. In all, we removed it from the analysis.

⁹ Our variable measuring the size of the river basin within the country as a percentage of the total area of the countries (i.e. sum/proxying for the importance of the basin to both states) also came out insignificant and highly correlated with another geographical variable. Thus it was removed from the statistical analysis.

international water (Raustiala and Victor 1998: 696; Zartman and Rubin 2000: 289; Dinar et al 2011; Brochmann 2012).

Some researchers have noted that cooperation and conflict can coexist in transboundary water relations, and thus, advocate against using a cooperation-conflict continuum, such as the BAR system (e.g., Zeitoun and Mirumachi 2008). For this reason, we also ran separate regressions using only cooperative events and only conflictive events. Results from these regressions were not qualitatively different from those presented above; thus, for the sake of brevity, they were not reported herein.

6. CONCLUSIONS AND POLICY IMPLICATIONS

Our study considers the resilience of river basins post-treaty. To that extent we couch our work in very recent empirical research, which investigates the general effectiveness of treaties in promoting cooperation (Tir and Stinnett 2012; Brochmann 2012; De Stefano et al. 2012). Our investigation contributes to these studies, by examining whether particular institutional and water allocation mechanisms contribute to a water allocation treaty's resilience, taking into consideration water variability over time.

Our results suggest that higher water variability across time actually drives states to further cooperate (which is in line with much of the work on water scarcity and cooperation). However, once variability increases beyond a certain threshold cooperative behavior is negatively affected (reflecting an inverted U-shaped curve). As such, the claim that climate change could have potentially destabilizing effects on international river basins (Intelligence Community Assessment 2012) is also supported. Looking particularly at the various allocation mechanisms, we find that only mechanisms that prescribe both flexibility and specificity in the allocation of water seem to contribute positively to cooperative behavior. In other words, allocation mechanisms that are either too vague or too rigid do not bode well for sustained cooperation. Our results for the non-allocative institutional mechanisms also reveal interesting findings. A treaty which strives to include these institutional mechanisms witnesses heightened cooperation. When considering them individually, particular mechanisms reflect higher importance than others. Treaties that codify side-payments and issue-linkage, direct enforcement measures, and adaptability to water variability provisos may be of particular importance for achieving higher levels of cooperation. Our results, therefore, imply that treaty design is

important and that policy makers should be mindful of the type of water treaties they negotiate. Particular allocation and institutional mechanisms do seem to make a difference in contributing to a given basin's resilience in the face of water variability across time.

Results for our control variables also support common findings in the hydro-politics literature suggesting that the control of the basin by both countries, the importance of the basin to a given country, a history of militarized conflict, increased trade, and differences between rich and less rich countries are important for understanding post-treaty hydro-relations.

References

Adger, N., Hughes, T., Folke, C., Carpenter, S., and Rockström, J. (2005) Social ecological resilience to coastal disasters. *Science*, 309, 5737,1036-1039.

Alavian, V., Qaddumi, H., Dickson, E., Diez, S., Danilenko, A., Hirji, R., Puz, G., Pizarro, C., Jacobsen, M., and Blankespoor, B. (2009). *Water and Climate Change: Understanding the Risks and Making Climate-Smart Investment Decisions*. (Washington, D.C.: World Bank).

Allan, J.A. and Cosgrove, W.J. with Balabanis, P. Connor, R., Hoekstra, A., Kansime, F., Pahl-Wostl, C., and Savenije, H. (2002). Policy analysis and institutional frameworks in climate and water. In P. Kabat, R.E. Schulze, M.E. Hellmuth, and J.A. Veraart (Eds.) *Coping with impacts of climate variability and climate change in water management: A scoping paper*. DWC-Report no. DWCSSO-01(2002), International Secretariat of the Dialogue on Water and Climate, Wageningen, 58-71.

Ansink, E., and Ruijs, A. (2008). Climate change and the stability of water allocation agreements. *Environmental and Resource Economics*, 41, 133-287

Arnell, N. (1999). A Simple water balance model for the simulation of streamflow for a large geographic domain. *Journal of Hydrology*, 217, 314-335.

Arnell, N. (2002). *Hydrology and Global Environmental Change*. Pearson Education Limited: Essex.

Arnell, N. (2004). Climate change and global water resources: SRES emissions and socio-economic scenarios. *Global Environmental Change*, 14, 31-52.

