Water Scarcity and Conflict Between Upstream and Downstream Riparian Countries

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Abstract

More than one-quarter of the world's population lives in water-scarce areas, while most countries share at least one river that crosses the boundary of at least one other riparian country. If water scarcity is this prevalent, should we expect riparian countries to fight over the water allocation of shared rivers? To answer this question, I develop a modified one-shot three-stage river sharing game where countries can resort to force to solve their water allocation problem. The purpose of this game is to show the decision process of two riparian countries facing water scarcity. Using backward induction, I solve for the probability of the downstream country initiating conflict against the upstream country, and the likelihood of the latter responding with force to the former's hostile actions. I test the model empirically using the complementary log-log model and a set of all upstream-downstream riparian dyads with available data from AQUASTAT and the Correlates of War Project for the years 1960 to 2010. The main contribution of this paper is that it demonstrates how upstream and downstream riparian countries differ in their decision to use force against the other country when facing different water stress levels. On average, the probability of the downstream country initiating conflict increases by 19 percent if the downstream country has a water scarcity problem that leads to regular water shortage or prevents the country from meeting its economics needs or the basic water demand of its population. In contrast, if the upstream country in the dyad can barely reach the basic water needs of its population and the downstream country is more powerful, the likelihood of the downstream country initiating conflict increases by 15 percent while the probability of the upstream country responding with force increases by up to 10 percent. The results suggest that increased conflict over water between upstream and downstream riparian countries is not farfetched.

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1. Introduction

Governments consider water to be a matter of national security whose scarcity could potentially lead to interstate conflicts. Water disputes have triggered many interstate conflicts. For instance, the Six-Day War between Israel and its Arab neighbors in 1967 erupted after Syria and Lebanon, the upstream countries, decided to divert the Yarmouk river, the tributary of the Jordan river, in order to limit Israel's access to water (Cooley 1984). More recently, Islam Karimov, the former Uzbekistani president, stated in 2012 that tension over the dams that the upstream countries, Tajikistan and Kyrgyzstan, were planning to build could lead to war in Central Asia (*The Economist* 2012). These incidents suggest that water has the power to ignite international conflicts.

Although water is not a scarce resource at the global level, spatial heterogeneity in its availability and access, paired with its necessity in human activities, can offer one explanation for how water can trigger international conflict. In the 2018 United Nations' annual "Water Development Report," the World Water Assessment Programme reported that the number of people living in water-scarce areas is 1.9 billion; this figure is expected to increase to 3.2 billion by 2050 (WWAP 2018). With the large number of people living in water-scarce regions, in addition to the heterogeneity and disparity in water stress levels between some riparian countries within the same river basin, as can be seen in Figure 1, the risk of hydro-political tension increases.[1,2] Furthermore, the percentage of riparian countries that are water-stressed has almost quintupled since 1960.[3]

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[1] A riparian country is defined as a country that has a transboundary river, or a river shared by two or more countries, that runs through its territory.

[2] One example of a river basin with high hydropolitical tension and a variety of water-stress levels is the Nile River Basin where Egypt and Sudan have absolute-water-scarcity (less than 500 m^3 per person per year), Rwanda is water-scarce (less than 1000 m^3 per person per year), Burundi is water-stressed (less than 1700 m^3 per person per year), while the rest of the 14 riparian countries sharing the Nile are water-abundant (Vörösmarty and Green 2010).

[3] The percentage of riparian countries that are water-stressed increased from 5 percent to 23 percent between 1958 and 2013. Additionally, the percentage of water-scarce countries increased from 4.2 percent to 10.6 percent and the percentage of absolute-water-scarce riparian countries increased from 0.9 percent to 5 percent) over the same period.

Courtesy of climate change and rapid population growth, over the next few decades, more riparian countries are expected to become water-stressed or have a regular water shortage. Many of the already water-stressed riparian countries are either expected to become water-scarce, which means that they will strive to satisfy their economic needs, or absolute-water-scarce, which means that they will struggle to meet the basic water demand of their population (FAO 2019, Falkenmark, Lundqvist and Widstrand 1989). This trend begs the question of whether we are heading towards a future of abundant water conflicts over scarce water resources. To answer this question, first, we need to understand the relationship between water scarcity and interstate conflicts.

The main objective of this paper is to investigate the relationship between water scarcity and interstate conflict between upstream and downstream riparian countries. Two main research questions need to be answered to understand this relationship. First, does water scarcity in either the upstream or the downstream country induce the downstream country to initiate conflict against the upstream country? Second, if the downstream country starts a conflict, does the water scarcity level of the upstream country affect its decision to fight back? In addition to these two questions, the paper demonstrates, theoretically and empirically, the relationship between the relative military power of the countries and their democracy level, on the one hand, and the decision to use force, on the other hand. Empirically, it will provide insight into the impact of water infrastructure, trade, wealth, population size, religion, and ethnicity on the conflict between riparian dyads.

Researchers in various disciplines have investigated the relationship between water scarcity and interstate conflict, yet no verdict has been reached on the nature of this relationship. Some studies have found that having at least one water-scarce country in the riparian dyad increases the probability of getting into serious militarized conflicts (Toset, Gleditsch and Hegre 2000). Others argue that water scarcity could lead to political instability that could potentially lead to violence, but it will neither lead to an all-out war nor will it lead to a large-scale violent international conflict (Wolf 1998). Some researchers have found that riparian dyads in water-scarce regions are not more prone to conflict compared to riparian countries elsewhere (Gleditsch, *et al*. 2006). Still, others have found that water scarcity leads to more cooperation and less conflict between riparian dyads (De Bruyne and Fischhendler 2013, Dinar, *et al.* 2010, Eidem, Fesler and Wolf 2012, Tir and Ackerman 2009). With all these contradicting empirical results, it is still not known what the nature of the relationship between water scarcity and interstate conflict between upstream and downstream countries is.

While all of the empirical studies in this area have focused on the onset of conflict between the countries in the dyad, this is the only paper that differentiates between a conflict initiated by a downstream country and the likelihood of the upstream country responding to this conflict with force. Additionally, this is the first paper to focus solely on dyads with a unidirectional river flow relationship, which means that a country is entirely downstream of the other country in all shared rivers between the dyad. Conceptually, these dyads would be the most vulnerable to water disputes as the water property rights would be fuzzy in these cases.

On the theoretical front, there have been very few studies on the relationship between water scarcity and conflict between riparian countries.[4] One theoretical study (Soubeyran and Tomini 2012) examines the relationship between water scarcity and the negotiation interval of water trade between a riparian dyad with an existing water-sharing treaty using a one-shot two-stage river-sharing game. They find that as the upstream-downstream dyad becomes more water-scarce, their

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[4] To my knowledge, there are only three theoretical papers that investigate conflict between upstream-downstream riparian dyads. Soubeyran and Tomini (2012) examine how water scarcity affect the onset of conflict between two-riparian countries with an existing water-treaty, as I discuss above. The other two papers are Janmaat and Ruijs (2006) and Ansink and Weikard (2009). Janmaat and Ruijs (2006) investigate the likelihood of a water conflict between an upstream-downstream riparian dyad in the presence of a hegemon nation. Ansink and Weikard (2009) study contested property rights to water and how that impedes water trade and leads to conflict.

likelihood of trading water declines, and their alternative will be to go to war.

Although the central research question in Soubeyran and Tomini's (2012) is the same as the one asked here, this paper deviates from theirs in multiple ways. First, the underlying assumption in Soubeyran and Tomini (2012) is that the only water resource available for the country is the one that originates in the transboundary river that the dyad shares. In reality, there are other renewable water sources that a country has access to, such as other transboundary or local rivers and groundwater. Thus, even if the water flow from the upstream to the downstream country is negligible, the downstream country can still be water abundant if it has other available water resources. Therefore, even in such extreme cases, conflict may not be the dominant strategy for the downstream country.

Second, Soubeyran and Tomini's (2012) outcome of interest is the onset of conflict. While this in itself may be of importance if the countries choose to participate in an all-out-war, empirical studies find that water conflicts are more likely to be small-scale conflicts than all-out-wars. Thus, differentiating between the decision making of an upstream and a downstream country is essential. A downstream country may threaten, display, or use force against an upstream country to extract more water without soliciting a response from the upstream country. This threat would still have economic consequences on the economies of both countries without causing a two-sided conflict.

On a similar note, the likelihood of the upstream country responding with force, in and of itself, is a significant determinant of whether the downstream country would initiate conflict. This is because a downstream country is less likely to attack an upstream country if they think that this would lead to a counter-attack. This paper is the first one to directly look at how the decision-making process of the upstream country is vital in the downstream country's decision to instigate a conflict. It is also the first paper to conduct an empirical analysis of the relationship between water scarcity and conflict that uses theoretically-driven hypotheses.

To investigate the relationship between water scarcity and conflict between upstream and downstream riparian countries, I first use a one-shot three-stage game-theoretic model with complete information that incorporates both a two-agent river sharing game and a conflict model. The model provides insight to how being water-scarce impacts the decision to use force while controlling for other factors such as aggregate welfare, relative military power, and diplomatic relations between the countries. In the game, an upstream-downstream riparian dyad interacts, and each country makes sequential decisions over the river's water allocation. Using backward induction, I solve for the probability of the downstream country initiating conflict against the upstream country, and the likelihood of the latter responding with force to the former's hostility. Historically, most water conflicts between upstream and downstream countries have been bilateral and were initiated by the downstream country after the upstream country either built a dam or diverted the water flow in one way or another. I use the results to derive testable hypotheses about the circumstances under which water scarcity can trigger interstate conflict.

Using the reduced form of these probability functions, I then test the theoretically-driven hypotheses empirically using a complementary log-log model. I use Falkenmark's water stress indices (Falkenmark, Lundqvist and Widstrand 1989) and AQUASTAT water availability data to indicate the level of national water stress and the Correlates of War militarized disputes dataset to itemize all interstate disputes between 1960 and 2010. I examine the association between water stress and interstate conflicts.

I find that the scarcity level of the downstream country is highly correlated with the use of force by both upstream and downstream countries. The probability of initiating conflict by the downstream country increases by 2 to 36 percent; the rise is more substantial as the scarcity level increases. Having an absolute-water-scarce upstream country in the dyad in itself lowers the likelihood of the downstream country initiating conflict by 4 percent and increases the likelihood of the upstream country responding with force by 2 percent. When the upstream country is absolute-water-scarce and the downstream country is more powerful, the likelihood of the downstream country initiating conflict increases by 15 percent and the probability of the upstream country responding with force increases by 10 percent.

The remainder of this paper is organized as follows. The second section summarizes the current state of international water law. The theoretical model is outlined in the third section. The fourth section discusses the probability of the riparian countries using force and how water scarcity and other factors influence their decision. The fifth section lays out the reduced-form model and presents the best ways to test it, given the available data. I discuss the results in the sixth section and conclude in the seventh section.

2. The Current State of International Water Law

In modern international law, there are usually laws that the majority of world countries agree to that regulate their disputes in an attempt to minimize conflicts between countries. However, when it comes to water disputes, there is no supranational authority that can enforce the rules and prevent countries from violating each other's rights. Having an internationally recognized set of water laws is important because when it comes to water rights, upstream and downstream countries hold different views over who owns the water, and many of them are willing to fight to protect their perceived rights. Upstream countries favor the *absolute territorial sovereignty* principle (also known as the Harmon Doctrine), which states that a country has the freedom to use the water that flows through its territory in any way that it deems appropriate, regardless of how that may affect its co-riparian downstream countries (Salman 2007). In contrast, downstream countries favor the *absolute territorial integrity* principle, which states that a country has the right to demand the continuation of the natural flow of any transboundary water that runs through its territory without any disturbance from upstream countries while allowing the natural flow of water to downstream countries as well (Salman 2007).

The Helsinki Rules that were issued by the International Law Association in 1966 are based on the *limited territorial integrity* principle. The *limited territorial integrity* principle states that a country has the right to use water flowing through its territory as long as its use does not harm other riparians (Salman 2007). The Helsinki Rules emphasize the "reasonable and equitable utilization" part of the *limited territorial integrity* principle. As a result, despite having no formal standing or legally binding effect, the Helsinki Rules became the single most authoritative rules in international water law, at least until the UN Watercourse Convention in 1997 (Salman 2007).

Formally titled as the UN Convention on the Law of the Non-Navigational Uses of International Watercourses, the UN Watercourse Convention emphasized the "equitable and reasonable utilization" and "no-significant harm" principles. Paragraph 1 of Article 5 of the convention states that "an international watercourse shall be used and developed by watercourse States with a view to attaining optimal and sustainable utilization thereof and benefits therefrom, taking into account the interests of the watercourse States concerned…" (United Nations 1997). In Article 6, it further explains the factors that need to be taken into consideration to define an equitable and reasonable utilization of transboundary water. These factors can be geographic, hydrographic, hydrological, ecological, climatic, economic, demographic, etc. (United Nations 1997). The tricky part though is determining how to weigh these factors. Paragraph 3 of Article 6 states that "[t]he weight to be given to each factor is to be determined by its importance in comparison with that of other relevant factors" (United Nations 1997). It remains unclear who gets to determine which factors are more important or which country gets the priority when it comes to certain factors. Article 7 Paragraph 1, on the other hand, states that a country needs to "take all appropriate measures to prevent the causing of significant harm to other watercourse States" (United Naitons 1997). Paragraph 2 of the same article states that in case of a significant harm, the country causing the harm needs to "take all appropriate measures… to eliminate or mitigate such harm, and where appropriate, to discuss the question of compensation" (United Nations 1997). Once again, the Convention does not specify what may be considered as significant harm or what the "appropriate measures" are. This is where problems may arise, as one country may deem its uses to be appropriate while another one may consider them harmful.

