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Climate Change and State Grievances: The Resiliency of International River Treaties to Increased Water Variability

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Climate Change and State Grievances: The Water Resiliency of International River Treaties to Increased Water Variability

As water variability in international river basins is expected to increase, due to the predicted effects of climate change, inter-state agreements to settle consequent disputes become paramount. Specifically, the mechanisms that states negotiate as part of these agreements are important. We argue that our best attempts to consider the ability of states to deal with variability in the future, rests with considering how the agreements have fared in the past. In this paper we investigate whether particular mechanisms help mitigate inter-country tensions over shared water. We utilize a corpus of documented international water treaties pertaining to water quantity or allocation, hydropower and flood-control (those issues most affected by water variability), and the Basins at Risk events database to test particular hypotheses regarding the viability, or resiliency, of treaties to water variability. In general, we argue that particular treaty features and mechanisms are more apt to deal with decreased or increased river flow – in our particular case measured as a derived coefficient of variation pertaining to precipitation and river run-off. In essence, the presence of these instruments in a given treaty should decrease the likelihood of riparian complaints, or grievances, regarding the issue at hand. Treaties are coded for the particular mechanisms sought, and the events database is combed for related grievances and events. Our theory considers other control variables, but in this draft paper we investigate one in particular – trade. Generally, our statistical analysis finds that treaty mechanisms that are flexible and binding, with respect to flow variability, correspond with a decrease in the frequency and intensity of country complaints. Particular institutional mechanisms (e.g. enforcement, conflict resolution/dispute resolution and drought adaptation) also matter in further reducing country grievances due to flow variability and consequent treaty compliance problems.

Introduction

Annual and seasonal variability in river flow is well known and well documented by riparian communities, scientists, engineers and policy makers. Yet, the predicted effects of climate change may render future river flow variability outside the bounds of previously observed run-off events (IPCC, 2007b, p. 31; Milly et al., 2008). These effects are particularly salient in international river basins where several riparians may be negatively affected, thereby complicating existing shared water management strategies. 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, 2004; Milly et al., 2005). These effects will continue to make water an enduring issue of contention with impacts on economic development and regional stability.

The environment and security, and hydro-politics literature further highlight the links between water, conflict and instability (Homer-Dixon, 1999). While instances of armed conflict as a result of water scarcity have been investigated (Toset et al., 2000; Gleditsch et al., 2006; Hensel et al., 2006), violent conflicts between states have been rare (Wolf and Hamner, 2000). This is not to say that conflicts over water do not take place but rather that they are often of a political nature (Gleditsch, 1998, p. 387). Nonetheless, such outcomes are also applicable to regional and national security. As the spatial and temporal distribution of water resources change, the ways in which water is allocated among its multitude of uses may need to be renegotiated. This may be especially challenging in regions already suffering from tense relations among users, whether they are individuals or countries. Additional works have likewise considered the security dimensions of climate change (Barnett, 2003).

Formal management regimes governing shared river basins, in the form of international water treaties, can be particularly instrumental in managing likely disputes among fellow riparians (Wolf et al., 2003; Dinar, 2006, 2008; Dombrowski, 2007). In particular, such regimes are crucial for managing disputes that may arise from variability intensified by the effects of climate change. Specifically, treaties that embody mechanisms that deal, directly or indirectly, with flow variability could assist states in managing the effects of climate change (Drieschova et al., 2008). Potentially, those treaties that do not exemplify such mechanisms may be less effective, providing more opportunities for grievances, or tensions, among the riparians.

With regard to issues particularly affected by decreased or increased water availability, this paper utilizes the corpus of documented international water treaties pertaining to water quantity or allocation, hydropower and flood-control since 1950 and up to 2005 and the Basins at Risk events database to test particular hypotheses regarding the viability, or resiliency, of treaties to water variability over time. To that extent we argue that any attempt to consider the viability of these treaties into the future, given the effects of climate change, requires an investigation of the past performance of these treaties in relation to water variability.

In particular, we argue that some treaty features and mechanisms are better apt to deal with variability. In essence, certain allocation and institutional mechanisms should mitigate riparian complaints, or grievances, that are a result of increased water variability over time. Treaties are coded for the particular mechanisms sought and the events database is combed for events which feature both general grievances and grievances dealing particularly with water variability. To proxy for water variability over time, we adopt a coefficient of variation in precipitation over time. Additional variables (or control variables) should also matter, but in our causal analysis we only utilize a measure of trade that proxies for the level of interdependence among the parties.

Below, we present a literature review and then continue with the essence of our theory and provide various hypotheses. We also describe our data collection and coding efforts. We then provide a results section with both simple statistical analysis and more rigorous multivariate and causal analysis. The former analysis is based on our expanded data set of treaties while the latter is based on a subset pertaining only to treaties governing rivers shared by only two states given our derived water variability data.

Climate Change and Water Variability

The most forceful link made between climate change and water variability came out of the 2007 Intergovernmental Panel on Climate Change (IPCC) Report. The report stated that 'There is high confidence that by mid-century, annual river run-off and water availability are projected to increase at high latitudes (and in some tropical wet areas) and decrease in some dry regions in the mid-latitudes and tropics. There is also high confidence that many semi-arid areas (e.g. Mediterranean basin, western United States, southern Africa and northeast Brazil) will suffer a decrease in water resources due to climate change' (IPCC, 2007b, p. 49).

Using an ensemble of 12 climate models, Milly et al. (2005, p. 347), for example, have projected '10–40% increases in runoff in eastern equatorial Africa, the La Plata Basin and high-latitude North America and Eurasia, and 10–30% decreases in runoff in southern Africa, southern Europe, the Middle East and mid-latitude western North America by the year 2050.' Focusing specifically on the river basin scale, Arora and Boer (2001, p. 3338) find that basins such as the Yenisey, Lena, Yukon, Volga, Columbia and the Ganges will experience increased mean annual discharge, while the Ob, Amur, Amazon, Yangtze and the Mekong will experience decreased mean annual discharge in their climate change simulations. An even more extensive study, using the river basin as the main observation, finds that international basins such as the Volta and Indus will experience increased relative change in river discharge of approximately 40%, while the Kura and Senegal River Basins will experience a decreased relative change in similar proportions (Palmer et al., 2008).

Security, climate change and water

While the notion and definition of what constitutes a security threat is under debate by academics and policy makers, proponents of the term 'environmental security' clearly see the links between environmental problems, externalities and instability (Myers, 1993; Deudney and Matthew, 1999; Homer-Dixon, 1999).

Studies with particular focus on the links between climate change and security have likewise been conducted (Brown, 1989; Rahman, 1999). Recently, this topic has received additional attention, both theoretically and empirically (Barnett, 2003, p. 8; Barnett and Adger, 2007; Nordås and Gleditsch, 2007). Barnett, for example, has argued that climate change may have indirect negative effects that can undermine the legitimacy of governments, undermine individual and collective economic livelihood and affect human health through reduced availability of food and increased exposure to new disease vectors (2003, p. 9). Barnett and Adger (2007), focusing particularly on countries with large populations dependent on natural resources and ecosystem services, claim that reduced access to such climate sensitive resources and natural capital places such groups at high risk from climate change.