Vivek, A. and Vamvakidis, A. (2005). Economic spillovers. *Finance and Development* September: 48-50.

Bakker, M. (2009). Transboundary river floods and institutional capacity. *Journal of the American Water Resources Association*, 45, 3, 553-566.

Barkin, S. and Shambaugh, G. (1999). Hypotheses on the international politics of common pool resources. In S. Barkin and G. Shambaugh (Eds.), *Anarchy and the environment: The international relations of common pool resources*, Albany, NY: State University of New York Press.

Basins at Risk. *International Water Event Database*. Oregon State University; <http://www.transboundarywaters.orst.edu/database/interwatereventdata.html>

Barnett, J. (2000). Destabilizing the environment-conflict thesis. *Review of International Studies*, 26, 271-288.

Barnett, J. (2003). Security and climate change. *Global Environmental Change* 13, 7-17.

Barrett, S. (2003). *Environment and statecraft: The strategy of environmental treaty-making*. Oxford: Oxford University Press.

Barnett, J. and Adger, N. (2007). Climate change, human security and violent conflict. *Political Geography*, 26, 639-655.

Bennett, L., Ragland, S. and Yolles, P. (1998). Facilitating international agreements through an interconnected game approach: The case of river basins. In R. Just and S. Netanyahu (Eds.), *Conflict and cooperation on trans-boundary water resources*. Boston, MA: Kluwer Academic Publishers, 61-85.

Bernauer, T. (1996). Protecting the river Rhine against chloride pollution. In R. Keohane and M. Levy (Eds.), *Institutions for the earth: Pitfalls and promise*. Cambridge, MA: The MIT Press, 201-232.

Bernauer, T. and Siegfried, T. (2012). Climate change and international water conflict in Central Asia. *Journal of Peace Research*, 49, 227-239.

Brochmann, M. and Hensel, P. (2009). Management of internationally shared rivers: Peaceful settlement attempts in international rivers. *International Negotiation*, 14, 393-418.

Brochmann, M. and Hensel, P. (2011). The effectiveness of negotiations over international river claims. *International Studies Quarterly*, 55, 859-882.

Brochmann, M. (2012). Signing river treaties: Does it improve cooperation? *International Interactions*, 38, 141-163.

Brochmann, M. and Gleditsch, N.P. (2012). Shared rivers and conflict: A reconsideration. *Political Geography*, 31, 519-527.

Brown, N. (1989). Climate, ecology, and international Security. *Survival*, 31, 6, 519-532.

Buhaug, H., Gleditsch, N.P., and Theisen, O. M. (2008). Implications of climate change for armed conflict. The Social Development Department, World Bank.

CNA Corporation. (2007). National security and the threat of climate change. Alexandria, VA.

Cooley, H., Christian-Smith, J., Gleick, P., Allen, L., Cohen, M. (2009). *Understanding and reducing the risks of climate change for transboundary waters*. Oakland, CA: Pacific Institute.

Dai, A., Qian, T., Trenberth, K. E., and Milliman, J. D. (2009). Changes in continental freshwater discharge from 1948 to 2004. *Journal of Climate*, 22, 2773-2791.

De Stefano, L., Edwards, P., de Silva, L., and Wolf, A. (2010). "Tracking cooperation and conflict in international basins: Historic and recent trends. *Water Policy*, 12, 6, 871-884.

De Stefano, L., Duncan, J., Dinar, S., Stahl, K., Strezepek, K., and Wolf, A. (2012). Climate change and the institutional resilience of international river basins. *Journal of Peace Research*, 49, 1, 193-209.

Dinar, S. (2006). Assessing side-payment and cost-sharing patterns: The geographic and economic connection. *Political Geography*, 25, 4, 412-437.

Dinar, S. (2009). Scarcity and cooperation along international rivers. *Global Environmental Politics*, 9, 1, 107-133.

Dinar, A., Blankespoor, B., Dinar, S., and Kurukulasuriya, P. (2010). Does precipitation and runoff variability affect treaty cooperation between states sharing international bilateral rivers? *Ecological Economics*, 69, 12, 2568-2581.

Dinar, S., Dinar, A., and Kurukulasuriya, P. (2011). Scarcity and cooperation along international rivers: An empirical assessment of bilateral treaties. *International Studies Quarterly*, 55, 809-833.

Dombrowski, I. (2007). *Conflict, cooperation, and institutions in international water management*. Cheltenham, UK: Edward Elgar.