Article 33 and the appendix in the UN Watercourse Convention detail the procedures that need to be taken in case disputes arise between riparian countries. When a dispute concerning the interpretation of any of the articles of the Convention arises between two or more riparian countries, the countries need to "seek a settlement of the dispute by peaceful means" (United Nations 1997, Article 33, Paragraph 1). If an agreement cannot be reached, the countries can jointly either request mediation by a third party, refer the dispute to a previously established joint watercourse institution, or submit the dispute to the International Court of Justice (United Nations 1997, Article 33, Paragraph 2). If neither option succeeds at reaching a resolution, they can create an impartial fact-finding committee chaired by a member who is neither a citizen nor a resident of any concerned or co-riparian nation (United Nations 1997, Article 33, Paragraphs 3 and 4). If they fail to do so, they can request the Secretary-General of the UN to appoint an impartial chair (United Nations 1997, Article 33, Paragraph 5). Once the commission reaches an agreement by majority vote, the resolution will be binding and cannot be appealed unless the parties agreed in advance to an appellate procedure (United Nations 1997, Annex, Paragraph 14).

In theory, the Convention outlines several ways to enable the parties involved to peacefully solve a dispute while offering a binding resolution to ensure the prevention of conflict, and therein lies the rub. The articles of the UN Watercourse Convention are only binding to parties that have already approved, accepted, acceded to, or ratified the Convention; moreover, they are only binding once the Convention enters into force. Article 36 of the Convention states that for the Convention to enter into force, it needs to have at least 35 instruments of ratification, acceptance, approval, or accession (United Nations 1997, Article 36, Paragraph 1). This did not happen until Vietnam acceded to the Convention in 2014. Today, there are only 36 parties to the Convention.

Interestingly, only 47 dyads have both countries as parties to the Convention. Thus, the rules of the UN Watercourse Convention are only enforceable to 7 percent of all riparian dyads, while 93 percent do not have to abide by the rules of the UN Watercourse Convention and can resort to other means to solve their water disputes, including starting an interstate conflict. There also seems to be a selection bias when it comes to the decision of ratifying or accepting the convention as countries that ratified the Convention, on average, have a significantly lower volume of total renewable water compared to those that did not ratify the Convention.

Figure 2 shows the relationship between river basins with high risks of hydro-political tension and the location of interstate conflicts between co-riparians from 1960 to 2010.[5] The map shows that water conflicts, militarized interstate disputes, and even wars are more likely to happen between co-riparians sharing a river basin that is at a higher risk of hydro-political tension with at least one of the countries being water-stressed or scarce.[6] Therefore, we need to understand better the relationship between water scarcity and interstate conflict as a first step to identifying policies

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[5] Hydro-political tension is defined as any political tension between two countries over water-related issues.

[6] Water conflicts are defined as any interstate conflict were water was declared to be one of its primary triggers. Militarized interstate disputes include any interstate conflict in which one of the countries used force against another country. Wars are militarized interstate disputes with more than 1,000 battle deaths.

that can mitigate conflict and make peaceful resolutions self-enforceable.

3. The River Sharing Game

Assume that two riparian countries share a transboundary river that flows from the upstream country, U, to the downstream country, D. Assume that an $e_u^R \in [0, E_u)$ cubic meters of water flows from U to D; E_u is U's river water endowment. The superscript $R \in \{A, N, C, F(D_\omega), F(U_\omega)\}$, where A refers to D accepting the water flow discharged by U. N refers to negotiating trading water in exchange for some kind of a transfer. C denotes the scenario in which D uses force and U concedes. If D uses force and U fights back, $F(D_\omega)$ indicates the situation in which D wins, whereas $F(U_\omega)$ denotes the situation in which U wins the conflict.

Naturally, D has no control over the size of e_u due to the river's geographic configuration. U, on the other hand, can control it in several ways. First, U can exploit the river to the point of limiting the amount of water that would reach D. This scenario is more likely to happen if the river basin is small while the agrarian needs of U are large; in this case, farmers in U will withdraw water from the river in U's territory for irrigation, which would lower the amount of water that flows into D. Second, if a dam is built in the river basin that U and D share somewhere near D's border, U would be able to close the dam either partially or entirely for any number of political or economic reasons; this would also limit the water inflow to D. Third, U can divert the headwaters to another local river or stream or fill out a local reservoir instead of letting the transboundary river run its natural course.

From U's perspective, according to the *absolute territorial sovereignty* doctrine, U has the right to all river water within its territory (Ansink and Houba 2015). Therefore, U can choose to take any of these actions and unilaterally determine e_u^R. On the other hand, from D's perspective, according to the *absolute territorial integrity* principle, D has the right to all river water within and upstream of its territory (Ansink and Houba 2015). Thus, U has no right to rob D of its rightful river water. The two contradicting principles, along with the lack of a supranational authority to enforce international water laws, can lead to a constant argument over who owns the river water.[7]

If D deems the water allocation to be unfair, and there is no prior enforceable agreement determining an explicit water allocation, D can choose to respond to this allocation in three different ways. D can accept $e_u^A \in (0, E_u)$, which depends on U's satiation point and any prior shared interest that might dictate U's decision.[8] It can also negotiate with U to increase the water flow from e_u^A to $e_u^N \in (e_u^A, E_u)$ in exchange for τ. τ can be a direct monetary transfer from D to U; this would typically be specified in a water treaty between the dyad such as the Treaty on the Lesotho Highlands Water Project in the Orange Basin in 1986 in which South Africa agreed to make annual payments to Lesotho in exchange for water (Ansink and Weikard 2009). τ can also be an in-kind transfer in which the volume of the water flow from U to D is linked to another issue that would benefit U. This linked issue can be of an economic nature; for example, in 1967, the Netherlands negotiated an increase in their water allocation from the Meuse river in exchange for improving Belgium's access to the port of Antwerp (Mostert 2003). τ can also be a political linkage issue; for instance, during the 1980s and 1990s, Syria used its support for the separatist Kurdistan Workers Party (PKK) to pressure Turkey to release more water from the Euphrates river to downstream Syria (Oktav 2003). D can also choose to use force against U if U lowers the water

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[7] One example of an international disagreement over who owns the water of a transboundary river is seen in the Euphrates-Tigris River Basin shared between Turkey, Syria, and Iraq. Turkey, the upstream country, adopts the Absolute Territorial Sovereignty principle, which means that as the upstream country, Turkey believes that it has the right to do whatever it deems appropriate with the water, and that it is not obligated to share it with the downstream neighbors. In contrast, Syria, the midstream country, favors the Limited Territorial Sovereignty principle; in other words, Syria believes that water should be shared among all riparian countries based on their needs and the river capacity. Iraq, the downstream country, adopts the Absolute Territorial Integrity principle as it believes that it has an ancient right to the river water and that the water flow should not be interrupted (Oktav 2003).

[8] If $e_u^A = E_u$, then this would be the maximum that U can discharge to D, and U would be discharging it willingly. In contrast, if $e_u^A = 0$, then this indicates that D already has alternative water resources and is in no need of any of the water running in the river shared with U.

discharge or if it chooses to divert the headwaters altogether, or sometimes if U chooses to build a dam that D views as a threat to D's future water flow. For example, in 1974, Iraq threatened to demolish the Tabqa Dam (a.k.a. Al-Thawra Dam) and massed its troops on the Syrian border as the rate of water discharged from the Euphrates to downstream Iraq declined (Gleick 1994).

If D chooses to use force against U, then U will face two options. First, U can concede to D's demands peacefully without any conflict.[9] That is what Sudan opted to do in response to Egypt's military expedition in its territory in 1958. In a case like this, the water flow to D will become $e_u^C \in (e_u^A, E_u)$. U can also choose to respond to D's hostility by force to defend its water rights. In that case, in the absence of third-party mediation, the tension could escalate into a large-scale conflict, if not an all-out war. For instance, India and Pakistan were on the brink of war over the Indus basin in 1948; the war was avoided when the World Bank intervened and conducted negotiations that led to the signing of the Indus Water Agreement in 1960 (Wolf 1998).[10]

If the countries choose to get involved in interstate conflict, then the water flow will depend on who wins that conflict. If D wins the conflict, the water flow will become $e_u^{F(D_\omega)} \in (e_u^C, E_u)$; $e_u^{F(D_\omega)}$ is also strictly greater than e_u^N. If U wins the conflict, then D will get $e_u^{F(U_\omega)} \in (0, e_u^A)$.[11] Since the water only flows downstream, U cannot take back any of the water they discharged

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[9] 22 percent of the incidents of militarized conflict between upstream-downstream riparian dyads where one-sided conflicts, in which the downstream country initiated the conflict while the upstream country did not respond with force.

[10] The dispute between India and Pakistan over the Indus basin exacerbated the on-going tension between the countries over the Kashmir region (Wolf 1998).

[11] A real-life example of this situation is the outcome of the Six-Day War in 1967. The primary participants of the conflict were Palestine, Israel, Syria, and Jordan. The Jordan River originates in Syria and flows into Israel, which is upstream to both Palestine and Jordan. Some skirmishes started between the Palestinian Liberation Organization and Israel prior to the war over water allocation (both the Jordan River and the groundwater aquifers in the West Bank and Israel). Soon after that, Israel invaded Syria and the Six-Day War started. Israel won the war, annexed the Golan Heights in Syria (which contains the tributary of the Jordan River), occupied the West Bank in Palestine (where the Jordan river flows and most of the shared aquifers are), and severely limited the water flow to Jordan (until Israel and Jordan negotiated a water treaty that allowed Jordan to get a larger share and avoid another conflict between the two countries). Today, Israel still controls water resources in both the Golan Heights and the West Bank; therefore, Syria gets none of the Jordan River water while Palestine's share is much smaller than what it was prior to the 1967 War.

downstream of the river. They can, however, limit the future flow of the river since the water flow is continuous.[12] If U decides to lower the discharge rate (measured in cubic meters per second), then that will lower the total volume of water flown into D. This is especially true since most water disputes are *ad-hoc* over the perceived or announced water flow rather than *post hoc* over a realized water flow.

Each government wants to maximize its objective function, which consists of aggregate welfare, military cost, and any monetary transfer from D to U. The general form of this objective function is:

$$G_s^R = \alpha_s W_s(\Omega_s(e_u^R), \ell_s^R, p_s^R) - M_s^R + \tau_s^R. \tag{1}$$

Where the subscript s denote the state, $s \in \{U, D\}$, and the superscript R denote a terminal strategy from the game tree in Figure 3, $R \in \{A, N, C, F(D_\omega), F(U_\omega)\}$. α_s is the weight the government in s assigns to its people's welfare; α_s is increasing in the democracy level of the country. W_s is the aggregate welfare of the voting population of country s which depends on three factors: the available water resource in s, $\Omega_s(e_u^R)$, total income, ℓ_s^R, and local food prices, p_s^R.[13] Ω_s^R is a function of all available water resources, including rainfall, groundwater, and any water inflow from other local or international rivers, in addition to e_u^R. The relationship between Ω_s^R and W_s^R is nonlinear. Based on the Falkenmark index (Falkenmark, Lundqvist and Widstrand 1989), the first $500\,m^3$ per capita is used for basic human water needs and it has a direct impact on the aggregate welfare function. The rest of the water supply is used in producing consumption goods; thus, $\Omega_s^R - 500$ affects aggregate welfare indirectly through its impact on total income, ℓ_s^R, and local food prices,

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[12] U's ability to limit the discharge rate is constrained by their water needs and the capacity of their reservoirs. Nonetheless, a satiated or flood-prone U is not likely to risk a flood in their own territory in order to punish D. Furthermore, a satiated U, which is not dependent on E_u and meets all of its water demand from other sources, is unlikely to disturb the natural flow of the river; therefore, e_u^A is likely to be high enough to eliminate the need for D to use force to get what they deem to be their fair share of the river water.

[13] To avoid using cluttered notation, let $W_s^R \equiv W_s(\Omega_s(e_u^R), \ell_s^R, p_s^R)$ and $\Omega_s^R = \Omega_s(e_u^R)$.

p_s^R. M_s^R is the military cost if the country chooses to use force against the other country. The military cost that D incurs when U responds with force and a conflict erupts is higher than the cost when U concedes, $M_D^F > M_D^C > 0$; $M_D^A = M_D^N = 0$. U, on the other hand, will only incur a military cost when it chooses to respond with force to D's hostility; $M_U^F > 0$ and $M_U^C = M_U^A = M_U^N = 0$. The military cost rises as the conflict's hostility level increases. τ_s^R is the monetary transfer from D to U in case of negotiations; $\tau_U^N \geq 0$, $\tau_D^N \leq 0$, $\tau_D^N = -\tau_U^N$, and $\tau_s^A = \tau_s^C = \tau_s^{F(D_\omega)} = \tau_s^{F(U_\omega)} = 0$. Although τ_s^N can be in the form of an economic or political favor or concessions, I assume that it can also be measured in monetary units. To avoid cluttered notation, let $\tau = \tau_U^N = -\tau_D^N$.