Studies considering the effects of climate change on migration and civil conflict are also relevant. Reuveny (2007), who considers climate change-induced migration in lesser developed countries, demonstrates that such movements of people could lead to conflict in receiving areas. Competition for resources, ethnic tensions, group distrust and the inability of receiving countries to absorb such migrants can all lead to conflict (2007, pp. 656–70). Taking account of water issues in particular, Levy et al. (2005) consider the effects of climate change on civil wars. The authors find that decreased rainfall correlates with increased intra-state conflicts. Finding somewhat weaker results for the effects of climate change on civil conflict, Raleigh and Urdal (2007) reveal that such variables as population growth, population density, water scarcity and land degradation have, nonetheless, a very moderate effect on the risk of civil conflict.

The above empirical studies, which have included a water component in their climate change-conflict models, have largely considered domestic violent conflicts or civil wars. As suggested earlier, water has rarely, if at all, been the main catalyst for an inter-state war. In fact, the history of international hydro-politics has been that of cooperation and negotiation rather than armed conflict between riparians (Wolf and Hamner, 2000; Yoffe et al., 2003).

That being said, military skirmishes, or close encounters, over water have been recorded in modern history (Wolf and Hamner, 2000; Hensel et al., 2006; Pacific Institute, 2008). To that extent, the effects of water variability, complicated by the effects of climate change, can aggravate already tense relations between riparians that may not have negotiated an agreement over their shared river or, given this paper's focus, lead to increased disputes and tensions between states that may have nonetheless negotiated an agreement over a shared river (Yoffe et al., 2003).

Thus far, empirical studies of international water treaties have focused primarily on explaining the mere formation of international water treaties or level of cooperation (Espey and Towfique, 2004; Song and Whittington, 2004; Dinar et al., forthcoming; Dinar, 2009; Tir and Ackerman, 2009; Brochmann and Hensel, 2009). In addition, such studies have not considered the effects of water variability but rather a single measure of water scarcity. Studies that have considered the impacts of variability (and by extension have contributed to the climate change literature) on international water treaties have stemmed mainly from the economics discipline but they have been largely theoretical or experimental (Ansink and Ruijs, 2008; Abbink et al., 2005).

We attempt to fill that void in the literature by considering the effects of variability on the stability of international water treaties. By building on other theoretical studies we go beyond the single case-study approach and adopt a more empirical methodology considering our hypotheses across a larger set of river treaty data.

Theory: Importance of Treaty Design for Water Variability Adaptability

Given the security dimensions of climate change, treaty adaptability and resiliency to water variability may be important. In fact, treaties may exemplify institutional robustness through the mechanisms codified in their respective texts. Several theoretical studies have provided indication as to which mechanisms may enhance an agreement's stability among the parties.

Although not directly relating to the manner by which regimes can adapt to climate change, Wolf (1999) analyzes 43 water allocation agreements and demonstrates how conflicting positions among countries are reconciled in actual negotiations. The assessment highlights particular mechanisms and principles that may enhance equity and promote tenets of fairness which are important in a treaty's resiliency to variability. Most importantly, Wolf demonstrates that quantifiable needs and the concept of the 'needs-based' approach for water allocation often emerge in some negotiations rather than the extreme and often intangible 'rights-based' approach. In other words, extreme legal principles, such as *absolute territorial sovereignty* and *absolute territorial integrity*, seldom hold and the parties often agree to a compromise based on their actual water requirements rather than 'abstract' water rights. As international legal scholars would contend, such water allocation agreements codify the compromise principle of equitable utilization through the 'needs based' approach. In fact, this 'needs-based' principle is mentioned in the 1997 UN Convention, in Article 6, as one way to determine equitable utilization. These findings have been further supported across 73 allocation agreements (Odom and Wolf, 2008).

Secondly, Wolf also found that in disputes between upstream and downstream states over water allocation, historical uses are most always protected. Wolf writes that in arid climates, agriculture first dominates the lower reaches of the river. Moreover, these agricultural sights tend to predate hydroelectric uses that are found further upstream toward the headwaters. Thus the downstream user tends to have a greater claim to water – whether measured by human need for food, or by prior appropriation (Wolf, 1999, p. 12). This is an interesting point, since

Article 6 of the 1997 UN Convention also recognizes the right of a state to develop and exploit the 'potential uses' of a watercourse – recognizing the needs of upstream states. Wolf's (1999) findings, therefore, demonstrate that while upstream riparians have the right to develop their water resources, past uses of the downstream states are protected. In fact, Article 6 of the UN Convention recognizes 'existing uses' as another factor in determining equitable utilization.

Wolf and Hamner (2000), provide a slightly more comprehensive assessment of international water agreements – focusing on 145 treaties, that span water allocation, hydropower, flood-control and water quality issues. The authors make several observations about their corpus of treaties, important for understanding treaty resiliency in general. First, for those treaties which allocate water, the particular water allocation method used is highlighted (these are similar to those already delineated by Wolf, 1999). They also delineate the treaties by those that have enforcement versus monitoring mechanisms. Finally, they consider 'non-water linkages.' In fact, the authors explain that in the spirit of broader benefit-sharing, enlarging the scope of water disputes to include non-water issues may facilitate resolution of a property right dispute (see also Sadoff et al., 2002; Phillips et al., 2006).

Although the above studies make few assessments as to the quality of the mechanisms (their advantages and disadvantages) in light of water variability, they are nonetheless instructive as a baseline for assessing which mechanisms might be particularly useful, making treaties more resilient in general and by extension more robust in mitigating the effects of variability across time. That said, Odom and Wolf (2008) clearly recognize some of the deficiencies in agreements that govern basins with regard to inherent variability in the water cycle, as well as other uncertainties. In a study based on 50 treaties from 1980, Drieschova et al. (2008) consider the different mechanisms negotiated among states to govern flow variability due to climate change. The authors consider a number of allocation and adaptation mechanisms suggesting that some agreements may be better at dealing with variability than other treaties. Finally, Stinnett and Tir (2009), while not examining variability or the effects of institutional mechanisms on treaty stability, do tout the general importance of treaty institutionalization.

Explaining specific mechanisms and their utility for dealing with variability

In contrast to a flood-control related agreement, both water quantity and hydropower agreements may be particularly sensitive to the type of allocation mechanism negotiated in the agreement. Since high variability produces fluctuations in available water, a flexible allocation mechanism may be better at dealing with variability than, say, a less flexible mechanism.

In coordination with the Transboundary Freshwater Dispute Database (TFDD) at Oregon State University and the International Water Management Institute (IWMI), we define eight allocation methods in Table 1. Specific examples are also provided in the table. We also identify whether or not the said mechanism is flexible and if it is binding or enforceable. This classification is not intended as a ranking order (or a way to determine the degree of flexibility or enforceability across the mechanisms) but rather to categorize the various mechanisms, given that dealing with variability may require both a flexible and binding allocation mechanism.