Drieschova, A., Giordano, M. and Fischhendler, I. (2008). Governance mechanisms to address flow variability in water treaties. *Global Environmental Change*, 18, 285-295.

Drieschova, A., Fischhendler, I. and Giordano, M. (2011). The role of uncertainties in the design of international water treaties: An historical perspective,” *Climatic Change*, 105, 3-4, 387-408.

Drieschova, A. and Fischhendler, I. (2011). Toolkit: Mechanisms to reduce uncertainty in international water treaties. *CLICO Report*, Hebrew University of Jerusalem.

Dziegielewski, B. (2003). Long-term and short-term measures for dealing with drought. In: G. Rossi, A. Cancelliere, L. Pereira, T. Oweis, M. Shatanawi, and A. Zairi (Eds.), *Tools for drought mitigation in the Mediterranean region*. Dordrecht: Kluwer Academic Publishers, 319-340.

Espey, M. and Towfique, B. (2004). International bilateral water treaty formation. *Water Resources Research*, 40, W05S05, doi:10.1029/2003WR002534.

Fischhendler, I. (2004). Legal and institutional adaptation to climate uncertainty: A study of international rivers. *Water Policy*, 6, 4, 281-302.

Fischhendler, I. (2008). Ambiguity in transboundary environmental dispute resolution: The Israeli-Jordanian water agreement. *Journal of Peace Research*, 45, 91-109.

Gerlak, A. and Grant, K. (2009). The correlates of cooperative institutions for international rivers. In T. Volgy, Z. Šabič, P. Roter, and A. Gerlak, A. (Eds.), *Mapping the new world order*. Oxford: Wiley Blackwell, 114-147.

Gleditsch, K.S. 2004. Expanded Trade and GDP Data. Accessed online on 2 August 2012 at: <http://privatewww.essex.ac.uk/~ksg/exptradegdp.html>

Gleditsch, N. P. (1998). Armed conflict and the environment: A critique of the literature. *Journal of Peace Research*, 35, 3, 381-400.

Gleditsch, N.P., Furlong, K., Hegre, H., Lacina, B., and Owen, T. (2006). Conflict over shared rivers: Resource scarcity or fuzzy boundaries. *Political Geography*, 25, 4, 361-382.

Gleick, P. (1989). The implications of global climatic changes for international security. *Climatic Change*, 15, 1-2, 309-325.

Gleick, P. (1992). Effects of climate change on shared fresh water resources. In I. Mintzer (Ed.), *Confronting climate change: Risks, implications, responses*. Cambridge: Cambridge University Press, 127-140

Gleick, P. (2010). Water, climate change, and international security. *Circle of Blue Water News*. Available at <http://www.circleofblue.org/waternews/2010/world/peter-gleick-water-climate-change-andinternational-security/>

Goulden, M., Conway, D., and Persechino, A. (2009). Adaptation to climate change in international river basins in Africa: A review. *Hydrological Sciences Journal*, 54(4), 805-828.

Hensel, P., Mitchell, Sowers, T., and Thyne, C. (2008). Bones of contention: Comparing territorial, maritime and river issues. *Journal of Conflict Resolution*, 52, 117-143.

Hijri, R. and Gray, D. (1998). Managing international waters in Africa: Process and progress. In S. Salman and L. Boisson de Chazournes (Eds.), *International watercourses: Enhancing cooperation and managing conflict*. Proceedings of a World Bank Seminar, World Bank Technical Paper, N 414.

House Permanent Committee on Intelligence. (2008). National intelligence assessment on the national security implications of global climate change to 2030. June 25. Available at http://www.dni.gov/testimonies/20080625_testimony.pdf

Iglesias, A., Garrote, L., and Flores, F. (2007). Challenges to manage the risk of water scarcity and climate change in the Mediterranean. *Water Resources Management*, 21, 775-788.

(IPCC) Intergovernmental Panel on Climate Change. (2001). *Climate change 2001: Impacts, adaptation, and vulnerability*. Contribution of Working Group II to the Third Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge: Cambridge University Press.

(IPCC) Intergovernmental Panel on Climate Change. (2007). Intergovernmental panel on climate change fourth assessment report, Climate Change 2007: Synthesis Report, Summary for Policymakers.

Intelligence Community Assessment. (2012). Global water security. Office of the Director of National Intelligence, February 2.