Figure 3 shows the extensive form of this modified version of the river sharing game where η is the probability of D winning the conflict, which depends on, among other things, the countries' relative power and military capabilities. Table 1 shows the objective function for each country under each outcome using the general equation in (1).

The extent to which a change in the water flow, e_u^R, affect income, ℓ_s^R, local food prices, p_s^R, and aggregate welfare, W_s^R, depends on the country's economic-dependency on water and the availability of other sources of water. An already satiated, water-abundant country will not be significantly affected by a change in the water flow, e_u^R. Satiation is defined here as the country's ability to meet *all* of its domestic and economic needs from alternative water sources (other than the shared basin) and still have a water surplus. If the satiated country is an upstream country, it will be able to meet all of its water demand even when the amount of water that flows downstream reaches U's water endowment of the shared river basin's water; $e_u^R \rightarrow E_U$. Therefore, neither its food production nor its income will be affected by a change in e_u^R; $\partial_{e_u^R} p_U^R = 0$ and $\partial_{e_u^R} \ell_U^R = 0$. Similarly, a water-abundant downstream country whose dependency on e_u is very small or zero, will not experience an increase in food prices, p_D^R, or a decrease in national income, ℓ_D^R, as $e_u^R \rightarrow$

0; $\partial_{e_u^R} p_D^R = 0$ and $\partial_{e_u^R} \ell_D^R = 0$.

In contrast, a water-stressed country will be more sensitive to changes in the water flow, e_u^R. A country is water-stressed if it has less than 1700 m^3 of water per person per year. This threshold was found by Falkenmar *et al.* (1989) to indicate that a country experiences water shortage regularly, although, depending on its stress-level, the country may still be able to meet its domestic and economic needs.[14] An unsatiated, water-stressed, upstream country that is quasi self-sufficient in food production will be particularly sensitive to changes in e_u^R. As the water flow to the downstream country increases, the water available for food production will decline, which would lower local food production. On the one hand, under autarky in the food and agricultural sector, the severity of this problem will increase as it will limit food availability and lead to a food shortage which will drive up food prices; $\partial_{e_u^R} p_U^R > 0$. On the other hand, in an open economy for food and agriculture, the country will use virtual water trade, i.e., food imports, to substitute for the local food shortage. In this case, $\partial_{e_u^R} p_U^R$ can still be positive, but its magnitude decreases as the economy's trade openness increases. Conversely, a water-stressed downstream country will be overly sensitive to changes in e_u^R in a closed economy in the agriculture sector; $\partial_{e_u^R} p_D^R < 0$. The magnitude of $\partial_{e_u^R} p_D^R$ decreases as the country's level of trade openness increases.

The sensitivity of national income, ℓ_s^R, to changes in the water flow from U to D, e_u^R is also affected by water availability and trade openness, but more importantly, it is affected by the country's economic-dependency on water. A country whose industries are highly dependent on water will be sensitive to changes in the water flow, e_u^R; this sensitivity is increasing in the water stress level of the country. For an upstream country, an increase in the amount of water released

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[14] If the country has less than 1000 m^3 per person per year, it will struggle to meet its economic needs. Whereas if it has less than 500 m^3 per person per year, it will struggle to meet the basic domestic water needs.

to the downstream country, e_u^R, can lead to a loss in production and, therefore, income; $\partial_{e_u^R}\ell_U^R < 0$. Also, organized interest groups in U are likely to support the adoption of the *absolute territorial sovereignty* principle and would frown upon what they might perceive to be an "excessive" discharge rate of the river water. This will further decrease aggregate welfare, W_U^R, especially if economic interdependence between the two countries is low. As economic interdependence between the dyad increases, a new wave of organized interest groups in U will emerge. These interest groups will act as protectors of D's water rights to protect their interests in D.

In contrast, for a downstream country with a high level of economic dependency on water, a decrease in the water flow, e_u^R, can significantly lower its production and employment in the water-dependent industries; $\partial_{e_u^R}\ell_D^R > 0$. If economic interdependence between the dyad is low, then there is not much that D can do to increase its national income, ℓ_D^R, unless the country switches to non-water-intensive industries in which it has a comparative advantage; nonetheless, this is more of a long-term solution as it may not be feasible in the short-term. On the other hand, if economic interdependence between the dyad is high, then D can use this to its advantage. It can use its economic power to pressure the interest groups in U who have financial interests in D to act on its behalf. In fact, Uzbekistan occasionally uses this strategy to ensure a larger share of water inflow from upstream countries. In multiple occasions, Uzbekistan cut natural gas exports to downstream countries either to pressure them to increase e_u^R or to protest proposals to build a dam that could potentially disturb the future water flow to Uzbekistan (Gleick and Heberger 2014, Kozhevnikov 2012). The lower water flow would severely affect cotton production which is important to the Uzbek economy (Abdullaev, *et al.* 2009).

Regardless of the relationship between the water flow and local flood prices, $\partial_{e_u^R}p_s^R$, or national income, $\partial_{e_u^R}\ell_s^R$, an increase in local food prices decreases food accessibility, whereas a decrease in national income lowers the country's standard of living. Both outcomes lower aggregate welfare; $\partial_{p_s^R} W_s^R < 0$ and $\partial_{\ell_s^R} W_s^R > 0$. Once again, trade openness decreases the magnitude of $\partial_{p_s^R} W_s^R$ and economic interdependence between the dyad decreases $\partial_{\ell_s^R} W_s^R$. Consequently, for the upstream country, $\partial_{e_u^R} W_U^R < 0$, while for the downstream country, $\partial_{e_u^R} W_D^R > 0$.

4. Likelihood of Conflict: Theoretical Model

The likelihood of either country using force against the other can be found using backward induction. The last stage in the game tree in Figure 3 is determined by nature and can be reduced to $G_s^F = \eta G_s^{F(D_\omega)} + (1-\eta) G_s^{F(U_\omega)}$. Therefore, if D uses force against U in the second stage of the game, U will respond by force in the third stage if and only if $G_U^F > G_U^C$,

$$\Leftrightarrow \; \alpha_U \left[\eta W_U^{F(D_\omega)} + (1-\eta) W_U^{F(U_\omega)}\right] - M_U^F > \alpha_U W_U^C .$$

Thus, if D initiates a conflict, U will respond by force if and only if:

$$M_U^F < \alpha_U \left[\eta W_U^{F(D_\omega)} + (1-\eta) W_U^{F(U_\omega)} - W_U^C\right]. \tag{2}$$

Based on the decision rule in (2), the probability of U responding with force is:

$$Pr(F_U) = \alpha_U \left[\eta W_U^{F(D_\omega)} + (1-\eta) W_U^{F(U_\omega)} - W_U^C\right]. \tag{3}$$

In contrast, D will initiate conflict against U if and only if $G_D^F > \max\{G_D^N, G_D^A\}$. Since $e_u^N > e_u^A$ and $W_D^N > W_D^A$, $G_D^N > G_D^A$ if and only if $\alpha_D W_D^N - \tau > \alpha_D W_D^A \Leftrightarrow \alpha_D [W_D^N - W_D^A] > \tau$. If D only resorts to negotiations if it believes that its payoff from the water treaty is higher than that of accepting the status quo, then $G_D^N > G_D^A$.[15] So, in the second stage of the game in Figure 3, D will

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[15] If we relax that assumption that $G_D^N > G_D^A$ and assume that the value of τ demanded by U is too high, the probability of D initiating a conflict against U is:

$$\Pr(F_D) = \alpha_D \alpha_U \left[\eta W_D^{F(D_\omega)} + (1-\eta) W_D^{F(U_\omega)} - M_D^C\right]\left[\eta W_U^{F(D_\omega)} + (1-\eta) W_U^{F(U_\omega)} - W_U^C\right] + \alpha_D [W_D^C - W_D^A]$$

use force if and only if :

$$\Pr(F_U) \times G_D^F + (1 - \Pr(F_U)) \times G_D^C > G_D^N$$

$$\Leftrightarrow \Pr(F_U)\left[\alpha_D\left[\eta W_D^{F(D_\omega)} + (1-\eta) W_D^{F(U_\omega)}\right] - M_D^F\right] + (1 - \Pr(F_U))[\alpha_D W_D^C - M_D^C]$$

$$> \alpha_D W_D^N - \tau.$$

Let the expected military cost incurred by D be $EM_D \equiv \Pr(F_U) \times M_D^F + (1 - \Pr(F_U)) \times M_D^C$. Country D will initiate a conflict if and only if:

$$EM_D < \alpha_D \alpha_U \left[\eta W_D^{F(D_\omega)} + (1-\eta) W_D^{F(U_\omega)} - M_D^C\right]\left[\eta W_U^{F(D_\omega)} + (1-\eta) W_U^{F(U_\omega)} - W_U^C\right] + \alpha_D [W_D^C - W_D^N] - \tau. \tag{4}$$

Using the decision rule in (4), the probability of D initiating conflict against U is:

$$Pr(F_D) = \alpha_D \alpha_U \left[\eta W_D^{F(D_\omega)} + (1-\eta) W_D^{F(U_\omega)} - M_D^C\right]\left[\eta W_U^{F(D_\omega)} + (1-\eta) W_U^{F(U_\omega)} - W_U^C\right] + \alpha_D [W_D^C - W_D^N] - \tau. \tag{5}$$

Per se, the size of e_u^R is not expected to incite conflict between D and U; nonetheless, the total amount of water available for the downstream country, $\Omega_D(e_u^R)$, is more likely to influence such decisions. A downstream country with high enough Ω_D to meet its domestic and industrial water demand is not expected to initiate a conflict simply because its water inflow is not what it ideally desires. A downstream country with low Ω_D, however, is more likely to resort to force if its water consumption is highly dependent on the level of e_u^R. Thus, the probability of conflict depends on the level of Ω_D, which, if low enough, is sensitive to the level of e_u^R itself. Therefore, to understand the effect of water scarcity on conflict over water, we must consider the relationship between water availability and the countries' decision to use force.

First, let us examine the relationship between water availability and the downstream country's decision to use force against U. By taking the partial derivative of $\Pr(F_D)$ in (5) with respect to Ω_D, we will get the following:

$$\partial_{\Omega_D} Pr(F_D) = \alpha_D\alpha_U \left[\eta\partial_{\Omega_D} W_D^{F(D_\omega)} + (1-\eta)\partial_{\Omega_D} W_D^{F(U_\omega)} - \partial_{\Omega_D} W_D^C \right]\left[\eta W_U^{F(D_\omega)} + (1-\eta) W_U^{F(U_\omega)} - W_U^C\right] + \alpha_D\left[\partial_{\Omega_D} W_D^C - \partial_{\Omega_D} W_D^N\right]. \tag{6}$$

The first expression in the first term in (6) is negative whenever:

$$\eta < \frac{\partial_{\Omega_D} W_D^C - \partial_{\Omega_D} W_D^{F(U_\omega)}}{\partial_{\Omega_D} W_D^{F(D_\omega)} - \partial_{\Omega_D} W_D^{F(U_\omega)}} \equiv \mu_D. \tag{7}$$

The numerator in μ_D in (7) is always larger than the denominator; $\partial_{\Omega_D} W_D^{F(D_\omega)} < \partial_{\Omega_D} W_D^C$ because if U concedes, there will be no destruction in D, and the marginal effect of an additional cubic meter of water will be higher. Thus, $\mu_D > 1$. Since $\eta \in [0,1]$, then the first expression in (6) is always negative. Hence, the first term is negative if and only if:

$$\eta > \frac{W_U^C - W_U^{F(U_\omega)}}{W_U^{F(D_\omega)} - W_U^{F(U_\omega)}} \equiv \lambda_U. \tag{8}$$

The denominator in λ_U in (8) is always negative since U will always be better off winning the conflict than losing to D. Thus, the only case in which $\eta \ngtr \lambda_U$ is if $W_U^{F(D_\omega)} > W_U^C$, ($\Leftrightarrow \lambda_U > 1$), which is only likely to be the case if U is water-scarce but highly dependent on the river water, and the economic interdependence between the two countries is low. Even when U loses water under $R \in \{C, F(D_\omega)\}$, U's population may blame the government if it is water-scarce and does not fight for its water rights and concede them to D. In contrast, if $W_U^{F(U_\omega)} > W_U^C > W_U^{F(D_\omega)}$, then $0 < \lambda_U < 1$ and term would be positive if D is powerful enough to the point where $\eta > \lambda_U$. This scenario is likely to happen if U is water-stressed, but it has other alternatives that make fighting for the water rights not worth the cost of losing; the fact that U is water-stressed means that they will still prefer fighting and winning over conceding to D. Therefore, in this scenario, the first term in (6) is negative when D is more powerful than U, and U expects D to win the conflict if the two countries fight each other. Finally, if $W_U^C > W_U^{F(U_\omega)} > W_U^{F(D_\omega)}$ then $\lambda_U < 0$; since $\eta \in [0,1]$, then, in this scenario, $\eta > \lambda_U$ and the first term in (6) will always be negative. This scenario will be true when U is water abundant, as they will always prefer to give D additional water instead of being involved in a militarized conflict.