While all allocation mechanisms may be relevant for treaty resiliency in the case of water allocation and hydropower, we are particularly interested (at least for theoretical purposes) in Mechanisms 1 and 4 (fixed quantities and percentages, respectively). In addition to both being binding stipulations, these mechanisms constitute a majority in our treaty sample and represent

Allocation Mechanism	Numeric Association	Definition	Generic Example(s)	Treaty Example(s)	Flexible	Enforceable
None	0	No allocation mechanism specified.		Agreement between the People's Republic of Bulgaria and the Republic of Turkey concerning cooperation in the use of waters of rivers flowing through the territory of both countries; 23/10/1968	NA	NA
Fixed quantities	1	Refers to allocations whereby a party receives a defined volume or rate of water that does not vary.	Country A gets 100 acre-feet of water every month. Country B is assured a minimum flow of 100 cfs at the border at all times.	Agreement between His Majesty's government of Nepal and the government of India on the Gandak Irrigation and Power Project; 14/12/1959	NO	YES
Fixed quantities which vary according to water availability	2	Refers to allocations whereby a party receives a defined volume or rate of water that varies according to the amount of water available.	Country A gets 100 acre-feet of water every month if there is 500 acre-feet available and 50 acre-feet of water if there is less than 500 acre-feet available. Country B is assured a minimum flow of 100 cfs during the wet season and 50 cfs in the dry season.	Treaty on the development and utilization of the water resources of the Komati River Basin between the government of the Kingdom of Swaziland and the government of the Republic of South Africa; 13/3/1992	YES	YES
Fixed quantities recouped in the following period	3	Refers to allocations whereby a party receives a defined volume or rate of water that is averaged over a set amount of time.	Country A gets 100 acre-feet of water every year on a 3 year average. Year 1 could be 90 acre-feet; Year 2 could be 95 acre-feet; and Year 3 could be 115 acre-feet. This would meet treaty obligations.	Exchange of notes between the United States and Mexico constituting an agreement concerning the loan of waters of the Colorado River for irrigation of lands in the Mexicali Valley; 24/8/1966	YES	YES
Percentage	4	Refers to allocations that divide water based on percentages or ratios.	Country A receives 50% and Country B receives 50%.	Agreement between Iran and the Soviet Union for the joint utilization of the frontier parts of the rivers Aras and Atrak for irrigation and power generation; 11/8/1957	YES	YES
Prior approval	5	Refers to allocations that may change with approval of certain parties.	Country A requires higher water use than was agreed upon because of a new irrigation system and has to seek the consent of the other party.	Agreement of withdrawal of water from Lake Constance between Switzerland, Austria and the Federal Republic of Germany; 30/4/1966	YES	NO
Allocation of entire rivers	6	Refers to allocations that are based on land/territory.	Country A gets full use of all streams that originate within its borders. Country B gets full use of all streams north of a certain geographic location.	Agreement between Norway and the Union of Soviet Socialist Republics on the utilization of water power on the Pasvik (Paatso) River; 18/12/1957	YES	YES
Consultation	7	Refers to allocations that are determined by a third party, typically a river basin organization or technical committee, or a group of negotiators at a later date.	Joint Commission will study the needs of each country and the availability of water, then determine allocations based on their findings. Water ministers of each country will consult and agree on allocations.	Agreement on the cooperation for the sustainable development of the Mekong River Basin between Thailand, Vietnam, Laos and Cambodia; 5/4/1995	YES	NO
Fixed quantities and percentages	8	Refers to allocations based on an equation of fixed volumes or flows and percentages.	Country A receives 75% of water in the wet season and 100 acre-feet in the dry season. Country B receives 50% of water at one geographic location and 100 acre-feet at another geographic location.	Treaty between the government of the Republic of India and the government of the People's Republic of Bangladesh on sharing of the Ganga/Ganges waters at Farakka; 12/12/1996	YES	YES
Prioritization of uses	9	Refers to allocations that meet certain needs/uses before others.	Country A receives enough water to fulfill domestic uses. Enough water is left instream to protect the environment. Indigenous water rights are protected first.	Complementary settlement to the agreement of cooperation between the government of the Eastern Republic of Uruguay and the government of the Federal Republic of Brazil for the use of natural resources and the development of the Cuareim river basin; 6/5/1997	YES	NO

Table 1: Allocation Mechanisms.

two extremes on a flexibility continuum. As suggested above, Mechanism 1, while binding the parties to an actual allocation is less flexible in dealing with variability. Interestingly, the Third Assessment Report hinted to this particular yet profound realization by stating 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, Section 4.7.3). One such example is the 1994 Jordan-Israel Peace Agreement. Since the agreement was signed, 18 complaints or grievances, from one of the treaty signatories, have been recorded. Mechanism 4, on the other hand, is binding in the sense that allocations, in the form of percentages, are clearly stipulated yet the allocation method is flexible, owing to the mere fact that it does mandate static or absolute allocations. All things being equal, such a mechanism for water and hydropower allocations might be particularly important in cases of increased variability (see also Kilgour and Dinar, 2001).

The type of institutional arrangements employed in the agreement may also be relevant. In other words, beyond the presence or absence of flexible and binding allocation mechanisms, overall treaty design is paramount for stable cooperation among various protagonists (Barrett, 2003). Naturally, a well-designed treaty may not necessarily be indicative of a trouble-free agreement. However, we assume that having adopted a set of mechanisms in a given treaty, parties, on the whole, will generally abide by the stipulations of these institutional instruments.

Building on the various studies cited above in combination with so-called institutionalist literature, it is quite feasible to enumerate a number of institutional mechanisms that add to the robustness of treaties. Most obviously, enforcement mechanism is imperative as it provides states or other relevant parties with the powers to punish defectors (Susskind, 1994, pp. 99–121). The agreement is consequently more robust, stable and adaptable to changes. Enforcement may be promoted 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). Here, a monitoring mechanism potentially provides the guarantees states may seek. Likewise, the presence of a conflict resolution mechanism could prove invaluable. To the extent that the treaty stipulates how disputes are to be resolved among the parties, the more confident parties may feel that their concerns will be met in an amicable and safe environment.

Another mechanism that further signals that the treaty is more institutionalized and may overcome challenges across time is the existence of a joint commission (usually a body of technocrats made up of an equal number of individuals from the respective riparians). In addition to being mandated with proposing water plans and projects for implementation, oftentimes the commission may also have a monitoring and conflict resolution mandate. In her study of the Indus Basin, for example, Zawahri (2009) finds that the joint commission established, or PIC (Permanent Indus Commission), 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). In fact, it is in large part due to the overwhelming success of the PIC to negotiate, monitor and manage, that stable cooperation over water has existed between the two riparians since the treaty's inception.

Finally, another mechanism important for treaty resiliency, in general, is expressed through the notion of 'self-enforcement' (Barrett, 2003). In other words, to the extent that the treaty itself restructures the incentives of the parties towards cooperation, makes it more stable. While self-enforcement can take on various forms, one such strategy may be the use of financial transfers/ side-payments (Dinar, 2006) or the linking of non-water related issues (Wolf and Hamner, 2000; Bennett et al., 1998). Both strategies may be used to bind the parties further to the agreement's tenants by making it costlier to defect as long as benefits accrue from cooperation. Side-payment transfers, for example, were used in the case of the 1961 Columbia River Agreement between the United States and Canada (i.e. the United States compensated Canada for flood-control and hydroelectric benefits derived from Canadian efforts). Issue-linkage was utilized in the case of the 1998 Framework Agreement between Kazakhstan, Kyrgyzstan and Uzbekistan on the Syr Darya Basin (i.e. in the form of coal and gas from downstream Kazakhstan and Uzbekistan for the sake of water deliveries from upstream Kyrgyzstan).