Just, R. and Netanyahu, S. (1998). International water resource conflict: Experience and potential. In R. Just and S. Netanyahu (Eds.), *Conflict and cooperation on transboundary water resources*. Kluwer Academic Publishers, Boston.

Kabat, P., R.E. Schulze, M.E. Hellmuth, and J.A. Veraart (Eds.). (2002). *Coping with impacts of climate variability and climate change in water management: A scoping paper*. DWC-Report no. DWCSSO-01(2002), International Secretariat of the Dialogue on Water and Climate, Wageningen.

Katz, D. and Fischhendler, I. (2011). Spatial and temporal dynamics of linkage strategies in Arab-Israeli water negotiations. *Political Geography*, 30, 13-24.

- Keohane, R. (1982). The demand for international regimes. *International Organization*, 36, 325-355.
- Keohane, R. (1984). *After hegemony: Cooperation and discord in the world political economy*. Princeton, N.J.: Princeton University Press.
- Keohane, R. and Martin, L. (1995). The promise of institutionalist theory. *International Security*, 20, 1, 39-51.
- Kundzewicz, Z., Budhakooncharoen, S., Bronstert, A., Hoff, H., Lettenmaier, D., Menzel, L., and Schulze, R. (2002). Coping with variability and change: Floods and droughts. *Natural Resources Forum*, 26, 4, 263-274.
- LeMarquand, D. (1977). *International rivers: The politics of cooperation*. Vancouver: Westwater Research Center and the University of British Columbia.
- Linerooth, J. (1990). The Danube River basin: Negotiating settlements to transboundary environmental issues. *Natural Resources Journal*, 30, 629-660.
- Lowi, M. (1993). *Water and power: The politics of a scarce resource in the Jordan River basin*. Cambridge: Cambridge University Press.
- Mansfield, E. and Pollins, B. (Eds.). (2003). *New perspectives on economic exchange and armed conflict*. Ann Arbor, MI: University of Michigan Press.
- Marshall, M., Gurr, T.R., and Jagers, K. (2013). *Polity IV project: Political regime characteristics and transitions, 1800-2012*, Available at <http://www.systemicpeace.org/inscr/inscr.htm>
- McCaffrey, S. (2003). The need for flexibility in freshwater treaty regimes. *Natural Resources Forum*, 27, 156-162.
- Milliman, J. D., Farnsworth, K. L., Jones, P.D., Xu, K. H., and Smith, L. C. (2008). Climatic and anthropogenic factors affecting river discharge to the global ocean, 1951-2000. *Global Planetary Change*, 62, 187-194.
- Milly, C., Dunne, K.A., and Vecchia, A.V. (2005). Global pattern of trends in streamflow and water availability in a changing climate. *Nature*, 438, 347-350.
- Milly, C., Betancourt, J., Falkenmark, M., Hirsch, R., Kundzewicz, Z., Lettenmaier, D., and Stouffer, R. (2008). Stationarity is dead: Whither water management? *Science*, 319, 573-574.
- Mitchell, T.D. and Jones, P.D. (2005). An improved method of constructing a database of monthly climate observations and associated high-resolution grids. *International Journal. of Climatology*, 25, 693-712.

- Neumayer, E. (2002a). Do democracies exhibit stronger international environmental commitment? A cross-country analysis. *Journal of Peace Research*, 39, 139-164.
- Neumayer, E. (2002b). Does trade openness promote multilateral environmental cooperation? *World Economy*, 25, 815-832.
- Nordås, R. and Gleditsch, N.P. (2007). Climate change and conflict. *Political Geography*, 26, 627-638.
- Odom, O. and Wolf, A. (2008). Defining and redefining needs in international water law. *Defining Water Needs in Areas of Fully Exploited Resource International Workshop*, Palais des Nations, Geneva, May.
- Phillips, D., Daoudy, M., McCaffrey, S., Öjendal, J., and Turton, A. (2006). *Trans-boundary water co-operation as a tool for conflict prevention and broader benefit sharing*. Global Development Studies, 4, Ministry of Foreign Affairs, Sweden
- Raustiala, K. and Victor, D. (1998). Conclusions. In D. Victor, K. Raustiala, and E. Skolnikoff (Eds.), *The implementation and effectiveness of international commitment: Theory and practice*. Cambridge, MA: MIT Press, 659-707.
- Sadoff, C., Whittington, D., and Gray, D. (2003). *Africa's international rivers: An economic perspective*. Washington, D.C.: World Bank.
- Salehyan, I. (2008). From climate change to conflict? No consensus yet. *Journal of Peace Research*, 45, 3, 315-326.
- Salman, S. and Uprety, K. (2002). *Conflict and cooperation on South Asia's international rivers: A legal perspective*. Washington, D.C.: The World Bank.
- Schwartz, P. and Randall, D. (2003). An abrupt climate change scenario and its implications for United States national security. *Environmental Defense Fund*
- Shmueli, D. (1999). Water quality in international river basins. *Political Geography*, 18, 437-476.
- Sigman, H. (2004). Does trade promote environmental coordination? Pollution in international rivers. *Contributions to Economic Analysis and Policy*, 3, Article 2.
- Song, J. and Whittington, D. (2004). Why have some countries on international rivers been successful negotiating treaties? A global perspective. *Water Resources Research*, 40, W05S06, doi:10.1029/2003WR002536.