The second term in (6) is expected to be negligible since an additional cubic meter of water is not likely to have a different marginal effect on aggregate welfare when it is obtained via trading water peacefully or threatening the other country without causing any destruction in D. The results derived from $\partial_{\Omega_D} \Pr(F_D)$ in (6) can be summarized in Hypothesis 1.

Hypothesis 1*:* If D is water-scarce and U is water abundant, D will be more likely to initiate conflict. The likelihood further increases if D is more powerful than U.

U's water availability also determines D's likelihood to initiate conflict against U. To find the nature of this relationship, I take the partial derivative of $\Pr(F_D)$ with respect to Ω_U:

$$\begin{aligned}\partial_{\Omega_U} P\,r(F_D) = \alpha_D \alpha_U \left[\eta W_D^{F(D_\omega)} + (1-\eta) W_D^{F(U_\omega)} - W_D^C\right] \Big[\eta \partial_{\Omega_U} W_U^{F(D_\omega)} \\ + (1-\eta)\partial_{\Omega_U} W_U^{F(U_\omega)} - \partial_{\Omega_U} W_U^C\Big].\end{aligned} \tag{9}$$

$\partial_{\Omega_U} Pr(F_D) < 0$ if and only if:

$$\mu_U \equiv \frac{\partial_{\Omega_U} W_U^C - \partial_{\Omega_U} W_U^{F(U_\omega)}}{\partial_{\Omega_U} W_U^{F(D_\omega)} - \partial_{\Omega_U} W_U^{F(U_\omega)}} < \eta < \frac{W_D^C - W_D^{F(U_\omega)}}{W_D^{F(D_\omega)} - W_D^{F(U_\omega)}} \equiv \lambda_D. \tag{10}$$

Ideally, D should prefer U's concession over fighting and winning the conflict; $W_D^C > W_D^{F(D_\omega)}$. As a result, $\lambda_D > 1$ in (10). Since $\eta \in [0,1]$, $\eta < \lambda_D$ and the right-hand-side of the inequality in (10) will always be true. Thus, $\partial_{\Omega_U} Pr(F_D) < 0$ in (9) if and only if $\eta > \mu_U$. The denominator in μ_U in

(10) is always negative, since the destruction in U would be smaller when they win the conflict compared to when they lose, and therefore, the marginal effect of an additional cubic meter of water when they win will be higher, holding everything else constant. So, if D is less powerful than U, and U expects to have a minimal level of destruction if they were involved in a two-sided conflict with D, then $\partial_{\Omega_U} W_U^{F(U_\omega)} > \partial_{\Omega_U} W_U^C$ and $\mu_U > 1$; so, $\eta \ngtr \mu_U$. However, as D becomes more powerful, the level of destruction that it can cause in U if the two countries fight each other increases, and μ_U starts to decrease. As U's water scarcity level increases, $\mu_U \rightarrow 0$ or becomes negative. Furthermore, as D becomes more powerful, the porability of D winning the conflict increases and $\eta \rightarrow 1$. The results derived from $\partial_{\Omega_U} \Pr\,(F_D)$ in (9) are summarized in Hypothesis 2.

Hypothesis 2: If U is water-scarce, and D is relatively more powerful than U, D will be more likely to initiate conflict against U.

U's decision to respond with force when D initiates a conflict is only dependent on water availability in U; there is no direct relationship between D's water scarcity and U's decision to use force. To find the relationship between U's decision and its water scarcity level, we need to examine the partial derivative of Pr (F_U) in (3) with respect to water availability, Ω_U:

$$\partial_{\Omega_U} Pr(F_U) = \alpha_U \left[\eta \partial_{\Omega_U} W_U^{F(D_\omega)} + (1-\eta) \partial_{\Omega_U} W_U^{F(U_\omega)} - \partial_{\Omega_U} W_U^C\right]. \tag{11}$$

$\partial_{\Omega_U} Pr(F_U) < 0$ in (11) if and only if:

$$\eta < \frac{\partial_{\Omega_U} W_U^C - \partial_{\Omega_U} W_U^{F(U_\omega)}}{\partial_{\Omega_U} W_U^{F(D_\omega)} - \partial_{\Omega_U} W_U^{F(U_\omega)}} \equiv \mu_U. \tag{12}$$

Holding everything else constant, a scenario in which D and U fight over water and U wins, indicates that U is more powerful than D and the destruction in U when it wins is less than that when it loses. Therefore, the marginal effect of each additional unit of water that becomes available to U is larger when U wins the conflict; $\partial_{\Omega_U} \ell_U^{F(U_\omega)} > \partial_{\Omega_U} \ell_U^{F(D_\omega)}$ and $\partial_{\Omega_U} p_U^{F(U_\omega)} \geq \partial_{\Omega_U} p_U^{F(D_\omega)}$. Thus, $\partial_{\Omega_U} W_U^{F(U_\omega)} > \partial_{\Omega_U} W_U^{F(D_\omega)}$ and the denominator in μ_U in (12) is always negative. Since $\eta \in [0,1]$, $\partial_{\Omega_U} Pr(F_U) < 0$ if and only if $\mu_U > 0$. In order for this to be true, $\partial_{\Omega_U} W_U^{F(U_\omega)} > \partial_{\Omega_U} W_U^C$, which is likely to happen as U becomes more water-scarce. The results derived from the $\partial_{\Omega_U} Pr(F_U)$ in (11) are summarized in Hypothesis 3.

Hypothesis 3: If U is water-scarce and D is more powerful, U will be more likely to respond with force to D's hostility.

5. Likelihood of Conflict: Empirical Model

5.1. Data

To analyze the effect of water scarcity on conflict between riparian countries, I use panel data on water scarcity and militarized conflict between upstream-downstream riparian dyads, in addition to several control variables. The data set is annual, with a temporal span from 1960 to 2010.

To match the main assumptions of the theoretical model and test it empirically in a meaningful way, I limit the analysis to riparian dyads with an upstream/downstream river configuration where all shared rivers cross the border only once and flow from the upstream country to the downstream country. I leave out riparian dyads where the river crosses the border multiple times, making one of the countries upstream in certain regions in the basin drainage area before it becomes downstream in another region. I also leave out any riparian dyads where at least part of the shared river runs along their border.

I identify riparian dyads in which one of the countries is entirely downstream of the other using the River Type Configuration dataset from Brochmann and Gleditsch (2012), merged with the Transboundary Waters Assessment Program (TWAP) River Basin Country Units dataset (Allen, Wood and Eynard 2014). I reduce the level of observation to dyad-year units and code a country in the dyad to be upstream (downstream) if the drainage area in all shared rivers of one country is upstream (downstream) of the other country in the dyad. Using this definition, I end up with 208 upstream-downstream riparian dyads; 79 of the dyads are in Africa, 61 are in Asia, 45 in Europe,16 in the Americas, 5 dyads with an upstream Asian country and a downstream European country, and 2 with an upstream African country and a downstream Asian country.[16]

5.1.1. Water Scarcity

To study the relationship between water scarcity and conflict, I use the total renewable water resources data from AQUASTAT (FAO 2019). The global dataset contains 5-year simple averages spanning from 1958 to 2017. Due to data limitations, I use the 5-year average data as annual data, and I merge it with the population data from the World Development Indicators to calculate each country's yearly stress level (World Bank 2017). To determine the water stress level, I use the water stress indicator that was defined by Falkenmark, Lundqvist, and Widstrand (1989). A country is considered *water abundant* if it has more than 1,700 cubic meters per person per year; above this threshold, water shortage occurs irregularly and locally. A country is considered *water-stressed* if it has less than 1,700 m^3/person/year but more than 1,000 m^3/person/year; within these thresholds, water stress appears regularly. A country is considered *water-scarce* if it has less than 1,000 m^3/person/year but more than 500 m^3/person/year; within these thresholds, water scarcity is "a limitation to economic development and human health and well-being" (Falkenmark, Lundqvist and Widstrand 1989). If the country has less than 500 m^3/person/year, then the country has *absolute water scarcity,* and the scarcity problem is a main constraint to life (Falkenmark, Lundqvist and Widstrand 1989). Table 3 shows the summary statistics of aggregate water

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[16] The Asian-African dyad is the result of the formation of the United Arab Republic between Egypt and Syria that was proclaimed in 1958 and ended in 1961 after a military coup in Syria. As a result of this union, Egypt became officially upstream of both Israel and Jordan.

availability (the 5-year average raw variable collected from AQUASTAT, measured in billion cubic meters), per capita water availability (aggregate variable divided by the population size, measured in cubic meters), and the various water stress levels for each country.

5.1.2. Conflict

To study the relationship between water scarcity and conflict, I use a dataset of incidents of $Militarized\ Interstate\ Disputes$ (MID) from the Correlates of War Project (Ghosn, Palmer and Bremer 2004, Jones, Bremer and Singer 1996, Maoz, *et al.* 2019).[17] The dataset covers all militarized interstate disputes, which are defined as "historical cases of conflict in which the threat, display or use of military force short of war by one member state is explicitly directed towards the government, official representatives, official forces, property, or territory of another state" (Jones, Bremer and Singer 1996). I limit the analysis to bilateral conflicts initiated by a downstream country against an upstream country. There are 146 incidents of conflicts initiated by a downstream country against its upstream co-riparian; they make up 2.38 percent of dyad-year observations used in the analysis. There are 11 incidents of two militarized disputes between a dyad within the same year, and three incidents of three militarized disputes within the same year. The rest of the incidents comprised of one incident a year. Of all 146 conflicts initiated by the downstream country, the upstream country responds with force in 114 conflicts.

To control for other types of conflicts that may affect water availability, I control for interstate disputes that are explicitly declared as water disputes. The variable is collected from the Water Conflict Chronology (Gleick and Heberger 2014), which covers interstate and intrastate water conflicts across the globe with the data spanning from 3000 BC to 2018 where water was a casualty, trigger, or weapon in the conflict. There are 20 incidents of interstate water conflict

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[17] I use version 4.3 of the Militarized Interstate Disputes dataset, which covers the years 1816 to 2010.

between the upstream and downstream riparian dyads over the years 1960 and 2010; 14 were initiated by the downstream country.

I also control for a current or a recent all-out war in the current year. I use *Interstate War* which includes any violent conflict between two governments that resulted in more than 1,000 battle-related deaths within twelve months (Sarkees and Wayman 2010).[18] There are 15 incidents of all-out wars between upstream and downstream riparian dyads; 8 initiated by the downstream country, and 7 initiated by the upstream country. Table 4 shows the summary statistics for the three conflict variables.

5.1.3. Control Variables

Beyond water scarcity, there might be other hydrological, political, economic, geographic, and demographic factors that can trigger conflict. Much of the current hydro-political tension between riparian countries is triggered by the construction of a dam in the upstream country. Thus, I control for the number of new dams built by the upstream country. The source of these data is the Global Reservoir and Dam Database (Lehner *et al.* 2011a, 2011b, 2011c).

There are also several political determinants of conflict that need to be included in the analysis. The relative power of the downstream country to the upstream country is not just a proxy for the credibility of a military threat; it also affects the countries' beliefs regarding their chances of winning the conflict if they were to get involved. Per Hirshleifer (1989) and Garfinkel and Skaperdas (2007), I create the relative military power index $r = \frac{\rho_D}{\rho_D + \rho_U}$, where ρ_s is either the military personnel or military expenditures. These variables are obtained from the National Material Capabilities dataset from the Correlates of War Project (Singer 1988, Singer, Bremer and Stuckey 1972).

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[18] I use version 4.0 of the Interstate War dataset, which covers the years 1816 to 2007.

I control for the democracy level of each country; the data is derived from the Polity IV dataset (Marshall, Gurr, and Jaggers 2017). I control for contiguity using data from the Direct Contiguity dataset from the Correlates of War Project (Correlates of War Project n.d., Gochman 1991, Stinnett, et al. 2002). I also control for the effect of fractionalization, in terms of ethnicity and religion, on conflict, I use the common religion index from the Gravity dataset from CEPII (Head and Mayer 2014, Head, Mayer and Ries 2010), and I also create a common ethnicity index from the Fractionalization dataset (Alesina, *et al.* 2003).

I use a number of economic indicators such as GDP per capita and trade openness level from the World Development Indicators (World Bank 2017), share of bilateral trade between the dyad in primary and secondary sectors from the TRADHIST dataset (Fouquin and Hugot 2016) and membership in WTO from the Gravity dataset from CEPII (Head and Mayer 2014, Head, Mayer and Ries 2010).