Pertaining to hydropower and water allocation treaties, in particular, adaptation mechanisms to drought may also be important. Such mechanisms may include infrastructure to increase available water supplies or to disperse water supplies throughout time (Drieschova et al., 2008). Pertaining to flood issues, the establishment of flood-control mechanisms, warning systems and information exchange are likewise important. In her study of transboundary flood and institutional capacity, for example, Bakker (2009) finds that, on average, death and displacement tolls relative to the population living in the respective international river basin, were lower in the basins with flood-related institutional capacity (which include flood-related treaty mechanisms). Interestingly, Bakker finds that such institutionalized river basins still boasted significantly higher flood magnitudes than those basins without those institutions.

Finally, considering control variables may also be important when analyzing country complaint likelihood. While various control variables may be important,[1] we consider only the effects of trade in our causal model. 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 (Neumayer, 2002b). Trade is also argued to act as a contract enforcing mechanism (Stein, 2003).

Hypotheses

Generally, we claim that certain allocation mechanisms may be better in deterring state grievances and complaints in the face of water variability and climate change. In particular, when variability across time is high a more flexible allocation mechanism should elicit less conflict for that basin in the form of fewer complaints. Effectively, a percentage allocation mechanism, as opposed to a fixed mechanism, is much more suitable for basins with high variability. While this applies mostly to water quantity and allocation issues, treaties dealing with hydropower are also relevant since the riparians rely on the flow of the river for the creation of hydroelectricity and a reduced flow may decrease hydroelectricity production while high variability may make hydropower production less stable. Consequently, for the water-quantity (and hydropower treaties as well), mitigating mechanisms for dealing with drought should also matter. Climate change driven variability also affects the above-average flow in the river. Therefore, for flood-control treaties, specific mechanisms that work to deal with or prevent flooding will also be crucial in inhibiting complaints. Finally, beyond the allocation mechanisms and the issue-specific instruments enumerated above, other institutional variables should be particularly helpful in mitigating complaints for the three subject areas investigated. Such institutions (monitoring, enforcement, conflict resolution, self-enforcement [i.e. non-water linkages such as side-payments and/or issue linkage] and international joint commission) not only help to make the agreement more stable but contribute to transparency in any given interaction. Trade interdependency among the riparians should also assuage instances of conflict.

Using Oregon State University's Basins at Risk Scale[2] to record climate related, and general, grievances and complaints among riparians, we argue that the frequency (and severity) of those complaints or state grievances should follow the following hypotheses:

H1: Basins, governed by treaties, experiencing increased variability over time will generally educe more complaints/intensity of complaints or state grievances.

H2: Treaties providing for specific conflict resolution, monitoring, enforcement and self-enforcement mechanisms will generally exhibit fewer complaints/lower intensity of complaints.

H3: Treaties regarding water allocation and hydropower, which provide for particular allocation mechanisms as opposed to others (percentage rather than fixed, for example) will generally exhibit fewer complaints/lower intensity of complaints, especially considering high variability.

H4: Treaties regarding water allocation, but likewise hydropower, which provide for adaptability mechanisms to drought (i.e. desalination, wastewater recycling, water augmentation strategies) will generally exhibit fewer complaints/lower intensity of complaints.

H5: Treaties regarding flood-control which prescribe specific mechanisms for dealing with floods (reservoirs, levies, dams and information exchange, for example) will generally exhibit fewer complaints/lower intensity of complaints.

H6: Treaties that govern relations among riparians with increased trade interdependence will generally exhibit fewer complaints/lower intensity of complaints.

Our model, therefore, can be depicted as

[1] $$C = f(V, CR, M, E, SE, AL, AD, FM, T)$$

Where C (generally measured as the existence of a complaint, the number of complaints and the intensity of the complaints) is a function of expected V (variability), CR (conflict resolution mechanisms), M (monitoring mechanisms), E (enforcement mechanisms), SE (self-enforcement mechanisms), AL (a particular water allocation regime), AD (adaptability mechanism) and FM (flood-control mechanism).

Methodology of Data Collection and Coding

Treaty data and state grievances

We constructed a dataset of basins by identifying treaties that pertained to water quantity allocation, hydropower allocation and flood control. The dataset also identified the signatories of the treaty, date signed, information on the allocation mechanisms stipulated above and information on the aforementioned institutional mechanisms. This information was compiled from TFDD and our own coding efforts through content analysis of each treaty.[3] The presence or absence of a variety of mechanisms was recorded as 1 or 0, respectively. If a given mechanism was present, a detailed explanation was also recorded.

Once the basins were identified, complaints were determined using the Basins at Risk (BAR) database, that contains events in the period from 1950 to summer of 2005 for the countries located in Asia, North America and Europe, and the period of 1950 to 2000 for basins located in Africa and South America (Bakker, 2005). First, events were compiled if they had received a neutral or negative BAR rating, indicating conflict. Here, neutral (0) is defined as rhetorical policy or indifferent statements while conflict ranges from strong displays of hostility (-6) to mild displays of dissatisfaction (-1) (Yoffe, 2001). We also identified if the treaty violation pertained to flow variability. This was indicated by specific mention of drought or flood in the event text. These complaints were then labeled as 'climate-driven.' Owing to the relatively small number of complaints that formally make reference to climate, we also consider general complaints per basin. Such complaints are important for their substance may also be due to flow variability, although that may not be formally mentioned. We tally event data for each treaty basin.

A single event that is captured multiple times in the BAR database (e.g. two newspapers report the same story), is treated as one event. However, region-wide complaints between, for example, Spain and Portugal that share the Duero, Mino and Guadiana basins, appeared in our database three times, i.e. a complaint for each of the three respective basins.

Events were then analyzed to determine whether a complaint pertained to a specific treaty. Here, the event must contain an explicit complaint by, say, Party A towards Party B that the latter was not upholding the terms of their joint agreement. In addition, the complaint had to have been filed at a date after the agreement had been signed. Moreover, complaints must have been made by government officials. Protests or complaints from citizens may give strong indication of the reality on the ground, but they are not signatories to the treaty. Their dissent with respect to an institutional arrangement may indicate that an arrangement is not equitable, but it does not necessarily indicate treaty failure.

If these qualifications were met, a 'treaty code' was assigned to link the complaint to the treaty that was being perceived as violated. Numerical treaty codes were pre-assigned to all treaties in the TFDD. A complaint was matched to a treaty based upon the date of complaint relative to ratification of an agreement, location and parties involved to account for basins with multiple treaties between various riparians. For example, within the Jordan River basin there are agreements between Israel and Jordan, Jordan and Syria and Israel and Palestine and each complaint was matched to a specific agreement within the greater basin. In all, we tallied the total number of flow driven complaints and number of complaints per year since the treaty was signed, summed and averaged the BAR scale values.

Our water variability information is derived from Dinar et al., 2010. Precipitation data is available from Mitchell and Jones (2005) from the Climate Research Unit (CRU) and downloaded from the CGIAR (Consultative Group on International Agricultural Research) website.[4] These global data are a time-series from 1900–2000 at 0.5 grid. Mean precipitation is summarized by basin and by country-basin separately, although in our causal analysis we use only the precipitation as summarized by basin. The aggregated data are provided by running the algorithm for both the basin-country-polygons and the basin polygons. Precipitation is expressed in units of centimeters. We utilize a coefficient of variation in precipitation (or CV) to proxy for variability across time. The higher the number of the CV, the higher the variability across time. While precipitation may not be the absolute best measure of variability, studies have shown that climate change is expected to alter the hydrological cycle by affecting the amount, distribution and temporal distribution of precipitation (Miller and Yates, 2006). In fact, '[...]variations in flow from year to year have been found to be much more strongly related to precipitation changes than to temperature changes' (IPCC, 2001).

