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Weathering climate change: Can institutions mitigate international water conflict?

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Jaroslav Tir

University of Colorado Boulder

Douglas M Stinnett

University of Georgia

Abstract

Although the subject remains contested, some have speculated that climate change could jeopardize international security. Climate change is likely to alter the runoff of many rivers due to changes in precipitation patterns. At the same time, climate change will likely increase the demand for river water, due to more frequent droughts and greater stress being placed on other sources of water. The resulting strain on transboundary rivers could contribute to international tensions and increase the risk of military conflict. This study nevertheless notes that the propensity for conflicts over water to escalate depends on whether the river in question is governed by a formal agreement. More specifically, the article argues that the ability of river treaties to adapt to the increase in water stress resulting from climate change will depend on their institutional design. It focuses on four specific institutional features: provisions for joint monitoring, conflict resolution, treaty enforcement, and the delegation of authority to intergovernmental organizations. Treaties that contain more of these features are expected to better manage conflicts caused by water stress. This expectation is tested by analyzing historical data on water availability and the occurrence of militarized conflict between signatories of river treaties, 1950–2000. The empirical results reveal that water scarcity does increase the risk of military conflict, but that this risk is offset by institutionalized agreements. These results provide evidence, albeit indirect, that the presence of international institutions can be an important means of adapting to the security consequences of climate change by playing an intervening role between climate change and international conflict.

Keywords

climate change, environmental security, river treaties, water conflict, water cooperation

Despite consensus regarding the basic propositions that climate change is real and will have serious ecological consequences, there is much less certainty regarding its social and political implications. It has been suggested, particularly in policy circles, that the ecological effects of climate change will lead to political instability and exacerbate the risk of armed conflict (CNA, 2007). Speculation about how climate change may endanger national security encompasses a variety of possible mechanisms, including extreme weather events and rising sea-levels; see Busby (2008) for a comprehensive review. Nevertheless, statements from public officials regarding the connection between climate change and security have rarely been based on peer-reviewed research (Nordås & Gleditsch, 2007; Salehyan, 2008). Until recently, there were very few systematic studies of the security consequences of climate change for policymakers to draw on. This is beginning to change as scholars are starting to move beyond single-case methods to address the possible connections between climatic factors and intrastate conflict with large-sample empirical studies.

Corresponding author:
jtir@colorado.edu

In this article we aim to apply a similar systematic empirical approach to the possible connection between climate change and *militarized international conflict* ('conflict' for short), focusing specifically on shared sources of freshwater as a potential causal mechanism. Our intended contribution to this larger question is to investigate the impact that international institutions might have on the relationship between climate change and conflict. In particular, we consider the degree to which international institutions that govern transboundary rivers are able to manage the political effects of water stress. We expect that those treaties that are highly institutionalized – with provisions for monitoring, conflict resolution, enforcement, and delegation of authority to intergovernmental organizations – will be better equipped to deal with the international tensions that can arise over transboundary water sources. Our empirical analysis tests the link between institutional design and the occurrence of conflict in a sample of river treaties formed since 1950. The empirical results reveal that water scarcity does increase the risk of conflict, but that highly institutionalized river agreements are effective at steering riparian state interactions away from conflict.

These findings have several implications. First, international institutions can function as an intervening variable in the relationship between climate change and security. Salehyan (2008) advises researchers to consider the social processes and governance mechanisms that play an intermediating role in the connection between the environment and conflict; our findings suggest that international institutions should be considered as one class of governance mechanisms. Forecasts that do not account for the important conflict management potential of international institutions will produce overly pessimistic scenarios regarding the impact of climate change on international security. Likewise, empirical studies of the effects of climate change that use historical data on environmental conditions but do not control for the effect of institutions could fail to undercover important empirical patterns; for example, null findings regarding the connection between water scarcity, shared water sources, and conflict might reflect the positive role played by existing international institutions.

Second, if climate change does have consequences for security, then researchers should start investigating possible policy responses. The theoretical literature on international environmental cooperation has long held that the design of international environmental institutions will condition their ability to promote cooperation (Haas, Keohane & Levy, 1993). The emphasis on the importance of regime design is echoed by specific studies of international water management (Bernauer, 2002; Marty, 2001; Giordano, Giordano & Wolf, 2005; Zawahri, 2009 a,b). This article provides a novel extension of this research. By observing whether the design of river treaties conditions their ability to prevent conflict, we can gain insight, albeit indirect, into methods of managing the effects of climate change on security.

International institutions are a policy response that can be undertaken in the short to medium term. In the long run, mitigation will be necessary to address climate change, but even rapid emissions reductions will have a lag time before atmospheric conditions improve. The political barriers to emissions reductions also make their timely implementation unlikely. Consequently, many have concluded that some effects of climate change are unavoidable, particularly for many tropical and subtropical developing countries. Given the need to adapt to some consequences of climate change, we investigate whether international institutions might be one type of adaptive response to a specific consequence of climate change: international conflicts arising from water stress.

We start by discussing the possible connection between climate change, shared rivers, and international conflict. The next section examines the possible intervening role played by international agreements. We then discuss how four different institutional design features can influence the effectiveness of treaties, followed by a section summarizing our hypotheses. After the research design, we present the empirical results and finally conclude by discussing the implications of our findings.