- Stahl, K. (2005). Influence of hydroclimatology and socioeconomic conditions on water related international relations. *Water International*, 30, 3, 270-282.
- Stein, A. (2003). Trade and conflict: Uncertainty, strategic signaling, and interstate disputes. In E. Mansfield and B. Pollins (Eds.), *New perspectives on economic exchange and armed conflict*. Ann Arbor, MI: University of Michigan Press.
- Stinnett, D. and Tir, J. (2009). The institutionalization of river treaties. *International Negotiation*, 14, 229-251.
- Susskind, L. (1994). *Environmental diplomacy: Negotiating more effective global agreements*. New York, NY: Oxford University Press.
- Tir, J. and Ackerman, J. (2009). Politics of formalized river cooperation. *Journal of Peace Research*, 46, 623-640.
- Tir, J. and Stinnett, D. (2011). The institutional design of riparian treaties: The role of river issues. *Journal of Conflict Resolution*, 55, 4, 606-631.
- Tir, J. and Stinnett, D. (2012). Weathering climate change: Can institutions mitigate international water conflict? *Journal of Peace Research*, 49, 1, 211-225.
- Toset, H.P.W., Gleditsch, N.P., and Hegre, H. (2000). Shared rivers and interstate conflict. *Political Geography*, 19, 8, 971-996.
- Transboundary freshwater dispute database. Oregon State University. *International Freshwater Treaties Database*. Available at <http://www.transboundarywaters.orst.edu/projects/internationalDB.html>, accessed 23 March 2013.
- Turton, Anthony. (2003). A southern African perspective on transboundary water management. *Environmental Change and Security Program Report*, 9, 75-79.
- Vörösmarty, C., Green, P., Salisbury, J., and Lammers, R. (2000). Global water resources: Vulnerability from climate change and population growth. *Science*, 289, 284-288.
- Walker, B., Gunderson, L., Kinzig, A., Folke, C., Carpenter, S., and Schultz, L. (2006). A handful of heuristics and some propositions for understanding resilience in social-ecological systems. *Ecology and Society*, 11, 1, Article 13.
- Weinthal, E. (2002). *State making and environmental cooperation: Linking domestic and international politics in Central Asia*. Cambridge, MA: The MIT Press.

- Wolf, A. (1998). Conflict and cooperation along international waterways. *Water Policy*, 1, 251-265.
- Wolf, A. and Hamner, J. (2000). Trends in transboundary water disputes and dispute resolution. In *Water for Peace in the Middle East and Southern Africa*. Geneva: Green Cross International, 55-66.
- Wolf, A., Kerstin S., and Macomber, M. (2003). Conflict and cooperation within international river basins: The importance of institutional capacity. *Water Resources Update*, 125, 31-40.
- Working Group II of the Navigating Peace Initiative. (n.d.) Water conflict and cooperation: Looking over the horizon. *Environmental Change and Security Program*. Available at http://www.wilsoncenter.org/index.cfm?topic_id=1413&fuseaction=topics.item&news_id=22578
- World Development Report*. (2011). Conflict, security, and development. Washington, D.C.: World Bank.
- Yoffe, S., Wolf, A., and Giordano, M. (2003). Conflict and cooperation over international freshwater resources: Indicators of basins at risk. *Journal of the American Water Resources Association*, 39, 5, 1109-1126.
- Young, Oran. (1989). The politics of international regime formation: Managing natural resources and the environment. *International Organization*, 43, 349-375.
- Young, Oran. (1994). *International governance: Protecting the environment in a stateless society*. Ithaca, NY: Cornell University Press.
- Zawahri, Neda. (2009). Third party mediation of international river disputes: The case of the Indus basin. *International Negotiation*, 14, 281-310.
- Zawahri, N. and Mitchell, S. (2011). Fragmented governance of international rivers: Negotiating bilateral versus multilateral treaties. *International Studies Quarterly*, 55, 835-858.
- Zartman, W. and Rubin, J. (2000). Symmetry and asymmetry in negotiation. In W. Zartman and J. Rubin (Eds.), *Power and negotiation*, Ann Arbor, MI: University of Michigan Press, 271-293.
- Zeitoun, M. and Warner, J. (2006). Hydro-hegemony – A framework for analysis of transboundary water conflicts. *Water Policy*, 8, 5, 435-460.
- Zeitoun, M. and Mirumachi, N. (2008). Transboundary water interaction I: Reconsidering conflict and cooperation. *International Environmental Agreements: Politics, Law and Economics* 8, 4, 297-316.