Results

We begin by providing the descriptive statistics, and results of some rudimentary statistical analysis, based on the entire sample of treaties with a water allocation, hydropower and flood control component. We then report the results of the analysis of the narrower sample that is based on the bilateral basins (only) that we used for the causal analysis. This latter regression analysis also includes the derived precipitation data important for inferring how variability may affect complaints (severity of complaints) and how institutional mechanisms may (or may not) mitigate such complaints. This analysis likewise uses the trade data and considers the trade hypothesis.

Results of the descriptive statistics of all basins

In analyzing the data we separated all of the flood-control, water quantity and hydropower agreements and tested our hypotheses within each issue-group. We conducted our analysis based only on the agreements that clearly stipulated the mechanisms and independent variables we were seeking to test. In fact, some of the treaty observations available through TFDD were either not available in English and/or had missing data since the actual treaty text was unavailable. Consequently, we had to remove these types of observations from our examination. In all, our study analyzed 40 flood-control related agreements, 31 hydro-power related agreements and 66 water-quantity related agreements. Table 2 likewise presents a summary of the number of complaints/grievances registered by issue type over time.

Time Period	Water Allocation	Hydropower	Flood
1950–1959	0	0	0
1960–1969	0	0	0
1970–1979	0	3	0
1980–1989	7	0	0
1990–1999	58	1	0
2000–2005	41	1	6

Table 2: Summary of total complaints by treaty issue type over time.

It is interesting, yet perhaps unsurprising, that more complaints or country grievances have been recorded in more recent years. First, is the sheer fact that environmental issues have not come onto the global agenda until only very recently – with the culmination of the 1972 Stockholm Declaration on the Human Environment. Reporting such events has consequently become more important (and newsworthy) over time. Second, since we code our complaints as variability-driven it is possible that the effects of variability have become more severe in recent years. Third, it is perhaps unsurprising that water quantity issues boast the largest share of complaints. Among these three issues, water allocation tends to be more salient, particularly since allocating water could be considered by some parties a zero-sum game – especially in arid areas.

Flood-control treaties

With regard to the flood-control agreements, several interesting findings can be gleaned from the descriptive statistics. Of the 40 treaties that were analyzed, the majority embody an ensemble of the institutional mechanisms described. In contrast, enforcement and conflict resolution mechanisms were constituted in only 17% and 40%, respectively, of the flood-control agreements analyzed. Table 3 presents the relevant mechanisms. Although it is fairly logical to expect flood control agreements to institute specific measures to deal with flood control (e.g. reservoirs, information exchange, earning systems, etc.), it is noteworthy that some 20% of flood-control treaties institute rather vague measures.

Mechanism	Number of flood-control treaties with mechanism
Self-enforcement (*Self enforce*)	25
Commission/Council (*Commission*)	26
Monitoring (*Monitor*)	26
Conflict resolution/Dispute resolution (*Dispute resol*)	16
Enforcement (*Enforce*)	7
Specific flood-control mechanisms (*Specific flood*)	32

Note: Individual treaties may include more than just one allocation mechanism.

Table 3: Institutional mechanisms for flood-control agreements.

In terms of the mechanisms' correlation with complaints, additional findings are also noteworthy. Of all the mechanisms we examine, those agreements that embody a monitoring and a commission/council mechanism exhibit fewer complaints than those that do not. The correlation coefficient is both negative and robust at the 20% level. Hypothesis 2 is thus inferred in this statistical analysis. The other mechanisms either follow the expected sign but are not highly correlated with complaints or exhibit the opposite correlation sign. Interestingly, while the flood-control mechanisms appear in the majority of agreements, they do not robustly correlate with fewer complaints – Hypothesis 5 is thus not inferred in this statistical analysis.

Hydropower

With regard to the hydropower agreements, several interesting findings can be gleaned from the descriptive statistics. Of the various mechanisms, the percentage allocation appears the most times at 49%. Table 4 presents the distribution of the various mechanisms.

Table 5 presents the distribution of the various institutional mechanisms. Of the 31 treaties that were analyzed, the majority embody an ensemble of the institutional mechanisms described above. Interestingly, the enforcement mechanism and adaptability mechanism to drought were in only a very small number of hydropower agreements, 22% and 13%, respectively.

We present additional descriptive statistics that correlate the type of mechanism with the number of complaints. Of all the mechanisms we examine those agreements that embody monitoring and conflict resolution mechanisms exhibit fewer complaints than those that do not. Hypothesis 2 is thus inferred in this statistical analysis. The other mechanisms are either not highly correlated with complaints or exhibit the opposite correlation sign. Interestingly, the adaptability mechanism to drought, while negatively correlated with complaints, is not robust – Hypothesis 4 is thus partly inferred in this statistical analysis.

Allocation Mechanism	Number of treaties with mechanism
None (*Allocation0*)	6
Fixed (*Allocation1*)	5
Fixed quantities which vary according to water availability (*Allocation2*)	1
Fixed quantities recouped in the following period (*Allocation3*)	0
Percentage (*Allocation4*)	18
Prior approval (*Allocation5*)	0
Allocation of entire rivers (*Allocation6*)	0
Consultation (*Allocation7*)	0
Fixed quantities and percentages (*Allocation8*)	1
Prioritization of uses (*Allocation9*)	0

Note: Individual treaties may include more than just one allocation mechanism.

Table 4: Distribution of hydropower allocation mechanisms.

Mechanism	Number of hydropower treaties with mechanism
Self-enforcement (*Self enforce*)	29
Commission/Council (*Commission*)	19
Monitoring (*Monitor*)	17
Conflict resolution/Dispute resolution (*Dispute resol*)	16
Enforcement (*Enforce*)	7
Adaptability mechanism to drought (*Drought adapt*)	4

Note: Individual treaties may include more than just one allocation mechanism.

Table 5: Institutional mechanisms for hydropower agreements.

Water quantity

Regarding the water quantity agreements, several interesting findings can be gleaned from the descriptive statistics. Table 6 presents the distribution of the various mechanisms across the treaties. Mechanisms 1 (fixed allocation), and 4 (percentage allocation) appear relatively more times across the treaties.

Table 7 also demonstrates that the majority of water quantity agreements embody an ensemble of the institutional mechanisms described above and in our hypotheses section. Interestingly, and like the hydropower agreements, the enforcement mechanism and adaptability mechanism to drought were exhibited in only a very small number of water quantity agreements, 10% and 15%, respectively.

Water Allocation Mechanism	Number of treaties with mechanism
None (*Allocation0*)	7
Fixed (*Allocation1*)	17
Fixed quantities which vary according to water availability (*Allocation2*)	9
Fixed quantities recouped in the following period (*Allocation3*)	3
Percentage (*Allocation4*)	10
Prior approval (*Allocation5*)	1
Allocation of entire rivers (*Allocation6*)	8
Consultation (*Allocation7*)	9
Fixed quantities and percentages (*Allocation8*)	2
Prioritization of uses (*Allocation9*)	0

Note: Individual treaties may include more than just one allocation mechanism.

Table 6: Distribution of water allocation mechanisms in water quantity treaties.