Climate change, water stress, and transboundary water conflicts

Hypotheses about how climate change leads to conflict encompass a variety of possible mechanisms, including the effects of climate change on precipitation, agricultural output, extreme weather events, economic growth, and human migration. In considering the possible influence on international security, we focus on one anticipated effect of climate change: the expected increase in the scarcity of renewable freshwater. We emphasize water for three reasons. First, although many climate models differ regarding the likely ecological effects of climate change, increases in both seasonal and overall water stress in many geographic regions are projected in several models (Bates et al., 2008).[1] Second, when considering

[1] Given the uncertainty in climate model projections, our findings are applicable to the effects of climate change predicted by several different climate models, although not all.

the effect of climate change on *international* conflict, an increase in water scarcity due to climate change represents the most likely scenario in which conditions in one country can have adverse repercussions in another, due to the importance of transboundary rivers as sources of freshwater. In effect, transboundary rivers are an important source of ecological interdependence, under which water stress in one country can be transmitted to another. Third, analyzing the historical record of water scarcity allows us to gain some valuable, although admittedly indirect, insights into what the consequences of increasing water scarcity in the future might be. Below, we first discuss the projected effects of climate change on water scarcity, and then present three possible routes by which greater water scarcity may increase the risk of international conflict.

Based on studies using both observational records and projections from climate models, Working Group II of the Intergovernmental Panel on Climate Change (IPCC) offers a comprehensive overview of the projected impacts of climate change on freshwater (Bates et al., 2008). The projected effects of climate change discussed in this section are limited to those rated with high or very high confidence by the IPCC. First, the overall level of water available annually is expected to decrease in many dry regions of the world by the middle of this century.[2] Reduced precipitation, more frequent droughts, and reduced river runoff are expected to occur particularly in arid and semi-arid regions where water is already scarce (e.g. the Mediterranean Basin and Southern Africa). Although some regions will experience an increase in precipitation and available freshwater, this will occur mostly in high latitude regions where water is already plentiful and drought is not a major concern to begin with. The benefits of any increase in precipitation will also be offset by the fact that some of it will occur as heavy precipitation events, making the water more difficult to capture and utilize.[3] Moreover, the total area of land subject to increased water stress due to climate change is expected to be double the area in which water stress is expected to decline (Bates et al., 2008). Thus, the total costs of climate change related to the availability of freshwater are expected to outweigh the potential benefits.

Additionally, climate change is anticipated to impact the seasonal variability of precipitation and river runoff. For many regions, reduced precipitation is projected to occur during summer dry periods, increasing the frequency of summer droughts. And because river flow in many regions depends on glacial and snowpack melt during warm and dry periods, an increase in winter precipitation falling as rain rather than snow will reduce melt water contributions to runoff from glaciers and snowpack in the spring – decreasing river flows during dry summer periods. This is especially problematic in arid regions, which already experience little to no summer precipitation, making them more reliant on surface water. Research supporting this conclusion includes evidence from the European Alps, Scandinavia and the Baltic, Russia, the Himalayas, and North America (Bates et al., 2008). The above trends are thus expected to reduce the availability of water in many geographic locations.

The manner in which climate change-induced water scarcity is likely to jeopardize international security is by damaging the relations between states sharing a freshwater source. Transboundary rivers, lakes, and aquifers are often the subject of conflicting utilization, as is typical of common pool resources. The value that states place on these water sources can be expected to increase as climate change amplifies water stress. Climate change can thus magnify water-related international tensions, increasing the risk of armed conflict both directly and indirectly.

First, the increased economic and political value of water due to scarcity caused by climate change will heighten the likelihood of international disputes over transboundary water sources. In response to reduced precipitation, states will likely increase their reliance on other water sources, including transboundary rivers. As is the case for common pool resources, increased unilateral consumption of a transboundary river by one user decreases the amount available to others.[4] Furthermore, the political reaction to water diversion will be more severe under conditions of increased scarcity, because it will be occurring at a time when water will be more valuable for all other riparian states. These issues were highlighted during a recent visit by the UN Secretary-General

[2] This is based on the projections of multiple climate models using the mid-range A1B non-mitigation scenario from the IPCC Special Report on Emissions Scenarios.

[3] Abundant precipitation may negatively impact interstate relations, for example when upstream states release excess water, causing flooding downstream. This possibility is, however, beyond the scope of this article.

[4] Increased scarcity of surface water will also likely cause greater withdrawal of water from underground aquifers. We omit transboundary aquifers from this analysis because there are few existing agreements governing them.

Ban Ki-moon to the Aral Sea. The lake has shrunk by 90% due to water diversion, damming, and irrigation projects on rivers feeding it. In addition to the current ecological disaster, the competition for remaining water among Kazakhstan, Uzbekistan, and Turkmenistan 'could become increasingly heated as global warming and rising population further reduce the amount of water available per capita' (Heintz, 2010).

Even when scarcity does not prompt new river diversion projects, the increased demand for water can lead to disagreements by making states more likely to object to the current behavior of other riparians. Previously acceptable river diversion (for human consumption, industrial use, agriculture, etc.) could become politically problematic after the river flow has been reduced due to climate change. These problems will be compounded when the externalities of the common pool resource are asymmetric, as in the case of rivers for which there are clear upstream and downstream states.

Climate-induced water stress can also lead to a greater reliance on coercive diplomacy. Whereas competing uses of a water source might be manageable politically during normal times, conditions of scarcity can make states less likely to wait for diplomatic options to resolve conflicts. For example, the increased sensitivity to water issues can lead to a more combative response to the damming of a river. Downstream states may use threats or overt military force as a bargaining tactic to coerce upstream states into limiting water diversion. The heightened value of the water source to both sides will shrink the zone of agreement and increase the potential payoff of using coercive bargaining. Accordingly, Hensel, Mitchell & Sowers (2006) find that water scarcity increases the likelihood of militarized conflicts over competing river claims between riparian states. Political and military tensions are also observable between Syria and Turkey over Turkish dams on the Euphrates, while Egypt vehemently opposes diversion of Nile waters by upstream riparians.