APPENDIX

Table I: Summary Statistics

Variable	Mean	Standard Deviation
AvgBAR	54.43	56.95
Allocation	0.48	0.50
Specific	0.33	0.47
Flexible	0.32	0.47
Specific*Flexible	0.18	0.38
Number of Institutional Mechanisms	3.38	1.14
Enforcement	0.43	0.50
Self-enforcement	0.24	0.43
Monitoring	0.82	0.39
Conflict resolution	0.70	0.46
Commission	0.96	0.19
Adaptability	0.24	0.43
CV	0.87	0.27
Basin sum-Control	47.96	32.30
Basin ratio- Importance	16.17	61.67
Democracy	-2.21	3.90
Military	2.57	5.13
Trade Importance	1.42	2.66
GDP ratio	9.92	19.20
GDP per capita ratio	2.15	1.36

Figure I: Number of BAR Events by BAR Value

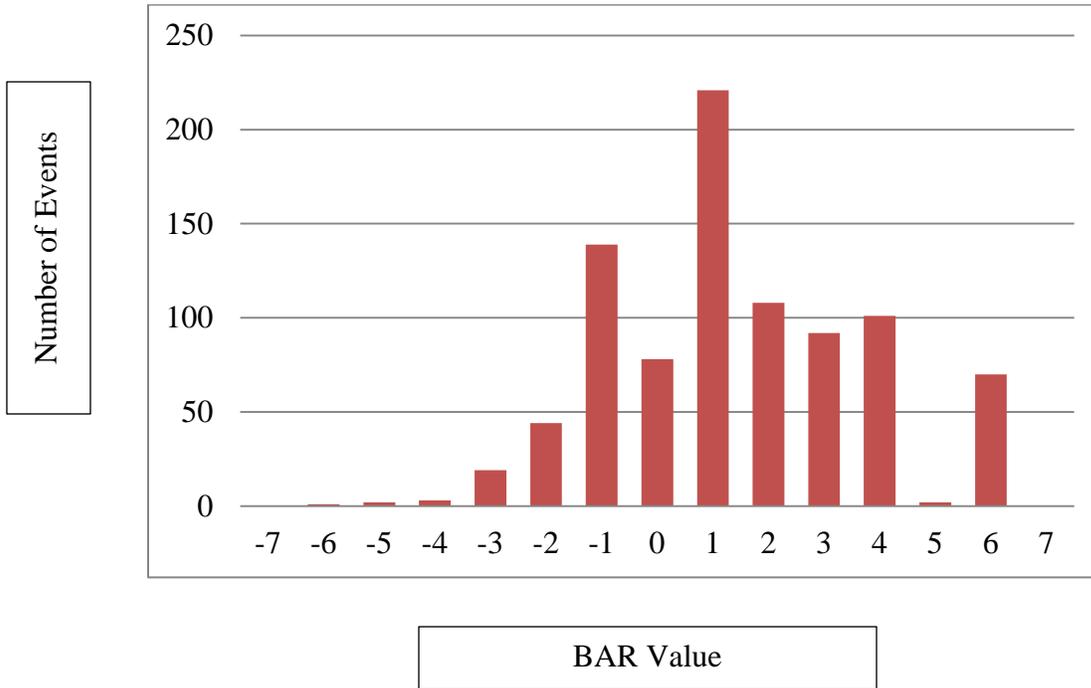


Table II: Distribution of Treaties by Region

REGION NAMES ¹⁰	EAP	ECA	LAC	MENA	SAR	SSA	Other	Former USSR/ Yugoslavia	TOTAL
EAP	9 (9)	0	0	0	0	0	0	1 (0)	10 (9)
ECA	0	32 (19)	0	2 (2)	0	0	30 (7)	3 (0)	67 (28)
LAC	0	0	13 (6)	0	0	0	8 (4)	0	21 (10)
MENA	0	2 (2)	0	4 (4)	2 (2)	2 (1)	1 (1)	1 (1)	12 (11)
SAR	0	0	0	2 (2)	12 (11)	0	0	0	14 (13)
SSA	0	0	0	2 (1)	0	67 (12)	0	0	69 (13)
Other	0	30 (7)	8 (4)	1 (1)	0	0	30 (16)	4 (3)	73 (31)
Former USSR/ Yugoslavia	1 (0)	3 (0)	0	1 (1)	0	0	4 (3)	0	9 (4)
TOTAL	10 (9)	67 (28)	21 (10)	12 (11)	14 (13)	69 (13)	73 (19)	9 (4)	

¹⁰ EAP = East Asia and Pacific, ECA = Europe and Central Asia, LAC = Latin America & the Caribbean, MENA = Middle East and North Africa, SAR = South Asia Region, SSA = Sub-Saharan Africa,

Table III: Water Allocation/Quantity Agreements Regression Results (continues on next page)

	Model 1 Basic Treaty Attributes Only	Model 2 Basic Treaty Attributes & Climatic and Geographic Controls	Model 3 Basic Treaty Attributes & all Controls	Model 4 Detailed Treaty Attributes Only	Model 5 Detailed Treaty Attributes & Climatic and Geographic Controls	Model 6 Detailed Treaty Attributes & all Controls