Mechanism	Number of water quantity treaties with mechanism
Self-enforcement (*Self enforce*)	33
Commission/Council (*Commission*)	47
Monitoring (*Monitor*)	43
Conflict resolution/Dispute resolution (*Dispute resol*)	37
Enforcement (*Enforce*)	7
Adaptability mechanism to drought (*Drought adapt*)	10

Note: Individual treaties may include more than just one allocation mechanism.

Table 7: Institutional mechanisms for water quantity agreements.

Given the emphasis placed on the allocation methods for water quantity agreements, and the extensive number of complaints recorded for this issue type, we conduct an ANOVA test (single-factor) for this treaty issue-type in particular. The purpose is to explore if simple statistically significant variations can be gleaned across the enumerated allocation methods described earlier and their relationship to state grievances.[5] The ANOVA test (Table 8) demonstrates that there is a statistically significant difference between the water allocation mechanisms. We can conclude, based on the ANOVA test that the various mechanisms are statistically different in their resiliency to complaints and grievances.

	MS	F	P-value	F crit
Between water allocation mechanisms	272.22	3.436	0.082	3.048

Table 8: ANOVA test for variance across mechanisms per total complaints.

Finally, further descriptive statistics are also indicative, pointing to the number of complaints associated with each mechanism. Mechanisms 5 and 7, 'prior approval' and 'consultation,' respectively, elicit the fewest number of complaints. In particular, mechanism 5 elicits no complaints and mechanism 7 elicits only two complaints. In line with our expectation, mechanism 4 elicits a small number of complaints as well – at five. Interestingly, mechanism 1 elicits the largest number of complaints (at 39), which is generally in line with the expectation that some mechanisms may elicit additional complaints given that they are, generally, less flexible.

Multivariate and Causal Analysis

In deriving multivariate and regression results we applied our analytical framework to a subset of our international water treaties. Specifically, we considered rivers shared by only two states. The reason for this was that the precipitation data was derived only for such rivers and associated riparian dyads. Current work is deriving respective precipitation data across all available treaty basins and associated dyads. Below we outline the empirical specifications to the variables, which affected also the estimation procedures that we applied.

The dependent variables

We use three variants of complaints as our dependent variables. We define the dichotomous variable *Complaints/No complaints* having a value of 1 if any number >0 of complaints have been recorded for the basin and a value of 0 if no complaints have been recorded. Another variant of the dependent variable, *Number of complaints*, holds integer values of 0, 1, …, 13, which are the number of complaints filed by the riparian states (starting with no complaints and ending with 13 – the maximum number of complaints filed by an individual riparian). The third variant is based on the BAR value associated with each complaint, as described in the data section. *Average BAR complaint* is the average value of the BAR index assigned to each of the complaints filed by the riparian state.

For regressions that include *Complaints/No complaints* as the dependent variable we employed the LOGISTIC estimation procedure due to the truncated nature (0/1) of that variable. For regressions that include the *Number of complaints* as a dependent variable we employed the General Linear Models (GLM) procedure that is usually applied when the dependent variable is an integer and spans over a range that spans also over the value 0. And, finally, for regressions that include the *Average BAR complaint* as a dependent variable we applied the Ordinary Least Square (OLS) and GLM estimation procedure. Below we provide only regression results for the *Average BAR complaint* as the dependent variable (using the GLM estimation procedure which provided the most interesting results). The other two dependent variables did not yield sufficiently consistent results, as will be explained below.

The independent variables

We used long term precipitation variability as an independent climate variable, measured as the Precipitation Coefficient of Variation (*PrecipCV*), expressed in percent. For water quantity and hydropower treaties we included dummy variables to distinguish among the eight allocation mechanisms (*Allocation0*, …, *Allocation8*) (see Table 1). The institutional arrangements, or mechanisms, that have been identified were assigned the following variables: Self-enforcement (*Self enforce*), Monitoring (*Monitor*), Enforcement (*Enforce*), Conflict resolution/Dispute resolution (*Dispute resol*), Basin commission (*Commission*) and Drought adaptability (*Drought adapt*), with the latter not being part of the flood control treaties. As explained in the theoretical section, we also included a control variable – *Trade*, that was found to be significant in previous studies. Following Dinar et al. (forthcoming) we included a linear and quadratic specification of the trade variable. The calculation of the trade variable and a discussion about its quadratic form can be found in Dinar et al. (forthcoming).

The regression specifications

Given the subset of treaties used for our regression analysis, we identified complaints in water quantity and flood control treaties but no complaints in the hydropower treaties. Therefore, the regressions we estimate will follow this data limitation.

For both the water quantity and flood control treaties we estimated separately the following two equations:

[2]

Dependent Variable = f(*PrecipCV, Allocation0, …, Allocation8, Self enforce, Monitor, Enforce, Dispute resol, Commission, Drought adapt*)

[3]

Dependent Variable = g(*PrecipCV, Self enforce, Monitor, Enforce, Dispute resol, Commission, Drought adapt*); where in the case of flood control, the variable *Drought adapt* is excluded from equations [2] and [3] because there is no drought adaptability mechanism in flood control treaties. Instead, a specific flood-control mechanism or *Specific flood* is examined instead.

After estimating these two equations, we combined the water quantity treaty data with the hydropower treaty dataset because we argue that they should behave in a similar pattern with regards to water variability. For this combined hydropower and quantity treaty dataset we estimated the following regressions:

[4]

Dependent Variable = h(*PrecipCV, Allocation0, …, Allocation8, Self enforce, Monitor, Enforce, Dispute resol, Commission, Drought adapt*)

[5]

Dependent Variable = j(*PrecipCV, Self enforce, Monitor, Enforce, Dispute resol, Commission, Drought adapt*)

[6]

Dependent Variable = k(*PrecipCV, Allocation0, …, Allocation8, Self enforce, Monitor, Enforce, Dispute resol, Commission, Drought adapt, Treaty type dummy*); where the treaty type dummy variable intends to distinguish between water quantity and hydropower treaties in case there are differences not accounted for by our model.

We also created a set of all treaties, including water quantity, hydropower and flood control issues.

[7]

Dependent Variable = m(*PrecipCV, Self enforce, Monitor, Enforce, Dispute resol, Commission)*

Dependent Variable = p(*PrecipCV, Self enforce, Monitor, Enforce, Dispute resol, Commission, Treaty type dummy*); where again, the treaty type dummy variable intends to distinguish between water quantity, flood control and hydropower treaties in case there are still differences not accounted for by our model.

Finally, we also included the control variable, *Trade and Trade-squared* in all the above regressions. Recall that the dependent variable in the various runs took the form of the three previously defined variables *Complaints/No complaints, Number of complaints* and *Average BAR complaint*.

Results of the multivariate and causal analysis

We begin by presenting, in Table 9, the descriptive statistics for the entire set of observations.