5.2. Econometric Specification

The ideal way to capture the relationship between water scarcity and conflict between upstream and downstream riparian countries is to use the water stress level in each country along with other determinants of conflict as the explanatory variables. In contrast, a binary variable that equals one if the downstream country initiates a conflict against the upstream country, or, if that is the case if the upstream country responds with force, can be used as the response variable. This leads to the following basic equations:

$$Pr\left(F_{D_{ijt}} = 1 | \boldsymbol{SL}_{it}, \boldsymbol{SL}_{jt}, r_{ijt}, \boldsymbol{X}_{ijt}\right) = f\left(\boldsymbol{SL}'_{it}\boldsymbol{\beta} + \boldsymbol{SL}'_{jt}\boldsymbol{\gamma} + \delta r_{ijt} + \boldsymbol{X}'_{ijt}\boldsymbol{\theta}\right), \qquad (13)$$

$$Pr\left(F_{U_{ijt}} = 1 | \boldsymbol{SL}_{it}, r_{ijt}, \boldsymbol{X}_{ijt}\right) = f\left(\boldsymbol{SL}'_{it}\boldsymbol{\psi} + \zeta r_{ijt} + \boldsymbol{X}'_{ijt}\boldsymbol{\nu}\right), \qquad (14)$$

where $F_{D_{ijt}}$ is a binary variable that equals 1 if, in a given year t, the downstream country, j, initiated a conflict against the upstream country, i, while $F_{U_{ijt}}$ equals 1 if, after j initiated the conflict, i chose to respond with force to j's hostility. $\boldsymbol{SL}_{st}$, where $s \in \{i, j\}$, is a 3×1 vector that includes water stress level indicators:

$$\boldsymbol{SL}_{st} = \begin{bmatrix} SL_{st}^{1} \equiv 1[\Omega_s \in [1000,1700)] \\ SL_{st}^{2} \equiv 1[\Omega_s \in [500,1000)] \\ SL_{st}^{3} \equiv 1[\Omega_s \in [0,500)] \end{bmatrix}.$$

Let $SL_{st}^{\mathcal{L}}$ denote each component of the $\boldsymbol{SL}_{st}$ vector where $\mathcal{L} \in \{1,2,3\}$. r_{ijt} is the relative military power of j to i. $\boldsymbol{X_{ijt}}$ is a vector of control variables, that includes political, economic, geographic, and demographic controls.

From the theoretical model, there is a nonlinear relationship between water scarcity and interstate conflict. Thus, the ideal candidates are probit and logit models. One of the main assumptions in probit and logit models is that the response curve has a symmetric appearance about $\Pr(\cdot) = 0.5$, which means that the probability function has the same rate for approaching both 0 and 1. Nonetheless, when a response variable is a rare event that is asymmetric in the [0,1] interval, using the complementary log-log model, which is the inverse of the cumulative distribution function of the extreme value (log-Weibull) distribution, may be better. To ensure that this is the case, I compare different measurements of fit from probit, logit, and complementary log-log estimations of Equations (13) and (14). As can be seen in Table 5, the fit statistics are very similar across the three models. However, the Bayesian information criterion (BIC) gives weak support of the complementary log-log model over the logit model, and strong support of both the complementary log-log and logit over probit when estimating Equation (13). When estimating Equation (14), BIC gives weak support for logit over the complementary log-log model, and positive support for both logit and complementary log-log, as can be seen in Table 6. The bottom line is, the complementary log-log and logit models are favored over probit model. Since the complementary log-log makes more sense when dealing with rare events, I will mainly focus on the results of the complementary log-log model estimation in the results section.

For the main results, the following complementary log-log models are estimated:

$$Pr\left(F_{D_{ijt}} = 1 | \boldsymbol{SL}_{it}, \boldsymbol{SL}_{jt}, r_{ijt}, \boldsymbol{X}_{ijt}\right) = 1 - e^{-e^{\boldsymbol{SL}'_{it}\boldsymbol{\beta} + \boldsymbol{SL}'_{jt}\boldsymbol{\gamma} + \delta r_{ijt} + \boldsymbol{X}'_{ijt}\boldsymbol{\theta}}}, \tag{15}$$

$$Pr\left(F_{U_{ijt}} = 1 | \boldsymbol{SL}_{it}, r_{ijt}, \boldsymbol{X}_{ijt}\right) = 1 - e^{-e^{\boldsymbol{SL}'_{it}\boldsymbol{\psi} + \zeta r_{ijt} + \boldsymbol{X}'_{ijt}\boldsymbol{\nu}}}. \tag{16}$$

The estimation in (15) test the basic relationship between water scarcity in either D or U, and the probability of the downstream country initiating conflict. The estimation in (16) tests the basic relationship between U's water scarcity level, and its likelihood to respond with force when D initiates the conflict.

Hypothesis 1 and Equation (6) suggest that the probability of D using force is decreasing in D's water availability, $\partial_{\Omega_D} \Pr(F_D) < 0$, whenever $\lambda_U < \eta$. This is equivalent to saying that $\Pr(F_D)$ is increasing in D's water stress level, $\boldsymbol{SL}_{jt}$;

$$\Pr\left(F_{D_{ijt}} \middle| \boldsymbol{SL}^1_{jt} = 1\right) < \Pr\left(F_{D_{ijt}} \middle| \boldsymbol{SL}^2_{jt} = 1\right) < \Pr\left(F_{D_{ijt}} \middle| \boldsymbol{SL}^3_{jt} = 1\right).$$

This relation will be true in two cases: if λ_U is small, suggesting that U is water abundant, or if η is large, suggesting that D is more powerful than U. To test the impact of the size of λ_U on the sign of $\partial_{\Omega_D} \Pr(F_D)$, I include an interaction term between D being absolute-water-scarce, and U being water abundant. This interaction term can be written as $(1 - \max\{\boldsymbol{SL}_{it}\})\boldsymbol{SL}'_{jt}$, since $(1 - \max\{SL^1_{it}, SL^2_{it}, SL^3_{it}\}) = 1$ when U is water abundant, or has $\Omega_U > 1700\, m^3$, and 0 otherwise. The following model will be estimated:

$$\begin{aligned} Pr&\left(F_{D_{ijt}} = 1 | \boldsymbol{SL}_{it}, \boldsymbol{SL}_{jt}, r_{ijt}, \boldsymbol{X}_{ijt}\right) \\ &= f\left(\boldsymbol{SL}'_{it}\boldsymbol{\beta} + \boldsymbol{SL}'_{jt}\boldsymbol{\gamma} + r_{ijt}(1 - max\{\boldsymbol{SL}_{it}\})\boldsymbol{SL}'_{jt}\boldsymbol{\sigma} + \delta r_{ijt} + \boldsymbol{X}'_{ijt}\boldsymbol{\theta}\right). \end{aligned} \tag{17}$$

To test the other part of Hypothesis 1, which states that if D is powerful, the likelihood of conflict will further increase, I include another interaction term that accounts for the relative power of U and D. The new interaction term will be the one from (17) times the relative power $r = \frac{\rho_D}{\rho_D + \rho U}$. So, the following model will be estimated:

$$\begin{aligned} &Pr\left(F_{D_{ijt}} = 1 | \boldsymbol{SL}_{it}, \boldsymbol{SL}_{jt}, r_{ijt}, \boldsymbol{X}_{ijt}\right) \\ &\qquad = f\big(\boldsymbol{SL}'_{it}\boldsymbol{\beta} + \boldsymbol{SL}'_{jt}\boldsymbol{\gamma} + r(1 - max\{\boldsymbol{SL}_{it}\})\boldsymbol{SL}'_{jt}\phi + \delta r_{ijt} + \boldsymbol{X}'_{ijt}\boldsymbol{\theta}\big). \end{aligned} \tag{18}$$

Hypothesis 2 and (9) suggest that the probability of D using force is decreasing in U's water availability, $\partial_{\Omega_U} \Pr(F_D) < 0$, whenever $\mu_U < \eta$. This is true when μ_U decreases as U water scarcity level increases. The probability further increases as D becomes more powerful. To test this hypothesis, I will include a new interaction term in (13), $r_{ijt}\boldsymbol{SL}'_{it}$.

$$\begin{aligned} &Pr\left(F_{D_{ijt}} = 1 | \boldsymbol{SL}_{it}, \boldsymbol{SL}_{jt}, r_{ijt}, \boldsymbol{X}_{ijt}\right) \\ &\qquad = f\big(\boldsymbol{SL}'_{it}\boldsymbol{\beta} + \boldsymbol{SL}'_{jt}\boldsymbol{\gamma} + r_{ijt}\boldsymbol{SL}'_{it}\boldsymbol{\pi} + \delta r_{ijt} + \boldsymbol{X}'_{ijt}\boldsymbol{\theta}\big) \end{aligned} \tag{19}$$

Hypothesis 3 also suggests that the probability of U responding with force will increase as U becomes more water-scarce, and D becomes more powerful.

$$Pr\left(F_{U_{ijt}} = 1 | \boldsymbol{SL}_{it}, r_{ijt}, \boldsymbol{X}_{ijt}\right) = f\big(\boldsymbol{SL}'_{it}\boldsymbol{\psi} + r\boldsymbol{SL}'_{it}\boldsymbol{\iota} + \zeta r_{ijt} + \boldsymbol{X}'_{ijt}\boldsymbol{\nu}\big) \tag{20}$$

Table 2 presents the theoretical model predictions of the coefficients of interest from the baseline specifications and the three hypotheses.

6. Results

6.1. Water Scarcity

6.1.1. Baseline Specifications

Columns 1 and 6 in Table 10 show the results of the baseline specifications. Overall, if the country is absolute-water-scarce, or cannot meet the needs of its people, its likelihood of being involved in a militarized interstate dispute increases. Using the average marginal effects, being a water-stressed downstream country increases the likelihood of the downstream country initiating a conflict against the upstream country by 4 percent. This likelihood increases to 7 percent when the downstream country is water-scarce, and 14 percent when the downstream country is absolute-water scarce. Thus, per the predictions in Table 2, $\gamma_3 > \gamma_2 > \gamma_1 > 0$. In other words, as the water scarcity problem in the downstream country intensifies, its likelihood of initiating a militarized interstate dispute against the upstream country increases. From Column 1 in Table 10, the scarcity level of the upstream country seems to have no significant effect on the probability of the downstream country initiating conflict; $\beta_3 = \beta_2 = \beta_1 = 0$. On the other hand, Column 6 in Table 10 shows that being either a water-stressed or water-scarce upstream country has no significant impact on the upstream country's likelihood of responding with force to a conflict initiated by the downstream country. However, when the upstream country is absolute-water-scarce, the likelihood of responding with force increases by 4 percent. Thus, $\psi_3 > \psi_2 = \psi_1 = 0$.

6.1.2. Hypotheses Testing

Hypothesis 1. The first hypothesis, which is derived from Equation (6) in the theoretical model, suggests that having a water-scarce downstream country and a water-abundant upstream country in the dyad increases the likelihood of the downstream country initiating conflict. It also indicates that this likelihood further increases when the two conditions hold, and the downstream country is more powerful than the upstream country. The empirical results from estimating (17) suggest that, in general, if the downstream country experiences some level of water stress, having a water-abundant country in the dyad increases the downstream country's likelihood of initiating conflict. Table 8 shows the marginal effect of having different combinations of water stress levels on the likelihood of the downstream country initiating conflict. The results suggest that when the upstream country is either water-stressed or water-abundant, the likelihood of downstream country initiating conflict increases. In other words, if the upstream country has enough water to meet the basic demands of its people and have some surplus that can be shared with the downstream country, the downstream country would be more likely to use force to obtain this surplus; the likelihood increases as the downstream country's water stress level increases. The likelihood is significantly higher when the downstream country is absolute-water-scarce; it reaches 36 percent when both countries are absolute water scarce. In this latter case, both countries would be struggling to meet the basic demand of their respective population, and as a result, water scarcity becomes a threat to national security, which increases the likelihood of the countries fighting to eliminate this threat.

Column 2 in Table 10 shows the results of the first part of Hypothesis 1. It shows that the downstream country's water scarcity level in itself still has a significant effect on the likelihood of conflict, even when I control for the interaction between the two countries scarcity level and their relative power. It retains the same relation found in the baseline specification, where $\gamma_3 > \gamma_2 > \gamma_1 > 0$. The average marginal effects of D's scarcity level are slightly different in this specification; being water-stressed increases the likelihood of D initiating conflict by 7 percent, while being water-scarce increases it by 10 percent and being absolute-water-scarce increases it by 11 percent.

The second part of Hypothesis 1 indicates that having a more powerful downstream country further increases its likelihood of initiating conflict when the country is water-scarce. To test this part empirically, I multiply the relative military power with the interaction terms from the previous specification, as is shown in (18). The results of this specification are shown in Column 3 in Table 10. The results show that whereas having a more powerful downstream country in itself increases the likelihood of the downstream country initiating conflict. Having a powerful, absolute-water-scarce downstream country and a water-abundant upstream co-riparian country in the dyad significantly increases the likelihood of the downstream country initiating conflict.

By looking at the average marginal effect, in general, having an absolute-water-scarce downstream country that is twice as powerful as the upstream country and a water-abundant upstream country increases the likelihood of the downstream country initiating conflict by 159 percent.[19] When I take a closer look at the effect of relative power on the probability of conflict for different stress levels, I find that the predicted probability of the downstream country initiating conflict is increasing in the downstream country's relative power as the water-scarcity problem intensifies, as can be seen in Table 9. As was suggested in the empirical model predictions in Table 2, $\phi_3 > \max\{\gamma_3, \sigma_3, \delta\}$. However, the coefficients of U's water-abundance and D's power interacted with D being water-stressed or water-scarce are not significantly different from 0.