Constant	24.925** 13.110	-37.795 34.511	-78.075** 35.843	41.854* 22.594	-50.355 40.696	-80.507 43.827
Allocation Mechanism	-52.503*** 8.219	-35.663*** 8.867	-36.285*** 9.731			
Flexible				-60.497*** 12.002	-36.726*** 12.808	-26.739** 13.090
Specific				-72.431*** 11.567	-59.309*** 11.923	-61.548*** 12.181
Flexible & Specific				93.632*** 18.197	69.553*** 18.066	68.425*** 17.912
Number of Institutional Mechanisms	16.096*** 3.620	10.545*** 3.516	10.899*** 3.471			
Enforcement				50.861*** 10.256	31.616*** 11.056	30.028*** 10.691
Self- enforcement				33.252*** 10.052	28.273*** 9.907	29.955*** 9.983
Monitoring				-2.759 11.456	13.203 11.190	11.793 10.766
Conflict Resolution				-16.989* 9.920	-22.927** 9.380	-19.465** 9.602
Commission				15.821 21.432	24.029 20.007	31.345 19.721
Adaptability				35.502*** 10.342	19.439* 10.179	19.080* 10.777
Precipitation CV		183.755** 77.462	236.509*** 82.498		225.391*** 77.178	249.631*** 84.188
Precipitation CV Squared		-79.241* 43.992	-100.428** 45.375		-114.731*** 43.639	-120.877*** 45.540
Basin Sum		-0.466*** 0.136	-0.487** 0.149		-0.447*** 0.137	-0.446*** 0.148
Basin Ratio		0.121** 0.062	0.123** 0.059		0.106* 0.060	0.084 0.059
Democracy			0.925 1.174			-0.177 1.282

Military			-1.829** 0.793			-2.634*** 0.789
Trade Importance			3084.150* 1778.690			2711.989 1788.494
GDP Ratio			-0.035 0.209			0.017 0.203
GDP Per Capita Ratio			6.796* 2.839			3.115 2.895
R-Squared	0.286	0.417	0.493	0.410	0.511	0.579

Table IV: CV Turning Points

Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Basic Treaty Attributes Only	Basic Treaty Attributes & Climatic and Geographic Controls	Basic Treaty Attributes & all Controls	Detailed Treaty Attributes Only	Detailed Treaty Attributes & Climatic and Geographic Controls	Detailed Treaty Attributes & all Controls

CV - Turning point

1.159

1.178

0.982

1.033