Variable	Observations	Mean	SD	Min.	Max.
Complaints / No complaints	74	0.243	0.432	0	1
Number of complaints	74	0.581	1.712	0	13
Average BAR complaint	74	0.395	0.868	-5	0
PrecipCV	74	0.823	0.291	0.355	1.625
Allocation0	57	0.070	0.257	0	1
Allocation1	57	0.245	0.434	0	1
Allocation2	57	0.052	0.225	0	1
Allocation3	57	0.017	0.132	0	1
Allocation4	57	0.333	0.475	0	1
Allocation6	57	0.122	0.331	0	1
Allocation7	57	0.140	0.350	0	1
Allocation8	57	0.017	0.132	0	1
Self enforce	74	0.594	0.494	0	1
Monitor	74	0.594	0.494	0	1
Enforce	74	0.094	0.294	0	1
Dispute resol	74	0.608	0.491	0	1
Commission	74	0.810	0.394	0	1
Drought adapt	57	0.087	0.285	0	1
Trade	60	0.044	0.092	0.0000149	0.315

Table 9: Descriptive statistics of variables associated with water quantity, hydropower and flood control treaties.

Table 9 provides information on the means and ranges of the variables included in our multivariate analysis. As can be seen, allocation mechanisms are included in 57 observations that comprise the water quantity and hydropower treaties (while none in the flood control observations). Also, our trade variable exists only for 60 of the 74 observations (due to missing values) in the sample and, thus, will allow us to refer only to a smaller set of observations.

The data in the table also tell us about the frequency of the allocation mechanisms and the institutions in the sample. The most frequent allocation mechanisms are *Allocation1* and *Allocation4*, capturing respectively one quarter and one third of the 57 observations of the water quantity and hydropower treaties. Allocation Mechanism 5 and Mechanism 9 were not reported in any of the treaties, used for the regression analysis, and therefore not included in any of the regression procedures.

Among the institutions present in the various treaties, *Enforce and Drought adapt* are present in only 7 percent of the treaties, while the other institutions are used in 60 to 80 percent of the treaties. We should mention that more than one institution may be present in each single treaty. Regression results are presented in Table 10 for the subset of water quantity and hydropower treaties. Of all possible data analyses the subset of these treaties yielded the most robust results.

Table 10, which presents results for treaties that deal with water quantity and hydropower treaties only, suggests that for the treaties with water allocation mechanisms we are able to explain quite reasonably the level of complaints, measured by the *Average BAR complaint* score.

Regression procedure	**GLM**	**GLM**	**GLM**	**GLM**
Dependent variable	***Average BAR complaint***			
Equation	**1**	**2**	**3**	**4**
PrecipCV	-0.724* (-1.68)	-0.821* (-1.70)	-1.32*** (-2.76)	-0.324* (-1.60)
Allocation0			-2.18*** (-2.65)	
Allocation1			-1.01* (-1.56)	
Allocation2			-1.33 (-1.25)	
Allocation4			1.93** (1.89)	
Allocation6			-1.99*** (-2.19)	
Allocation7			-0.775 (-0.87)	
Allocation8			-1.583 (-1.49)	
Self enforce	-0.420 (-1.27)	-0.046 (-0.19)	-0.527 (-1.13)	-0.290 (-0.80)
Monitor	0.234 (0.96)	0.163 (0.72)	-0.053 (-0.26)	-0.033 (-0.14)
Enforce	1.43*** (3.85)	1.31*** (2.97)	1.14*** (2.15)	0.969*** (2.65)
Dispute resol	0.325 (1.28)	0.460* (1.65)	0.471** (1.87)	0.523*** (2.26)
Commission	-0.357 (-0.91)	-0.343 (-0.86)	-0.455 (-1.26)	-0.356 (0.58)
Drought adapt	0.630* (1.54)	0.778* (1.80)	1.04** (2.70)	0.613 (1.47)
Trade				38.20** (2.11)
Trade square				-109.26** (-2.04)
Water quantity dummy	-0.760*** (-2.81)		-1.19*** (-2.20)	
Constant	1.04** (1.94)	0.338 (0.59)	3.58*** (2.93)	-0.451 (-0.48)
Observations	57	57	57	46
Log Pseudo Likelihood	-68.65	-72.15	-59.68	-58.08

*Note: *, ** and *** indicate significance levels of 0.10, 0.05 and 0.01, respectively.*

Table 10: Regression results for the water quantity and hydropower treaties.

We present 4 models or equations. In equation 1 we present results for equations that include only the institutional mechanisms and a dummy variable to distinguish between the water quantity and the hydropower treaties. In equation 2 we present a similar equation but without the distinction between the two types of treaties, viewing them as similar due to the fact that both may be similarly affected by flow variability. These two specifications correspond to the seventh regression equation presented earlier. In equation 3 we introduce a specification that includes both the allocation mechanisms and the institutional mechanisms. This third specification corresponds to the fourth regression equation presented earlier. And finally, in equation 4 we introduce a control variable – *Trade* – which has been suggested in our theoretical framework to explain riparian interactions. This fourth specification corresponds to the fifth regression equation presented earlier plus the trade variable. We also use the quadratic form of *Trade* to capture the well-established phenomenon of possible likely conflicts between the dyad states as trade interactions increase.

Results of the various equations indicate that the level of complaints increases with water variability – specifically the BAR score becomes more negative (conflictive) as *PrecipCV* increases. The results are significant in all four models but more so in the third model. This provides some interesting support of the water and climate change literature which has theorized that increased variability could test the viability of international water agreements. It also complements the findings of other studies that have demonstrated that increased water scarcity leads to more country claims over a given river (Brochmann and Hensel, 2009). In other words, these results suggest that if water variability is predicted to increase given the effects of global warming, the trend could further challenge governance regimes. Consequently, the institutional capacity of such regimes to deal with possible inter-country disputes is paramount. Hypothesis 1 is thereby inferred.

The examination of the institutional mechanisms also provided some interesting results. Of the institutional mechanisms we examined, enforcement, conflict resolution/dispute resolution and drought adaptability seem to reduce the intensity of complaints, although the dispute resolution institution is not significant in equation 1 and the drought adaptability mechanism is not significant in equation 4. Interestingly, the coefficients of the self-enforcement, monitoring and international joint commission are not significant in any of the equations, although some carry the expected sign. It is noteworthy, however, that many agreements bestow the mandate of monitoring, enforcement and conflict resolution/dispute resolution on the joint commission. This correlation could explain the insignificant results of some of these institutional mechanisms. In addition, the enforcement and self-enforcement mechanisms are also correlated (negatively at 40%), which may explain why the latter mechanism is not significant. Finally, it is particularly noteworthy that the presence of a drought adaptability mechanism is also important for reducing the intensity of complaints. In all, Hypotheses 2 and 4 are inferred with regards to particular institutional and adaptability mechanisms.

Our results suggest that the particular allocation mechanism negotiated in the treaty also matters. Among the water allocation mechanisms evaluated in equation 2, only the percentage allocation (*Allocation4*) has a positive sign, indicating a reduction impact on the intensity of the BAR score. The other water allocation mechanisms have a negative sign, indicating an increase impact on the BAR scale. However, of all water allocation mechanisms only *Allocation0, Allocation1* and *Allocation6* (indicating no allocation mechanism, fixed allocation mechanisms and allocation of entire rivers, respectively) are significant. It is perhaps unsurprising that the 'no allocation' mechanism would elicit more intense country complaints. Since the countries did not or could not agree on any allocation regime this could potentially lead to increased tensions in the face of increased variability. One would expect the 'allocation of entire rivers' mechanism to yield a lower intensity of complaints given that the parties physically divide the actual shared river(s) between them and thus reduce the level of interdependency between them. However, it is possible that since the parties are still, at least, physically interdependent vis-à-vis their shared river, the actions of one party affects the other. Not having an allocation regime that takes into account this inevitable interdependency could potentially lead to tensions. Pertaining in particular to mechanisms 1 and 4, the results are in line with our expectations. A percentage allocation (which tends to be more flexible and binding) helps reduce the degree of country grievances and complaints, while a fixed allocation mechanism (which happens to be binding but not flexible) may actually exacerbate the degree of country grievances. Hypothesis 3 is thus inferred.