Hypothesis 2. The second hypothesis, which is derived from Equation (9), suggests that as the water stress level in the upstream country increases and the downstream country becomes more powerful, the probability of the downstream country initiating conflict increases. To test this hypothesis empirically, I use the specification in Equation (19). The coefficients of interest from this specification are $\boldsymbol{\beta}$, which tests the effect of the impact of having an upstream country in the dyad with water scarcity problems and $\boldsymbol{\pi}$, which interacts U's water stress levels with D's relative military power. The results, shown in Column 4 in Table 10, show that merely having an absolute-water-scarce upstream country in the dyad lowers the likelihood of the downstream country initiating conflict against the upstream country. However, having an absolute-water-scarce upstream country in the dyad along with a downstream country that is twice as powerful as the upstream country increases the likelihood of the downstream country initiating conflict. Using the

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[19] Detailed average marginal effects from each specification are available upon request.

average marginal effect, having an absolute-water-scarce upstream country in the dyad lowers the likelihood of the downstream country initiating conflict by 3 percent, which is the opposite of what was predicted in Table 2. Whereas having an absolute-water-scarce upstream country and a twice-as-powerful downstream country increases the likelihood of the downstream country initiating conflict by 15 percent, which matches the predictions from Table 2. In contrast, the coefficients of water-stress and water-scarce variables, along with their interactions with relative power, are not significantly different from zero.

Hypothesis 3. Similar to Hypothesis 2, the third hypothesis shows the relationship between U's water scarcity, and the likelihood of the upstream country responding with force to a conflict initiated by the downstream country. As can be seen in Column 7 in Table 10, only the coefficient of U being water-stressed is statistically different from zero, and it matches the prediction in Table 2 that $\psi_3 > 0$. The coefficient on the interaction term between D's relative power in U being absolute-water-scarce is significantly higher than that of the variable of whether U is water-scarce. This shows that $\pi_3 > 0$, which is what was predicted in Table 2. The magnitude of the effect is small and ranges between 2 to 4 percent.

6.2. Control Variables

Relative Military Power. Several studies (such as Wolf 1998), claimed that conflict over water only happens when the downstream is a hegemon country in the region. To test this claim, I include in the specification whether the relative military power of D to U in itself increases the likelihood of either country using force. The marginal effect of this variable is greater than zero; however, it is still less than 3 percent. This shows that δ is still less than π and ϕ, which indicate that having a more powerful downstream country in the dyad does not automatically translate into having a submissive upstream country that concedes to whatever the downstream country demands.

Democracy Level. Unlike the common belief that democracies are less likely to go to conflict compared to autocracies and semi-democracies, the results show that there is no significant relationship between D's democracy level and its likelihood to initiate conflict. However, having a democratic upstream country in the dyad increases the likelihood of D initiating the conflict by 2 percent compared to having a semi-democracy. Having an autocratic upstream country seems to increase the likelihood of D initiating conflict by 1.5 percent. Being a democracy increases the likelihood of the upstream country responding with force by 2 percent.

Dam Construction. Many hydro-political tension incidents between riparian countries seem to be over the construction of a new dam by the upstream country. Nonetheless, it has no statistically significant impact on the likelihood of the downstream country initiating a militarized interstate dispute. This is true regardless of whether I control for a dam currently being constructed, a dam that was just built and ready to start operating, or a dam that was built in the previous year. The coefficient of these three variables are insignificant in all specifications.

Conflict in Neighboring States. Conflict decisions might simply be due to a spillover effect from a nearby conflict in a neighboring or a regional state. To test for that, I control for major episodes of political violence in countries that are either contiguous or are in the same region as the upstream and downstream countries. I find that an interstate dispute in D's region lower its probability of initiating conflict, while a civil conflict in a neighboring country increases its likelihood of initiating conflict. Interestingly, a civil conflict in a neighboring state to U decreases D's likelihood of initiating conflict, and an interstate conflict in U's region increases the likelihood of both countries using force. As would be expected, an all-out war between the dyad in the current or previous year is associated with an increase in the likelihood of using force against each other.

Dyad Characteristics. Certain characteristics of the dyad can also affect the likelihood of an interstate conflict between the two countries. Contiguity increases the likelihood of the downstream country initiating a militarized interstate dispute and the likelihood of the upstream country responding with force by around 6 percent. The percentage of the population in each country that shares the same religion significantly lower the likelihood of either country using force. Sharing the same ethnicity, on the other hand, does not seem to have a significant impact.

7. Summary and Conclusion

This paper investigates the relationship between water scarcity and the likelihood of interstate conflict between upstream and downstream riparian countries. There are several contributions of this paper. First, it differentiates between a conflict initiated by a downstream country and the likelihood of the upstream country responding to this conflict with force. Second, it takes into account any other renewable water sources that a country has access to, such as other transboundary or local rivers and groundwater. Third, to my knowledge, this is the first paper to directly look at how the decision-making process of the upstream country affects the downstream country's decision to instigate a conflict. The primary finding is that the water scarcity level of the downstream country affects its likelihood of initiating conflict, while that of the upstream country only affects it when the downstream country is water-scarce and/or more powerful. The importance of this research is to help identify credible water conflict threats. Having this ability will allow politicians in upstream countries to consider these likelihoods when determining how much water to discharge and those in downstream countries to take them into account when considering whether to accept the volume discharged or peacefully negotiate a more favorable water treaty.

More research needs to be done to better understand these conflicts and how to anticipate them and avoid them before they occur. Since the main concern is that climate change may exacerbate this problem, a closer look at the impact of climate change and the uncertainty in water availability that it brings with it is a vital next step. Exploring the different solutions that can be used to cope with water scarcity problems such as virtual water trade and the increase in economic interdependence between the countries is also important to better understand water conflicts and mitigate the likelihood of them happening.

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Appendix

Table 1: U and D's Payoffs at Each Possible Outcome

Regime	*U*	*D*
Accept	$G_U^A = \alpha_U W_U^A$	$G_D^A = \alpha_D W_D^A$
Negotiate	$G_U^N = \alpha_U W_U^N + \tau$	$G_D^N = \alpha_D W_D^N - \tau$
D uses force; *U* concedes	$G_U^C = \alpha_U W_U^C$	$G_D^C = \alpha_D W_D^C - M_D^C$
Both use force; *D* wins	$G_U^{F(D_\omega)} = \alpha_U W_U^{F(D_\omega)} - M_U^F$	$G_D^{F(D_\omega)} = \alpha_D W_D^{F(D_\omega)} - M_D^F$
Both use force; *U* wins	$G_U^{F(U_\omega)} = \alpha_U W_U^{F(U_\omega)} - M_U^F$	$G_D^{F(U_\omega)} = \alpha_D W_D^{F(U_\omega)} - M_D^F$
The expected payoff when both use force	$G_U^F = \alpha_U \left[\eta W_U^{F(D_\omega)} + (1-\eta) W_U^{F(U_\omega)}\right] - M_U^F$	$G_D^F = \alpha_D \left[\eta W_D^{F(D_\omega)} + (1-\eta) W_D^{F(U_\omega)}\right] - M_D^F$

Table 2: Predicted signs and relative sizes of the reduced-form parameters

Hypothesis	Equation	Predictions
Baseline: $\Pr(F_D)$	(13)	$\gamma_3 > \gamma_2 > \gamma_1 \geq 0$
Baseline: $\Pr(F_D)$	(13)	$\beta_3 > \beta_2 > \beta_1 \geq 0$
Baseline: $\Pr(F_U)$	(14)	$\psi_3 > \psi_2 > \psi_1 \geq 0$
Hypothesis 1	(17)	$\sigma_3 > \sigma_2 > \sigma_1 \geq 0$
Hypothesis 1	(18)	$\phi_3 > \max\{\gamma_3, \sigma_3, \delta\}$
Hypothesis 1	(18)	$\phi_2 > \max\{\gamma_2, \sigma_2, \delta\}$
Hypothesis 2	(19)	$\pi_3 > \pi_2 > \pi_1 \geq 0$
Hypothesis 3	(20)	$\iota_3 > \iota_2 > \iota_1 > 0$

Table 3: Summary Statistics of Water Availability/Stress Levels Variables

Variable	Variation	Mean	Standard Deviation	Min	Max	Observations
Total renewable water resources in U, measured in billion cubic meters per year	overall	410	1105	0.70	8647	N = 6133
	between		1105	0.70	8647	n = 208
	within		0.75	399	416	T-bar = 29.49
Total renewable water resources in D, measured in billion cubic meters per year	overall	461	1239	0.94	8647	N = 6133
	between		1151	0.94	8647	n = 208
	within		0	461	461	T-bar = 29.49
Water per capita in U, measured in cubic meters per year	overall	21459	43174	88	646206	N = 6133
	between		37366	132	369101	n = 208
	within		14410	-157977	298564	T-bar = 29.49
Water per capita in D, measured in cubic meters per year	overall	34713	95074	130	761701	N = 6133
	between		72665	191	415386	n = 208
	within		35913	-191009	381028	T-bar = 29.49
U is water-stressed	overall	0.0931	0.29	0	1	N = 6133
	between		0.25	0	1	n = 208
	within		0.20	-0.78	1.05	T-bar = 29.49
D is water-stressed	overall	0.0307	0.17	0	1	N = 6133
	between		0.10	0	0.61	n = 208
	within		0.13	-0.58	0.94	T-bar = 29.49
U is water-scarce	overall	0.0311	0.17	0	1	N = 6133
	between		0.09	0	0.54	n = 208
	within		0.14	-0.51	0.93	T-bar = 29.49
D is water-scarce	overall	0.0351	0.18	0	1	N = 6133
	between		0.13	0	1	n = 208
	within		0.13	-0.87	0.90	T-bar = 29.49
U is absolute-water-scarce	overall	0.0502	0.22	0	1	N = 6133
	between		0.20	0	1	n = 208
	within		0.09	-0.52	0.54	T-bar = 29.49
D is absolute-water-scarce	overall	0.0316	0.18	0	1	N = 6133
	between		0.14	0	1	n = 208
	within		0.08	-0.71	0.74	T-bar = 29.49

Table 4: Summary Statistics of Conflict Variables

Variable		Mean	Standard Deviation	Min	Max	Observations
Onset of militarized interstate dispute	overall	0.0437	0.204	0	1	N = 6133
	between		0.115	0	0.895	n = 208
	within		0.169	-0.851	1.023	T-bar = 29.49
Incident of militarized interstate dispute initiated by D	overall	0.0238	0.152	0	1	N = 6133
	between		0.070	0	0.684	n = 208
	within		0.136	-0.660	1.003	T-bar = 29.49
Incident of U responding with force to a militarized interstate dispute initiated by D	overall	0.0186	0.135	0	1	N = 6133
	between		0.065	0	0.632	n = 208
	within		0.119	-0.613	0.997	T-bar = 29.49
Onset of water conflict	overall	0.0028	0.053	0	1	N = 6133
	between		0.014	0	0.111	n = 208
	within		0.051	-0.108	0.964	T-bar = 29.49
Incident of water conflict initiated by D	overall	0.0024	0.049	0	1	N = 6133
	between		0.014	0	0.111	n = 208
	within		0.048	-0.109	0.980	T-bar = 29.49
Incident of U responding with force to a water conflict initiated by D	overall	0.0016	0.040	0	1	N = 6133
	between		0.009	0	0.065	n = 208
	within		0.039	-0.064	0.980	T-bar = 29.49
Onset of an all-out war	overall	0.0021	0.046	0	1	N = 6133
	between		0.009	0	0.065	n = 208
	within		0.045	-0.063	0.981	T-bar = 29.49
Incident of an all-out war initiated by D	overall	0.0013	0.036	0	1	N = 6133
	between		0.006	0	0.045	n = 208
	within		0.035	-0.044	0.980	T-bar = 29.49

Table 5: Summary Statistics of Control Variables

Variable		Mean	Std. Dev.	Min	Max	Observations
Number of new dams built by U	overall	0.059	0.351	0	6	N = 6133
	between		0.153	0	1.152	n = 208
	within		0.303	-1.093	5.111	T-bar = 29.49
Relative power of D to U (using military expenditures)	overall	0.490	0.344	-0.001	1.009	N = 6127
	between		0.318	0.001	1.000	n = 208
	within		0.143	-0.413	1.413	T-bar = 29.49
Relative power of D to U (using military personnel)	overall	0.498	0.334	-3.5	4	N = 6113
	between		0.310	-0.381	1.019	n = 208
	within		0.151	-2.621	3.878	T-bar = 29.49
U is a democracy	overall	0.374	0.484	0	1	N = 6133
	between		0.424	0	1	n = 208
	within		0.272	-0.581	1.330	T-bar = 29.49
U is an autocracy	overall	0.366	0.482	0	1	N = 6133
	between		0.361	0	1	n = 208
	within		0.341	-0.613	1.310	T-bar = 29.49
D is a democracy	overall	0.364	0.481	0	1	N = 6133
	between		0.396	0	1	n = 208
	within		0.306	-0.586	1.250	T-bar = 29.49
D is an autocracy	overall	0.384	0.486	0	1	N = 6133
	between		0.346	0	1	n = 208
	within		0.367	-0.593	1.341	T-bar = 29.49
Countries are contiguous	overall	0.479	0.500	0	1	N = 6133
	between		0.501	0	1	n = 208
	within		0	0.479	0.479	T-bar = 29.49
An index for shared ethnicity (percentage of countries' population)	overall	0.041	0.130	0	0.807	N = 6133
	between		0.112	0	0.807	n = 208
	within		0	0.041	0.041	T-bar = 29.49
An index for shared religion (percentage of countries' population)	overall	0.357	0.332	0	0.985	N = 6133
	between		0.328	0	0.985	n = 208
	within		0	0.357	0.357	T-bar = 29.49
U's GDP per capita	overall	4039.228	9341.598	37.518	74276.720	N = 6133
	between		9754.88	146.252	52345.510	n = 208
	within		4086.943	-26250.650	45894.680	T-bar = 29.49
D's GDP per capita	overall	2749.467	5835.896	7.125	56630.850	N = 6133
	between		4522.106	120.202	34086.500	n = 208
	within		3593.027	-17736.620	40670.670	T-bar = 29.49