Finally, water stress can increase the risk of conflict indirectly, whereby transboundary water source disagreements damage the general relations between states. Because poorly managed interdependence contributes to overall tensions between states (Starr, 1997), disagreements over water may spill over into other issue areas. For example, the sluggish implementation of the Israel–Jordan peace agreement's water-related provisions damaged overall relations between the parties (Fischhendler, 2008a). More broadly, several empirical studies link shared river basins with an increased risk of dyadic conflict (Toset, Gleditsch & Hegre, 2000; Furlong, Gleditsch & Hegre, 2006; Gleditsch et al., 2006); because these studies use a general measure of international conflict – the Militarized Interstate Dispute data – their findings support the notion that water disputes can spill over to other areas of interstate relations.

For both the direct and indirect scenarios, climate change and attendant increases in water scarcity could heighten the risk of conflict. The most pessimistic version of this 'neo-malthusian' prediction is that water scarcity will lead to future full-scale 'water wars' (Gleick, 1993; Klare, 2001), a prediction criticized on both empirical and theoretical grounds (Lonergan, 1997; Gleditsch, 1998; Wolf, 1998). One important objection is that international cooperation over transboundary water sources has thus far been much more common than conflict (Yoffe, Wolf & Giordano, 2003). Additionally, international agreements can help manage transboundary rivers and thus discourage international conflict. The next section explores this in greater detail.

Transboundary river treaties and international conflict

While this study is motivated by the premise that water scarcity can contribute to militarized international conflict, we echo some of the skepticism regarding the 'water wars' scenario. As Salehyan (2008) observes, proponents of the deterministic view that environmental scarcity leads to armed conflict tend to overlook the role of human agency and the moderating effects of institutions. International institutions, in particular, are one important factor that helps explain why international conflicts over water are comparatively rare. Rather than simply being the opposite of conflict, formal international cooperation is one method for managing transboundary water sources and thereby preventing the emergence and escalation of international water disputes. We thus view international institutions as critical explanatory variables that have been largely overlooked in many discussions of international water conflict.[5]

International treaties have become an increasingly common means of managing transboundary rivers. International organizations, such as the United Nations and World Bank, often advocate the formation of river treaties. In the case of tensions in the Aral Sea basin, for example, the UN Secretary General has recommended a formal international accord to better manage the rivers feeding the Aral Sea (Heintz, 2010). This trend has been

[5] Important exceptions include Wolf, Yoffe & Giordano (2003), Hensel, Mitchell & Sowers (2006), and Brochmann & Hensel (2009).

reflected in recent academic research investigating the conditions leading to river treaty formation (e.g. Tir & Ackerman, 2009; Stinnett & Tir, 2009; Tir & Stinnett, 2011). River treaties can specify how the river will be shared, set water quality targets, determine acceptable water withdrawal rates, or balance navigation, water level, and water quality needs; this will, in turn, help minimize the stresses placed on the river and make use more effective in the long run. By helping to resolve the underlying problems that occur because of the competing use of rivers – and which are likely to be exacerbated by increased water scarcity – treaties can alleviate political tensions and reduce international conflict (Wolf, Yoffe & Giordano, 2003).

Nevertheless, river treaties will be effective conflict management tools only to the extent that the signatories actually comply. In this respect, they face several limitations. First, states might engage in intentional cheating. The same incentives that necessitate formalized cooperation in the first place can also tempt parties to cheat on the treaty obligations (e.g. drawing more water for irrigation and industrial purposes than permitted by the treaty). This incentive structure is typical of common pool resources, where the cheater can enjoy the collective benefits created by other parties' actions, while avoiding the private costs of compliance. Second, failure to comply can occur because the language of the agreement is imprecise and open to multiple interpretations in specific situations (Chayes & Chayes, 1995). For example, Fischhendler (2008b) observes that the water use provisions in the 1994 Israel–Jordan peace treaty were left intentionally vague to facilitate domestic acceptance of the agreement. While ambiguity may give a treaty some flexibility, it also allows multiple interpretations of an agreement. Combined with imprecise treaty language, unforeseen conditions can lead to disagreements over treaty compliance. This is uniquely problematic for river management treaties, given both annual and seasonal variability of river conditions. Third, failure to comply with a river treaty can result from a lack of the technical, regulatory, or economic capacity needed to implement it (Chayes & Chayes, 1995). For example, improvements in water infrastructure typically require long-term, capital-intensive investments (Dombrowsky, 2007).

Achieving compliance can be a difficult proposition even under the best circumstances, but climate change – and its consequences for the availability of freshwater – will greatly complicate both the willingness and the ability of the parties to adhere to a river treaty. By increasing the value of water, scarcity will raise the incentive to violate treaty provisions that prohibit unilateral infrastructure development or limit the consumption of river water.[6] It might also prompt small-scale diversion by non-state actors, resulting in unintended violations. Climate change will also exacerbate problems of treaty ambiguity by creating hydrological conditions that were not anticipated when an agreement was formed. When unexpected circumstances in river flow arise, ambiguity can create diverging interpretations of how to behave under these conditions and lead to agreement abrogation. Finally, the lack of capacity to deal with droughts may lead to treaty violations. In 1999, for example, drought reduced Israel's ability to deliver water to Jordan under the terms of the 1994 peace agreement (Kilgour & Dinar, 2001).

In short, the effects of climate change may exacerbate the causes of noncompliance and compromise the ability of river treaties to manage riparian disputes. Despite these limitations, we expect that some river treaties will be more effective than others in helping us adapt to climate change. Next, we focus on institutional provisions of agreements that can improve their ability to manage conflicts and adapt to new environmental conditions.