The coefficients of the *Trade* variable are significant and behave as expected. The linear relationship demonstrates that as trade relations increase and intensify, relations in turn become more interdependent. Consequently, such a mutually dependent relationship reduces the intensity of country complaints. The results of the quadratic relationship regarding *Trade*, however, demonstrate that as trade relations become overly strong a diminishing returns effect on complaint intensity takes place. This supports some of the international relations literature that suggests that very high interdependence leads to more opportunities for conflict and friction (Barbieri, 2002, p. 121).

The coefficient of the dummy variable distinguishing the water quantity from the hydropower treaty, is significant and negative, indicating that water quantity treaties are associated with higher BAR-level of their complaints. While this is not a hypothesis we formally tested, it does confirm that water quantity treaties tend to be more salient among riparians.

The results of the regression employing the other two dependent variables – *Complaints/No complaints* and *Number of complaints* – did not yield consistent results across all specifications. Of the subsets of treaty analyses that we ran separately – such as flood control treaties – we faced some missing data difficulties, which affected the significance level of the results. Consequently, we ended up with a lower number of observations in certain equations, leading to over specification of these equations. This is also why we had elected to remove the flood-control agreements from the regression analysis. Efforts in future work will focus on closing the missing value gaps we faced.

Conclusions and Future Research

Models considering the effects of climate change point to both decreased and increased river run-off. Such studies have also speculated about the conflict educing characteristics of such climate change effects. To that extent, river management institutions should be fairly important in mitigating conflict between states. Also important are the mechanisms that states build into their institutions, whether consciously or not, to deal with the effects of water variability and its intensification due to climate change.

We believe that future predictions regarding the viability of international treaties, given the effects of climate change, have to be based on the performance of these treaties in the face of past variability. Building on various theoretical studies, this analysis empirically investigated the effectiveness and utility of particular treaty mechanisms included in the design of water quantity, hydropower and flood-control treaties. In general, it was hypothesized that particular allocation mechanisms for water quantity and hydropower agreements may provide more opportunities for fewer/more country grievances and increased/decreased intensity of those grievances. For example, for water allocation treaties, it was hypothesized that the 'percentage' allocation mechanism will be better at dealing with increased variability than, say, the 'fixed' allocation method. The same can be said for hydropower agreements, which depend on a certain allocation of water. The existence of flood-control mechanisms, on the other hand, may be particularly important in river basins predicted to experience high variability. (These mechanisms were coded for flood-control related agreements.) If such specific mechanisms are not part of the agreement, the likelihood of grievances was expected to increase while the intensity of such grievances was likewise expected to levitate.

We also expect that particular institutional mechanisms should matter. Overall, we discuss five such mechanisms, including self-enforcement, monitoring, enforcement, conflict resolution and a joint commission. Adaptability mechanisms to drought should also matter, particularly for water quantity and hydropower treaties.

We began our quantitative analysis with some rudimentary statistical analysis. An ANOVA test was conducted only for the water-quantity agreements, given the large amounts of available complaints, and confirmed that the various allocation mechanisms are effectively different in their relationship to riparian complaints. Although our ANOVA analysis did not examine the allocation mechanisms and base them on overall variability across time, our tabulation did reveal that treaties with the 'fixed' allocation, mechanism 1, exhibited the highest number of complaints. Interestingly, mechanism 4, the 'percentage' mechanism, exhibited much fewer complaints. These were the two main allocation mechanisms we were curious about given their differing levels of flexibility to deal with variability.

Additional correlation analysis yielded other interesting results. In the case of hydropower and flood control agreements, the monitoring, conflict resolution and commission/council mechanisms were well correlated with fewer complaints. In other words, to the extent that agreements (with these issues) include these mechanisms, they may elicit fewer complaints.

Our regression and causal results revealed that institutions matter and so do the allocation mechanisms. Likewise, the intensity of complaints is well explained by the degree of variability. These are probably the most important three findings in our study. Treaties with certain institutional mechanisms that allow for resolution of disputes, enforcement of the agreement and adaptation when facing drought situations help riparian states face increased water supply variability. Our results also suggest that those treaties pertaining to hydropower and water quantity that embody a fixed allocation mechanism, as opposed to a percentage allocation, are less able to withstand situations with higher water variability. These two types of agreements are more variability-prone and in need of more careful design of their supporting institutions. Concerned states or international organizations may find these various findings useful as they design, or aid states in designing, particular water management regimes. This may be the case for all river basins, but perhaps most importantly in river basins that have either experienced increased variability or are predicted to experience increased variability.

The trade variable, used as a control variable and proxy for other aspects that affect the relations between riparian states, also matters for treaty stability. As trade relations among the riparians increase, this in turn aids in confidence building among the parties and provides for an additional indirect forum for mitigating or assuaging disputes or grievances. This may be particularly important when variability is increasingly high, thus taxing not only the formal agreement negotiated but the relations among the riparians.

We believe to have accomplished several goals with this paper and look forward to extending our analysis. First and foremost, we demonstrated that the allocation mechanisms are indeed statistically different in their relationship to the number of complaints. There is something to be said about the quality of each allocation mechanism, its flexibility (or lack thereof) and the extent to which it is binding (or not), in assessing treaty resiliency. This is particularly the case when contrasting mechanisms 1 and 4, as suggested by other theoretical studies and our Hypothesis 3. Still, further refinement of this general conclusion is required as we apply the larger data set. Second, we also demonstrate that particular mechanisms are more robustly correlated with decreased grievance intensity – as per Hypotheses 2 and 4. It is also here that additional refinement of our data collection and results will have to take place given that we were not able to consider flood-control related agreements (in the causal analysis) and given that some of the institutional mechanisms may be correlated.

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Notes

[1] First, a history of militarized disputes and diplomatic relations, for example, may proxy for overall relations. The argument being that good overall relations should also trickle down to good relations over water issues (Yoffe et al., 2003, p. 1117). Second, governance levels can proxy for the institutional capacity within the basin. The argument being that the higher the institutional capacity and governance levels with the basin, the more commitment the said riparians may exhibit towards the environment (Neumayer, 2002a) and the more general capacity they will have to deal with changes in the river due to variability and not necessarily have to resort to complaints and inter-government protests. Third, power asymmetry in the basin can proxy for the ability of a hegemonic state to, say, provide leadership or incentives so as to assuage lingering problems (Barkin and Shambaugh, 1999). Finally, the geographical configuration of the river can proxy for more (or fewer) opportunities for conflict based on the physical typology of the river (LeMarquand, 1977). The argument being, that river typologies that build in more physical asymmetry are more conducive to disputes (and hence complaints) among the riparians.

[2] http://www.transboundarywaters.orst.edu/database/interwatereventdata.html

[3] http://www.transboundarywaters.orst.edu/database/interfreshtreatdata.html

[4] http://cru.csi.cgiar.org/

[5] In our treaty data, mechanism 9 did not appear in any of the treaties.

[6] We note a number of observations that had to be dropped due to missing trade values.

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