Table 5: Summary Statistics of Control Variables (Continue)

Variable		Mean	Std. Dev.	Min	Max	Observations
U's trade openness level (percentage of GDP)	overall	61.726	32.663	0.17	311.360	N = 6133
	between		31.085	0.415	183.714	n = 208
	within		15.761	-23.288	237.933	T-bar = 29.49
D's trade openness level (percentage of GDP)	overall	71.568	42.163	0.17	531.737	N = 6133
	between		34.502	0.415	221.282	n = 208
	within		23.676	-104.898	382.024	T-bar = 29.49
Share of the primary sector in U's GDP	overall	21.483	16.347	0	79.042	N = 6133
	between		14.049	0	49.028	n = 208
	within		7.834	-22.840	60.002	T-bar = 29.49
Share of the secondary sector in U's GDP	overall	25.070	13.024	0	87.797	N = 6133
	between		10.115	0	60.605	n = 208
	within		8.047	-14.791	87.167	T-bar = 29.49
Share of the primary sector in D's GDP	overall	19.711	15.638	0	79.042	N = 6133
	between		13.226	0	66.909	n = 208
	within		7.627	-23.932	59.696	T-bar = 29.49
Share of the secondary sector in D's GDP	overall	25.578	14.546	0	77.414	N = 6133
	between		11.108	0	63.466	n = 208
	within		9.315	-28.463	70.385	T-bar = 29.49
U is a member of the WTO	overall	0.692	0.462	0	1	N = 6133
	between		0.394	0	1	n = 208
	within		0.262	-0.288	1.552	T-bar = 29.49
D is a member of the WTO	overall	0.706	0.455	0	1	N = 6133
	between		0.400	0	1	n = 208
	within		0.247	-0.273	1.546	T-bar = 29.49

Table 6: Fit Statistics for the Estimations of Equation (13)

Model	Probit	Logit	Complementary log-log
N	5503	5503	5503
Log-Likelihood Intercept Only	-615.369	-615.369	-615.369
Log-Likelihood Full Model	-399.929	-396.553	-396.107
D	799.858(5450)	793.105(5450)	792.214(5450)
LR	430.880(36)	437.633(36)	438.524(36)
Prob > LR	0	0	0
McFadden's R2	0.35	0.356	0.356
McFadden's Adj R2	0.264	0.269	0.27
Maximum Likelihood R2	0.075	0.076	0.077
Cragg & Uhler's R2	0.376	0.381	0.382
Efron's R2	0.191	0.199	0.205
Count R2	0.977	0.977	0.978
Adj Count R2	0.046	0.031	0.054
AIC	0.165	0.163	0.163
AIC*n	905.858	899.105	898.214
BIC	-46141.258	-46148.01	-46148.901
BIC'	-120.811	-127.563	-128.454

Table 7: Fit Statistics for the Estimations of Equation (14)

Model	probit	logit	Complementary log-log
N	5503	5503	5503
Log-Lik Intercept Only	-515.751	-515.751	-515.751
Log-Lik Full Model	-333.809	-331.915	-332.572
D	667.618(5456)	663.829(5456)	665.145(5456)
LR	363.885(33)	367.674(33)	366.358(33)
Prob > LR	0	0	0
McFadden's R2	0.353	0.356	0.355
McFadden's Adj R2	0.262	0.265	0.264
Maximum Likelihood R2	0.064	0.065	0.064
Cragg & Uhler's R2	0.374	0.378	0.377
Efron's R2	0.179	0.184	0.186
Count R2	0.981	0.981	0.982
Adj Count R2	0.019	0	0.048
AIC	0.138	0.138	0.138
AIC*n	761.618	757.829	759.145
BIC	-46325.176	-46328.964	-46327.649
BIC'	-79.654	-83.443	-82.128

Table 8: Average Marginal Effect of Different Water Stress Levels on the Probability of the Downstream Country Initiating Conflict (*** p<0.01, ** p<0.05, * p<0.1)

	U is water-abundant	U is water-stressed	U is water-scarce	U is absolute-water-scarce
D is water-stressed	4 percent***	3 percent*	2 percent	7 percent
D is water-scarce	4 percent**	3 percent**	2 percent	6 percent
D is absolute-water-scarce	32 percent**	23 percent**	21 percent	36 percent***

Table 9: Marginal Effect of Relative Military Power for Different Water Stress Levels on the Probability of the Downstream Country Initiating Conflict (*** p<0.01, ** p<0.05, * p<0.1)

	U is water-stressed	U is water-scarce	U is absolute-water-scarce
D is water-stressed	6.2 percent**	5.3 percent	13.9 percent*
D is water-scarce	7.1 percent**	6.3 percent*	14.6 percent*
D is absolute-water-scarce	8 percent**	7 percent	15.2 percent*

Table 10: Complementary Log-Log Model: Likelihood of a Militarized Interstate Dispute

VARIABLES	(1) Baseline: $Pr(F_D)$	(2) H1a: $Pr(F_D)$	(3) H1b: $Pr(F_D)$	(4) H2: $Pr(F_D)$	(5) All: $Pr(F_D)$	(6) Baseline: $Pr(F_U)$	(7) H3: $Pr(F_U)$
U is water stressed = 1	-0.407	-0.531*	-0.732**	0.154	-0.180	-0.0293	1.520**
	(0.345)	(0.308)	(0.311)	(0.607)	(0.638)	(0.546)	(0.645)
D is water stressed = 1	2.018***	2.370***	2.214***	2.036***	2.350***		
	(0.422)	(0.390)	(0.439)	(0.418)	(0.378)		
U is water scarce = 1	-0.469	-0.409	-0.615	-0.924	-0.826	-0.0608	-0.758
	(0.903)	(0.970)	(1.033)	(1.152)	(1.178)	(1.211)	(1.557)
D is water scarce = 1	1.039***	1.623***	1.487***	1.105***	1.724***		
	(0.372)	(0.407)	(0.484)	(0.382)	(0.413)		
U is absolute water scarce = 1	1.154	1.017	0.765	-4.663*	-4.542*	1.744**	-2.708
	(0.794)	(0.789)	(0.829)	(2.435)	(2.478)	(0.684)	(2.953)
D is absolute water scarce = 1	2.013***	1.629**	1.511**	2.244***	1.892**		
	(0.629)	(0.652)	(0.659)	(0.690)	(0.741)		
U's water dependency on external water resources	0.0141**	0.0152***	0.0152***	0.0135**	0.0143**	0.0174**	0.0170**
	(0.00583)	(0.00563)	(0.00567)	(0.00606)	(0.00599)	(0.00791)	(0.00779)
D's water dependency on external water resources	-0.0186***	-0.0200***	-0.0203***	-0.0190***	-0.0204***	-0.0197***	-0.0203***
	(0.00649)	(0.00675)	(0.00680)	(0.00669)	(0.00695)	(0.00661)	(0.00708)
D is water stressed while U is water abundant = 1		5.893			5.885		
		(4.041)			(3.811)		
D is water scarce while U is water abundant = 1		17.54**			17.26**		
		(6.998)			(7.079)		
D is absolute-water-scarce while U is water-abundant = 1		-20.89***			-15.00***		
		(2.658)			(2.620)		
D is water-stressed and more powerful while U is water-abundant = 1		-17.84	-18.37		-17.51		
		(12.96)	(13.20)		(12.34)		

Robust standard errors clustered at the dyad level in parentheses
*** $p<0.01$, ** $p<0.05$, * $p<0.1$

Table 10: Complementary Log-Log Model: Likelihood of a Militarized Interstate Dispute (Continue)

VARIABLES	(1) Baseline: $Pr(F_D)$	(2) H1a: $Pr(F_D)$	(3) H1b: $Pr(F_D)$	(4) H2: $Pr(F_D)$	(5) All: $Pr(F_D)$	(6) Baseline: $Pr(F_U)$	(7) H3: $Pr(F_U)$
D is water-scarce and more powerful while U is water-abundant = 1		-40.97***	-40.83***		-40.56***		
		(14.63)	(14.56)		(14.77)		
D is absolute-water-scarce and more powerful while U is water-abundant = 1		62.87***	63.90***		48.16***		
		(6.405)	(24.70)		(6.263)		
U is water-stressed, and D is more powerful				-1.230	-0.784		-3.439**
				(1.140)	(1.179)		(1.573)
U is water-scarce, and D is more powerful				1.533	1.204		2.692
				(2.408)	(2.278)		(2.382)
U is absolute-water-scarce, and D is more powerful				8.017**	7.603**		5.937
				(3.260)	(3.334)		(3.655)
Relative power of D to U (using military personal)	1.091***	1.105***	1.099***	1.120***	1.125***	1.109***	1.200***
	(0.315)	(0.313)	(0.314)	(0.338)	(0.334)	(0.361)	(0.384)
U is a democracy = 1	0.297	0.117	0.111	0.395	0.205	0.610	0.720
	(0.432)	(0.426)	(0.428)	(0.427)	(0.426)	(0.481)	(0.462)
U is an autocracy = 1	-0.562	-0.701*	-0.706*	-0.599	-0.729*	-0.385	-0.376
	(0.372)	(0.405)	(0.405)	(0.377)	(0.413)	(0.460)	(0.465)
D is a democracy = 1	0.311	0.349	0.342	0.264	0.296	0.346	0.262
	(0.305)	(0.318)	(0.318)	(0.312)	(0.324)	(0.329)	(0.327)
D is an autocracy = 1	0.110	0.102	0.0905	0.0999	0.0821	0.0515	0.00731
	(0.331)	(0.347)	(0.347)	(0.330)	(0.352)	(0.354)	(0.342)
Sum of interstate MEPV magnitude scores for U's neighboring states	-0.00335	-0.0295	-0.0325	0.00470	-0.0232	-0.0152	-0.0133
	(0.0858)	(0.0809)	(0.0808)	(0.0847)	(0.0803)	(0.0905)	(0.0887)
Sum of societal MEPV magnitude scores for U's neighboring states	-0.0482*	-0.0548*	-0.0523*	-0.0441	-0.0515*	-0.0275	-0.0218
	(0.0281)	(0.0300)	(0.0291)	(0.0278)	(0.0303)	(0.0356)	(0.0353)

Robust standard errors clustered at the dyad level in parentheses

*** $p<0.01$, ** $p<0.05$, * $p<0.1$

Table 10: Complementary Log-Log Model: Likelihood of a Militarized Interstate Dispute (Continue)

VARIABLES	(1) Baseline: $Pr(F_D)$	(2) H1a: $Pr(F_D)$	(3) H1b: $Pr(F_D)$	(4) H2: $Pr(F_D)$	(5) All: $Pr(F_D)$	(6) Baseline: $Pr(F_U)$	(7) H3: $Pr(F_U)$
Sum of interstate MEPV magnitude scores for U's regional states	0.258***	0.289***	0.288***	0.254***	0.288***	0.253***	0.259***
	(0.0855)	(0.0752)	(0.0755)	(0.0883)	(0.0787)	(0.0889)	(0.0895)
Sum of societal MEPV magnitude scores for U's regional states	0.0216	0.0175	0.0169	0.0193	0.0153	-8.44e-05	0.00205
	(0.0312)	(0.0340)	(0.0340)	(0.0322)	(0.0351)	(0.0421)	(0.0410)
Sum of interstate MEPV magnitude scores for D's neighboring states	0.0936	0.102	0.108	0.106	0.112	0.0916	0.103
	(0.0726)	(0.0786)	(0.0769)	(0.0739)	(0.0802)	(0.0766)	(0.0767)
Sum of societal MEPV magnitude scores for D's neighboring states	0.0984***	0.0998***	0.0996***	0.0946**	0.0950**	0.0815**	0.0767*
	(0.0368)	(0.0372)	(0.0375)	(0.0370)	(0.0376)	(0.0407)	(0.0402)
Sum of interstate MEPV magnitude scores for D's regional states	-0.231***	-0.232***	-0.233***	-0.250***	-0.251***	-0.189***	-0.215***
	(0.0640)	(0.0622)	(0.0628)	(0.0691)	(0.0688)	(0.0571)	(0.0610)
Sum of societal MEPV magnitude scores for D's regional states	-0.0126	-0.00845	-0.00840	-0.0116	-0.00635	0.00594	0.00651
	(0.0281)	(0.0288)	(0.0289)	(0.0279)	(0.0293)	(0.0341)	(0.0330)
An incident of an interstate conflict between the dyad triggered primarily by w = 1	-0.554	-0.222	-0.294	-0.550	-0.198	-0.133	-0.0719
	(0.704)	(0.748)	(0.713)	(0.739)	(0.768)	(0.871)	(0.940)
An incident of an all-out war between the dyad in the previous year = 1	0.846**	0.970**	0.948**	0.816**	0.929**	0.975***	0.924***
	(0.352)	(0.445)	(0.434)	(0.354)	(0.451)	(0.354)	(0.341)
An incident of an all-out war between the dyad in the current year = 1	1.688***	1.763***	1.712***	1.736***	1.806***	1.644***	1.687***
	(0.473)	(0.531)	(0.503)	(0.472)	(0.541)	(0.466)	(0.471)
U's GDP per capita	-8.15e-05	-9.61e-05	-0.000101	-6.92e-05	-8.65e-05	-0.000203	-0.000166
	(8.84e-05)	(9.67e-05)	(9.91e-05)	(8.53e-05)	(9.68e-05)	(0.000201)	(0.000186)
D's GDP per capita	1.36e-05	2.25e-05	2.37e-05	4.13e-06	1.47e-05	5.37e-05	4.79e-05
	(3.70e-05)	(3.54e-05)	(3.54e-05)	(3.79e-05)	(3.79e-05)	(3.92e-05)	(4.07e-05)