River treaty design and conflict management

Our central expectation is that river treaties that utilize formal institutions will be more likely to prevent riparian conflicts and alleviate the deleterious consequences of water scarcity for international security. This expectation is based on two related causal logics. First, international institutions help make treaties more effective at preventing conflicts by minimizing the various causes of noncompliance listed above, including those that are generated or exacerbated by the consequences of climate change. For instance, specific institutional provisions can help monitor behavior, facilitate enforcement, resolve disagreements over treaty obligations, and help boost the capacity of member countries. In the event of growing scarcity, better treaty compliance will help preserve available water provided by the corresponding river. This will lessen the stress placed on the river and minimize the temptation to engage in unilateral river diversion. Second, in the event that disputes emerge between signatories, institutions can prevent escalation by facilitating conflict resolution. If climate change, by placing countries in conditions of increasing water scarcity, generates new or intensifies existing conflicts between riparian states, highly institutionalized treaties will be better able

[6] Stress on surface water may also result in increasing conflict over groundwater.

to diffuse such situations than their less institutionalized counterparts.

We focus on four specific institutional features of river treaties. Among treaties signed between 1950 and 2000, taken from the International Freshwater Treaties Database (Hamner & Wolf, 1998), 72% contain at least one institutional provision. The remainder of this section discusses each institutional feature in detail, namely, monitoring provisions (found in 47% of the treaties), enforcement (7%), conflict management (35%), and delegation of authority to an intergovernmental organization (35%).

Monitoring

Formal treaty provisions mandating collection and sharing of river data, such as flows, can improve the functioning of river agreements. Given the complexities of transboundary river systems and the natural variability in river conditions, assessing treaty compliance often requires highly specialized and detailed data (Elhance, 2000; Dombrowsky, 2007). This uncertainty will be exacerbated by climate change; for example, reduced flow can be caused by drought rather than excessive diversion by the upper riparian. In addition, hydrological data can be difficult and costly to collect, especially for developing countries (Elhance, 2000).

Greater transparency and data sharing can reduce fears that the other parties are violating the treaty, though it is certainly no panacea (Feitelson & Chenoweth, 2002). This function of formal monitoring will be even more important if climate change reduces total annual river flow or flow during the critical dry-season. In such cases, better information will help the parties distinguish between the effects of climate change versus the actions of other riparians and provide the basis for addressing water-related consequences of climate change in a comprehensive manner. In other cases, a signatory may be deterred from temptation to cheat because the likelihood of being caught is greater. Finally, provisions for coordinated monitoring can help address capacity limitations by sharing these costs.

Conflict management

To cope with disagreements among signatories, some river treaties specify a variety of formal procedures for dispute management. The Permanent Indus Commission, for example, is responsible for resolving disputes between India and Pakistan over the implementation of the Indus Waters Treaty. Disputes are managed primarily through regular meetings of the officials that make up the two national sections of the Commission (Zawahri, 2009b). At the opposite end of the spectrum lie mandates for binding arbitration or adjudication by an existing international institution. For example, Hungary and Slovakia have resorted to the ICJ to resolve a dispute involving a 1977 treaty governing water infrastructure projects on the Danube (McCaffrey, 2003).

Dispute resolution provisions can address different sources of noncompliance, including those related to anticipated consequences of climate change. A formal process of resolving disputes can address overt cheating by raising the visibility of noncompliance (Abbott & Snidal, 2000). By increasing the costs of violations – some of which may appear particularly tempting due to the effects of climate change (e.g. unilaterally increase withdrawal rates to compensate for lack of water due to a number of dry years) – dispute settlement mechanisms can improve compliance.

Conflict management institutions can also address disputes over an agreement's exact obligations. If climate change causes changes to a river system that were not envisioned at the time of the treaty signing, such as lower flow or greater seasonal variation, then these conditions will make the treaty less effective and increase the risk of conflict. In these circumstances, provisions in a treaty for dealing with unforeseen conditions will become important for preventing conflict. The rulings of a third-party arbitration panel, court, or even informal mediation through a secretariat or intergovernmental body can clarify the terms of a treaty (Chayes & Chayes, 1995). This enhances compliance by limiting the occurrence of unintended violations that result from treaty ambiguities or changed circumstances.

Enforcement provisions

Formally specified procedures for enforcement can improve a treaty's ability to prevent and deal with disputes in multiple ways. First, the reduction in the transaction costs of punishing cheaters increases the costs of non-compliance and deters violations – and thus supports the decentralized self-enforcement of an agreement by its signatories (Keohane, 1984). Furthermore, sanctioning according to the rules laid out in an international agreement will be seen as more legitimate than direct, unilateral retaliation by an aggrieved state; punishments seen as legitimate will help prevent dispute escalation and relations from collapsing in a spiral of retaliatory and counter-retaliatory measures. Finally, even in the absence of strong punitive sanctions, institutionalized enforcement procedures can deter violations by increasing the reputational consequences of non-compliance by disseminating information.

If climate change introduces a host of unexpected shocks to the relationship between riparian states, then the frequency of both intentional and unintentional defection is likely to grow. Enforcement provisions can help force states to comply with the agreement while coping with the changes, punish cheaters to assure broader compliance, and manage disputes so that the mutually-retaliatory, escalating conflicts are avoided.

Intergovernmental organizations

Lastly, some river treaties delegate authority to new or existing intergovernmental bodies. These organizations vary widely in their structure and functions. An example of a complex organization is the Mekong River Committee, which consists of the Secretariat, a permanent executive; the Joint Committee, which makes technical decisions and oversees the Secretariat; and the Council, which is composed of representatives from each member state and has the authority to make policy decisions. Some organizations also include technical committees made up of engineers and other experts, responsible for daily operations. These bodies include the Permanent Indus Commission, the Israel–Jordan Joint Water Committee, and the International Joint Commission for rivers shared by Canada and the United States. Finally, simpler organizations are basically consultative committees that facilitate diplomacy.

Intergovernmental bodies can help manage disputes through several different means. In the event that treaty violations occur, intergovernmental bodies, as centralized venues for communication and diplomacy, will enhance the reputational consequences of noncompliance and thus help sustain cooperation over time (Keohane, 1984). By facilitating diplomacy between member states, intergovernmental bodies can also help clarify the understanding of an agreement's obligations and prevent the escalation of disputes. For technical committees, conflict management is enhanced by the fact that water experts, engineers, and regulators from member states will often address issues in a nonpolitical manner. For example, the success of cooperation on the Komati River in southern Africa under the Komati Basin Water Authority has been attributed to the fact that most issues have been addressed by technical experts, rather than at a political level (Keevy, Malzbender & Petermann, 2009). Finally, intergovernmental organizations can address shortfalls in technical or economic capacity by coordinating national efforts through a centralized administrative structure and by pooling members' technical capacities (Abbott & Snidal, 1998).

All these functions will enhance treaty signatories' ability to weather the water-related effects of climate change while keeping their relationship from devolving toward violent confrontations. As climate change introduces new challenges and unanticipated scenarios, river treaties supported by intergovernmental organizations will be better able to enhance the signatories' technical capacity, promote treaty compliance, deter violations, and provide unbiased interpretation of signatories' obligations.

Water scarcity, institutional design, and militarized conflict

Conducting an empirical study of the security consequences of climate change presents a unique problem because it involves conditions that are expected to occur in the future. Therefore, social scientists have few data points with which to study its potential effects. As Salehyan (2008) observes, however, environmental conditions in the past can provide a basis for testing conjectures about the future. Several recent studies addressing the effects of climate change on violent conflict have taken a similar empirical approach; see, for example, Raleigh & Urdal (2007) and Hendrix & Glaser (2007).

Based on this logic, this study uses historical data on renewable freshwater to gain, admittedly indirect, insight into how climate change might impact international security through the mechanism of increased water scarcity. Specifically, we use annual data for a state's total renewable water per capita, where higher numbers indicate less scarcity. This gives us an empirical record with which we can analyze the effects of localized water scarcity on international conflict. We concentrate on overall water scarcity, rather than changes in annual precipitation or discrete weather events, for several reasons. First, the forecasts of climate models are most certain when they address overall levels of water availability for large regions. As the spatial scale of climate model projections decreases, the models become less consistent (Bates et al., 2008: 3). Second, the causal mechanisms connecting rainfall to international conflict are not entirely clear, whereas there is previous evidence connecting water scarcity and conflict. Finally, precipitation alone is not the whole story when it comes to a country's available freshwater. Data on overall renewable water sources will encompass both precipitation and other sources of freshwater, most notably rivers.

The amount of renewable freshwater a state has will affect its reliance on shared transboundary rivers to meet its water demands. When water becomes scarcer for a

state, it will be more likely to come into conflict with its riparian neighbors. In particular, we expect that conflict behavior between a pair of countries will be influenced by the degree of water availability for the state with the lower amount of available freshwater. It will be the water poorer state that will be more likely to divert water going to downstream states, or more likely to become hostile to diversion by other riparians. In short, the water poorer state's reactions to scarcity are the most likely – and the earliest – sources of political conflict.

To assess the conflict management potential of river treaty institutions, we compare their effects on conflict along with the effect of water scarcity. Although we have discussed the various institutional features separately, our main interest is in understanding the overall, cumulative effect of the institutional design of river treaties. Accordingly, we measure institutions using an index comprised of all four institutional features. We refer to this measure as the degree or level of river treaty institutionalization. Our central hypothesis is that the more institutional features a treaty contains, the more effective it will be in preventing the occurrence of militarized conflicts between signatory states. In addition, we expect that water scarcity will have a lower impact on the occurrence of conflict for agreements containing more institutional provisions.

Research design

Our empirical sample covers the signatories of 315 river cooperation agreements signed between 1950 and 2002, identified by the International Freshwater Treaties Database. We conduct the empirical analysis at the level of the dyad, rather than at the level of the agreement or basin, because militarized international conflict is essentially a dyadic phenomenon; this approach has become standard in studies of international conflict. For each dyad the analysis begins the year after each agreement is signed. We analyze annual interactions between all treaty member pairs; the unit of analysis is therefore the dyad-year.[7] We utilize a large-N empirical analysis in order to control for many other factors that influence conflict and to avoid the problem of selecting only high-profile cases – which has been common in the case study freshwater literature.

[7] If multiple treaties are signed between the same states, we act on the assumption that the latest treaty is the most relevant to future relations.

The dependent variable

To identify militarized conflict between riparians, we use the Militarized Interstate Dispute (MID) project (Ghosn, Palmer & Bremer, 2004). Each dyad-year is coded 1 if it experiences the onset of a MID. A potential limitation of using the MID data is that the militarized interactions may not be water or river related; yet, we follow the logic that water conflicts can escalate by spilling over and damaging relations in other issue areas, as explained above. In addition, using these data has important precedents in the water conflict literature (Gleditsch et al., 2006). Although the MID data do not distinguish between river and non-river related events, they suggest that proper management of river-induced interdependence can temper general conflictual relations between riparian states.