Robust standard errors clustered at the dyad level in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table 10: Complementary Log-Log Model: Likelihood of a Militarized Interstate Dispute (Continue)

VARIABLES	(1) Baseline: $Pr(F_D)$	(2) H1a: $Pr(F_D)$	(3) H1b: $Pr(F_D)$	(4) H2: $Pr(F_D)$	(5) All: $Pr(F_D)$	(6) Baseline: $Pr(F_U)$	(7) H3: $Pr(F_U)$
U is a member of the WTO = 1	0.0114	-0.0389	-0.0384	-0.0460	-0.0949	0.0342	-0.0390
	(0.402)	(0.417)	(0.417)	(0.416)	(0.430)	(0.587)	(0.603)
D is a member of the WTO = 1	-0.973**	-0.904**	-0.900**	-0.912*	-0.828*	-0.775	-0.795
	(0.447)	(0.446)	(0.447)	(0.475)	(0.472)	(0.560)	(0.572)
U's trade openness level	-0.0149**	-0.0155***	-0.0154***	-0.0172***	-0.0175***	-0.0164***	-0.0197***
	(0.00589)	(0.00585)	(0.00585)	(0.00661)	(0.00650)	(0.00635)	(0.00704)
D's trade openness level	-0.0206***	-0.0201***	-0.0201***	-0.0202***	-0.0196***	-0.0172***	-0.0184***
	(0.00574)	(0.00602)	(0.00600)	(0.00558)	(0.00591)	(0.00618)	(0.00637)
Total bilateral trade flow in millions of dollars	5.95e-05**	6.99e-05**	7.09e-05**	6.36e-05**	7.15e-05**	-0.000262	-0.000246
	(2.78e-05)	(3.14e-05)	(3.20e-05)	(2.86e-05)	(3.14e-05)	(0.000378)	(0.000283)
U's population in millions	0.000515	0.000409	0.000353	0.000388	0.000318	0.000686	0.000475
	(0.000470)	(0.000519)	(0.000482)	(0.000485)	(0.000527)	(0.000909)	(0.000868)
D's population in millions	-0.000775	-0.000352	-0.000310	-0.000712	-0.000337	-0.000957	-0.000980
	(0.00100)	(0.00113)	(0.00114)	(0.00102)	(0.00116)	(0.00119)	(0.00124)
An index for shared ethnicity	-0.950	-1.011	-0.941	-0.537	-0.594	-0.349	-0.322
	(1.486)	(1.527)	(1.513)	(1.460)	(1.485)	(1.792)	(1.955)
An index for shared religion	-1.816***	-1.913***	-1.926***	-1.944***	-2.007***	-1.887***	-1.987***
	(0.460)	(0.472)	(0.470)	(0.499)	(0.494)	(0.657)	(0.631)
Contiguity = 1	3.763***	3.798***	3.841***	3.831***	3.851***	3.526***	3.615***
	(0.599)	(0.643)	(0.654)	(0.620)	(0.671)	(0.702)	(0.713)
Constant	-4.376***	-4.277***	-4.000***	-4.242***	-4.172***	-4.681***	-4.492***
	(1.017)	(1.020)	(1.139)	(1.065)	(1.062)	(1.002)	(1.064)
Observations	5,503	5,503	5,503	5,503	5,503	5,503	5,503

Robust standard errors clustered at the dyad level in parentheses

*** p<0.01, ** p<0.05, * p<0.1

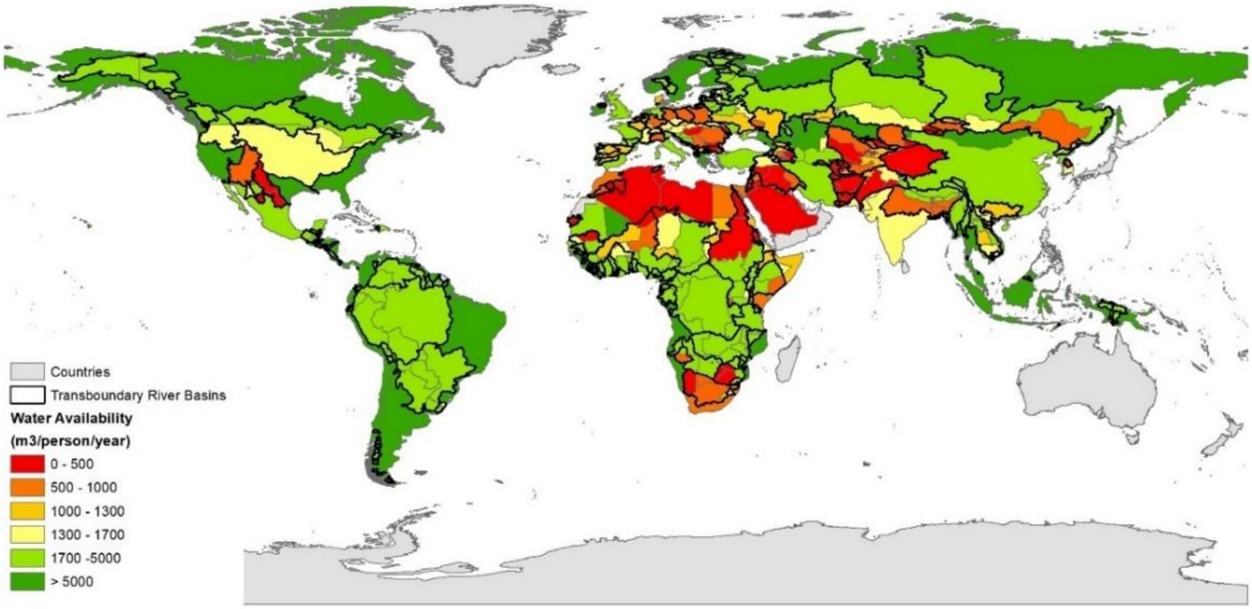

Figure 1: Water Availability in Riparian Countries.
The map was created by the author using the 2012 country-level water availability data from AQUASTAT and country-basin water-stress levels from the Transboundary Waters Assessment Programme (TWAP).

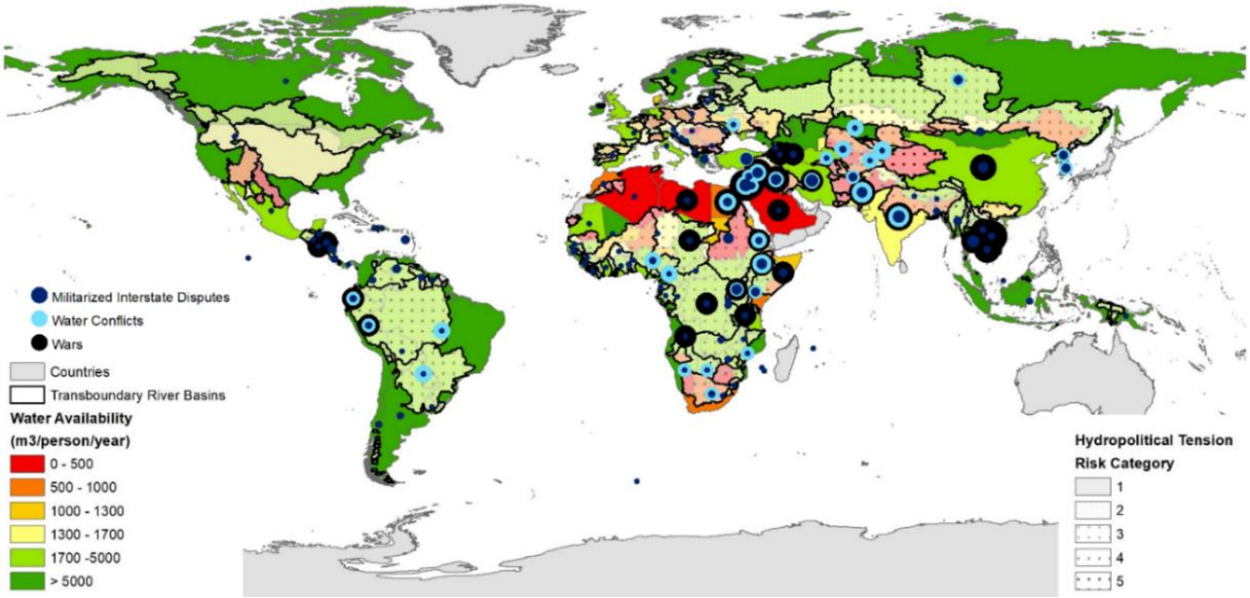

Figure 2: Water Stress, Hydropolitical Tension, and Conflict Between Riparian Countries.
Figure 2 was created by the author using the 2012 country-level water availability data from AQUASTAT and country-basin water stress level and hydro-political tension data from the Transboundary Waters Assessment Programme (TWAP). Water conflict data was obtained from the Water Conflict Chronology list (Gleick and Heberger 2014). Militarized interstate disputes and war data are from the Correlates of War Project (COW).

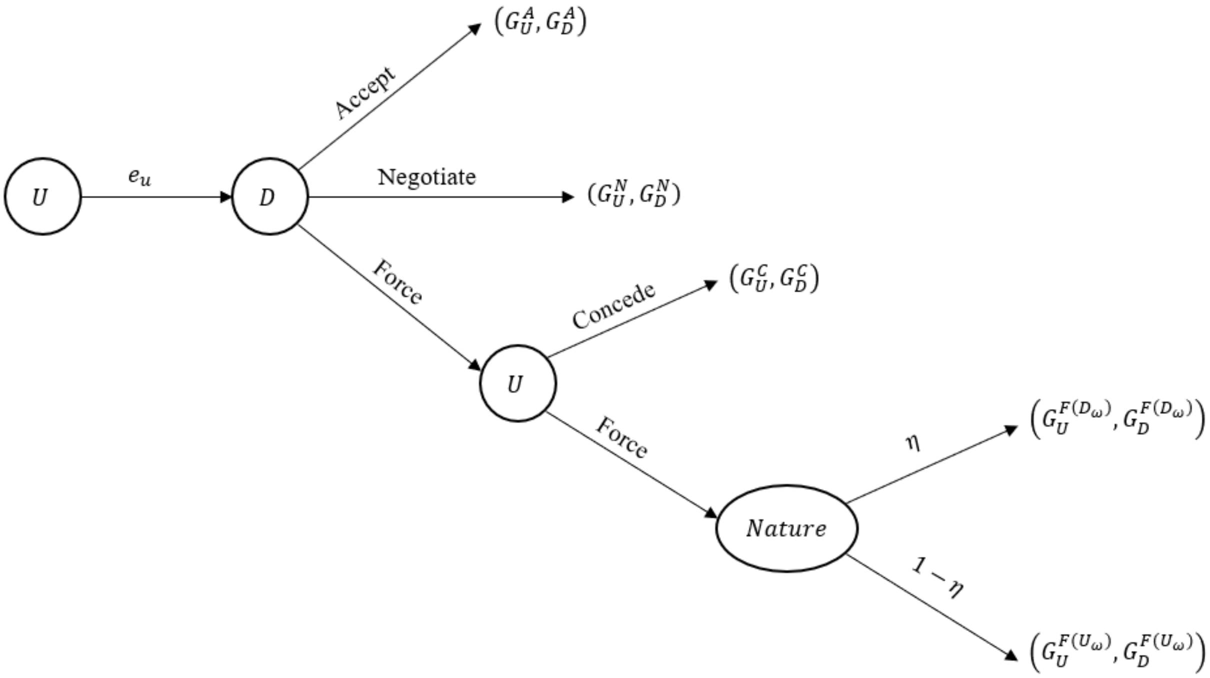

Figure 3: The Extensive Form of the One-Shot River Sharing Game.

In the first stage of the game, U decides how much water to discharge to D. In the second stage, D chooses between accepting the water flow released by U, negotiating with U for more water in exchange for a monetary transfer, or using force against U to increase their share of river water. If D initiates a militarized conflict against U, U decides in the third stage whether to concede to D's demands or fight back. "Nature" determines the relative military power of both countries in the one-shot game; η represents the likelihood of D winning the conflict. The payoff of each outcome, G_s^R, depends indirectly on the water flow which affects the total water resources in each country and, therefore, it affects the aggregate welfare. The payoff also depends on the military cost if the states choose to fight, or the transfer payments from D to U if they decide to negotiate trading water.