Primary explanatory variables

Our first key explanatory variable is an additive *river treaty institutionalization index*. It is composed of the following institutional features potentially contained in each of the 315 agreements: monitoring, enforcement, conflict resolution, and international organization. The first three components are variables recorded in the International Freshwater Treaties Database. International organization was identified using the comments section of the database and was coded 1 if the agreement created a new international organization to oversee the agreement or delegated authority to an existing organization. Each component is scored 0 or 1, and then all four component variables are summed for each agreement. This produces a scale of institutionalization ranging from 0 to 4, with a mean of 1.25 and a median score of 1 in our sample. Although we weigh each component equally, we only make the weak assumption that the final index is ordered, rather than an interval scale. Second, we capture the political pressure related to water scarcity by measuring *water availability* for the water poorer dyad member (see the above rationale), using the renewable water per capita data found in the FAO Aquastat database (Engelman, 2000). As this variable increases, the state's degree of water scarcity declines.

Control variables

We control for several potential influences on conflict proneness between signatory countries. These are drawn from the water politics and international conflict literatures and can be divided roughly into riparian, liberal, and realist groupings. Starting with the former, Toset, Gleditsch & Hegre (2000) provide data for whether a

shared river bisects a boundary, creating an *upstream/downstream relationship* between treaty signatories.[8] Such a relationship is thought to be particularly problematic, as it allows the upstream state to impose negative externalities on the downstream state (Mitchell & Keilbach, 2001; Stinnett & Tir, 2009). Furthermore, in order to make sure that the observed dyadic conflict patterns are indeed a function of the institutional quality of the river treaty – and not simply a function of the quantity of treaties signed – we control for the *number of treaties* in effect between the dyad members.

Turning to the liberal influences, much international relations scholarship reports that democracies have a special conflict-minimizing relationship with each other (Russett & Oneal, 2001). We therefore control for *joint democracy*, using the net regime score from the Polity IV data (Marshall & Jaggers, 2006), a dataset commonly used to measure regime characteristics. The level of *economic development* affects water affordability (Feitelson & Chenoweth, 2002) and is thought by some to affect relations between riparian states (Biswas, 2001); both systematic riparian (e.g. Gleditsch et al., 2006; Tir & Ackerman, 2009) and general international conflict (e.g. Russett & Oneal, 2001) researchers, however, tend to report insignificant findings. This variable is measured by the wealthier dyad member's gross domestic product per capita. Furthermore, economic interdependence provides a positive context in which states will be more amenable to resolving their disagreements peacefully (Elhance, 2000). More generally, established trade relationships can act as signals of countries' trustworthiness and create environments in which cooperation can flourish and costs of conflict are increased (Gartzke, Li & Boehmer, 2001). *Trade interdependence* is measured by the ratio of trade between the dyad members to the total trade they engage in with the world. The data for both economic variables come from Gleditsch (2002).

Finally, we include three control variables related to the realist theory. We control for the influence of *relative power* distribution, which is measured as the natural logarithm of the stronger to weaker state's capabilities, based on the Correlates of War Material Capabilities composite index (Singer, Bremer & Stuckey, 1972). Second, we control for whether the dyad members are *allies*, with data from Gibler & Sarkees (2004). Finally, using the ordinal COW contiguity data (Stinnett et al., 2002), we capture the effects of *distance*. Both the ability to fight and the interest in engaging other states is strongly conditioned by proximity.[9]

Method of analysis

Given the dichotomous nature of the dependent variable, we utilize logit regression. The Beck, Katz & Tucker (1998) binary time-series cross-section correction is added to account for the fact that the data are composed of several cross-sections (i.e. dyads) and to deal with potential duration dependence as these cross-sections are observed over time. To save space, the associated years of peace and natural cubic spline (with three interior knots) variables are omitted from the tables. Finally, robust standard errors are employed to account for the observations from the same dyad being related.

Empirical results and discussion

Model 1, Table I, is a baseline model composed of the control variables. Overall, these results are very similar to those typically found in the standard empirical model of international conflict and demonstrate that the sample of river treaty signatories is not skewed due to sample selection bias.[10] The only apparent exception is the joint democracy coefficient's insignificance. Yet, this is a function of multi-collinearity with the trade interdependence variable; dropping the latter makes the joint democracy coefficient negative and significant ($p = .01$). Furthermore, the conflict-reducing impact of trade-based interdependence is confirmed, as is the general lack of relationship between the level of economic development and interstate conflict. The findings for all three liberal variables are thus consistent with well-established findings (see Russett & Oneal, 2001). Likewise, the results concerning power distribution, alliance ties, and distance comport well with the literature (see Russett & Oneal, 2001).

Model 2 adds the river- and water-politics variables and, most importantly, provides two findings critical to

[8] Whether this variable reports upstream/downstream relationships for contiguous countries only (per Toset, Gleditsch & Hegre, 2000) or includes both contiguous and non-contiguous states (per Gleditsch et al., 2006) has no appreciable effect on the findings.

[9] Inclusion of additional controls for contiguity and dyad size, based on Hegre's (2008) gravity model of international conflict, had no appreciable effect on the findings: both river treaty institutionalization and water availability coefficients remained negative and significant.

[10] Additional empirical analyses demonstrate that the effect of river treaty institutionalization is not unduly influenced by the selection and endogeneity effects, that is, the processes by which (highly institutionalized) river treaties are formed.

Table I. Analyses of MID onset between river treaty signatories

	Model 1: Control variables only	*Model 2: River- and water-related variables added*	*Model 3: Interaction term added*
Level of river treaty institutionalization		–.173** (.066)	–.409 (.389)
Water availability		–.132** (.047)	–.168* (.076)
Institutionalization * water availability			.027 (.044)
Upstream/downstream relationship		.820** (.154)	.842** (.158)
Number of treaties		.012 (.023)	.010 (.023)
Joint democracy	–.357 (.219)	–.189 (.221)	–.165 (.225)
Level of economic development	.0000 (.0001)	.0000 (.0001)	.0000 (.0001)
Trade interdependence	–54.611** (19.726)	–56.864** (20.049)	–57.145** (20.049)
Relative power	–.090* (.049)	–.117* (.054)	–.116* (.054)
Alliance	–.582** (.137)	–.597** (.144)	–.592** (.144)
Distance	–.468** (.054)	–.385** (.066)	–.383** (.067)
Constant	–.397** (.150)	.326 (.470)	.632 (.682)
N	6,816	6,620	6,620
Chi-square (df)	489.82** (10)	546.29** (14)	546.66** (15)

Cell entries report logit coefficients and robust standard errors (in parentheses). Significance levels (one-tailed): * $p < .05$; ** $p < .01$. MID = Militarized Interstate Dispute. Statistics correcting for the binary time-series cross-sectional nature of the data (see Beck, Katz & Tucker, 1998) are omitted from the table to save space.

our study. First, the water availability coefficient is significant. Its negative direction indicates that as water becomes more plentiful, the likelihood of conflict decreases. Conversely, this means that water scarcity increases the chances for militarized conflict, which is consistent with the basic argument found in much of the water conflict literature. For states that share a source of water, militarized conflict is more likely under conditions of scarcity. In sum, water scarcity is highly problematic from the militarized conflict perspective and a problem that needs to be managed. Predictions that climate change will increase the strain on freshwater sources suggest that climate change, if not addressed, may increase the risk of international conflict in the future.

Second, Model 2 demonstrates the beneficial effects of river treaty institutionalization. The significant and negative coefficient indicates that the more institutionalized the river treaty, the lower the likelihood of militarized conflict between the river treaty signatory states. This result suggests that the institutional design of river treaties conditions their potential as tools of conflict management. Due to provisions for monitoring, conflict resolution, enforcement, and/or delegation of authority to intergovernmental organizations, institutionalized treaties are better equipped to prevent tensions over transboundary water issues from contributing to military conflicts. This provides hope that the security consequences of water stress stemming from climate change can be effectively managed.

As can be seen from Model 2, the liberal and realist variable findings remain similar to those reported in Model 1, with collinearity continuing to obscure the importance of joint democracy. The river-related variable findings follow our expectations. The upstream/downstream relationship significantly increases the proneness for militarized conflict. As discussed above, this relationship is thought to be highly problematic, as it allows the upstream state to impose negative externalities on the downstream state (Mitchell & Keilbach, 2001; Stinnett & Tir, 2009). This complicates the dyadic relationship considerably as it provides the downstream state with incentives to resort to militarized threats and actions in order to curtail the upstream state's behavior. Furthermore, the insignificance of the number of treaties coefficient is not surprising given that we suspect that the quality (i.e. institutionalization) of river treaties matters more than their quantity (i.e. how many have been signed).

Returning to the main findings for Model 2, we have established that both water scarcity and river treaty institutionalization have significant, yet opposing impacts on the likelihood of MID onset. Next, we investigate the extent to which institutionalization can actually mitigate the ill effects of water scarcity in two ways. First, we calculate marginal effects based on Model 2 and compare the effects of these two (and other significant) variables. The calculations – obtained while holding the explanatory variables at their mean or mode values and then varying the value of the variable of interest – reveal that some of the control variables have the most influence. Namely, upstream/downstream relationship and distance, at +91% and –90%, respectively, are the most

Table II. Marginal effects

Explanatory variable	*Change in the explanatory variable value*	*Impact on the probability of MID onset*
Level of river treaty institutionalization	0 → 1	–23%
	0 → 2	–42%
	0 → 3	–58%
	0 → 4	–71%
Water availability	1 standard deviation around the mean	–17%
	From the 90th to the 10th percentile	+40%
Upstream/downstream relationship	0 → 1	+91%
Trade interdependence	1 standard deviation around the mean	–43%
Relative power	1 standard deviation around the mean	–15%
Alliance	0 → 1	–30%
Distance	1 standard deviation around the mean	–90%

Marginal effects are calculated for Model 2 significant variables, by holding variable values at their mean or mode values and then varying the value of the variable of interest. MID = Militarized Interstate Dispute.

influential; see Table II. Yet, the calculations also further support our finding that river treaty institutionalization matters. Specifically, adding just one institutional dimension to an un-institutionalized treaty reduces the probability of MID onset by nearly one-quarter, while the addition of three institutional dimensions reduces that probability by over one-half. Most prominently, a fully institutionalized treaty reduces the probability of MID onset by 71% compared to a treaty with no institutional features.

Meanwhile, varying water availability by one standard deviation around the mean (as is typically done with continuous variables) reveals that increases in water availability reduce the likelihood of MID onset by only 17%. This would seem to indicate that even lower levels of treaty institutionalization are easily capable of negating the problematic effects of scarcity. Yet, the around-the-mean water availability values hardly capture the condition of water scarcity. To address this shortcoming, we perform an additional calculation by decreasing the water availability levels from the 90th (water abundance) percentile to the 10th (severe water scarcity). This produces a much more notable marginal effect, +40%. The good news is that in comparison to the impact of institutionalization, water scarcity is less influential. This is important as it suggests that even mid-levels of institutionalization can eliminate many of the ill effects of water scarcity. Our findings thus support the contention that institutionalized river treaties can be used to deal with the expected future increases in water scarcity, due in part to climate change.

Second, we consider the conditioning effect of institutionalization on scarcity. Model 3, Table I, therefore, introduces the related interaction term. Because with a multiplicative interaction term the empirical results cannot be directly interpreted from the lower-order coefficients (Brambor et al., 2006), we estimate the combined marginal effect of the interaction and component variables. If our argument is correct, higher levels of institutionalization should weaken the link between water availability/scarcity and MID onset. The marginal effect calculations are presented in Table III and show the impact of institutionalization under the conditions of severe water scarcity (10th percentile of water availability), notable water scarcity (30th percentile of water availability), modal level of water availability (50th percentile of water availability), and water abundance (90th percentile).

The marginal effects in Table III reveal that river treaty institutionalization has a uniformly mitigating effect on the link between water scarcity and MID onset across different levels of water availability. The conditioning effect of institutionalization is most apparent under the condition of severe water scarcity (10th percentile of water availability), where a fully institutionalized treaty cuts the likelihood of MID onset by over one-half, compared to an agreement without any institutional provisions; similar effects hold for the 30th and 50th percentiles of water availability. And as water scarcity turns into abundance (90th percentile), the impact of institutionalization is less, but still notable, at over one-third decrease in the likelihood of MID onset. Institutionalization therefore has a somewhat decreasing marginal benefit as we move away from the worst- to the best-case scenarios regarding water availability. But most importantly, its beneficial impact is the greatest precisely where it is needed the most. These calculations hence

Table III. Conditional marginal effects of the level of river treaty institutionalization on the likelihood of MID onset, given different water availability amounts

Water availability amount	*Change in the level of river treaty institutionalization*	*Impact on the probability of MID onset*
10th percentile (condition of severe water scarcity)	0 → 1	–18%
	0 → 2	–34%
	0 → 3	–46%
	0 → 4	–56%
30th percentile (condition of moderate water scarcity)	0 → 1	–17%
	0 → 2	–32%
	0 → 3	–44%
	0 → 4	–54%
50th percentile (modal amount of water availability)	0 → 1	–16%
	0 → 2	–29%
	0 → 3	–41%
	0 → 4	–50%
90th percentile (condition of water abundance)	0 → 1	–11%
	0 → 2	–21%
	0 → 3	–29%
	0 → 4	–37%

Marginal effects are calculated based on Model 3, by varying the values of treaty institutionalization and water availability while holding the other variable values at their means or modes. MID = Militarized Interstate Dispute.

suggest that river treaty institutionalization should be an effective policy for dealing with the expected, global climate-change related decreases in water availability and attendant interstate tensions.

The fact that states voluntarily select themselves into river treaties raises the possibility that the empirical results are influenced by endogeneity or sample selection bias. The logic is that dyads which are prone to conflict could also be less likely to form institutionalized agreements. Thus, the reasoning goes, the negative sign on the institutions coefficient is simply a product of a spurious correlation and not indicative of a causal relationship. Yet, there are several reasons to discount this possibility. First, other studies have shown that the previous conflict propensity of a dyad is not correlated with the formation of river treaties (Tir & Ackerman, 2009) or the tendency of river treaties to include more institutional provisions (Stinnett & Tir, 2009; Tir & Stinnett, 2011). Second, both received international relations theory and previous empirical studies suggest that the opposite should be true: agreements are actually *more* likely to contain institutional provisions in difficult circumstances. Institutionalist theory holds that states form international institutions when they are otherwise unable to cooperate (Keohane, 1984). It is precisely when states have a need for institutions that they will be willing to pay the costs necessary to create them. Empirical studies of river cooperation also bear this claim out. Previous empirical research shows that water scarcity prompts countries to form river treaties (Tir & Ackerman, 2009)[11] and include more institutional features (Stinnett & Tir, 2009). This suggests that, if anything, institutions are *more* prevalent in conflict prone situations, which would bias the institutions coefficient in a *positive* direction. Finally, follow-up analyses using different two-stage statistical techniques to model agreement formation and conflict simultaneously show that agreement design retains an independent effect on the initiation of conflict even after the process of formation is accounted for.

Conclusion

A literature survey compiled by Working Group II of the IPCC (Klein et al., 2007) concludes that some degree of adaptation to the effects of climate change is unavoidable, even if the most ambitious emissions reductions targets are to be met. With this in mind, this article

[11] This finding is also partially supported by Dinar (2006).

explores the ability of international institutions to help adapt to some of the potential security consequences of climate change. As localized water stress increases in many regions of the world, particularly those in which water is already scarce, states will have to rely more on sources of freshwater shared with other states, chief among them being transboundary rivers. This will bring states into conflict with one another over the use of the limited resource, which in turn can contribute to international tensions and increase the possibility of military conflict. Under these circumstances, international agreements can help manage the interdependent relationship by setting rules for the sustainable joint use of a river.

The results of this study show that agreements supported by more extensive institutions tend to be better equipped to prevent conflicts from escalating. Highly institutionalized river treaties can help regulate the use of the shared river, stipulate rights and obligations, and provide mechanisms for managing disputes before they escalate. We conclude that international institutions could be useful tools for addressing some of the predicted consequences of climate change, such as water scarcity and changes in the seasonal flow patterns of rivers. Given the uncertainty inherent in climate model forecasts, improving the governance institutions for international river basins is a no-regret strategy. In the event that the effects of climate change are less severe than predicted, either globally or in specific river basins, the establishment of institutionalized river treaties will have very few drawbacks.

Replication data

Replication files for analyses performed in this article can be found at http://www.prio.no/jpr/datasets and http://sobek.colorado.edu/~jati3108.

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JAROSLAV TIR, b. 1972, PhD in Political Science (University of Illinois, 2001); Associate Professor, Department of Political Science, University of Colorado Boulder. Current research interests include international riparian relations, territorial disputes, domestic conflict management, and diversionary theory of war.

DOUGLAS M STINNETT, b. 1974, PhD in Political Science (University of Illinois, 2005); Instructor, Department of International Affairs, University of Georgia. Current research interests include international cooperation, international environmental politics, and the design of international institutions.