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Water Shortages and Interstate Conflict *

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Abstract

For a few decades, a growing literature has examined the role of water resources in interstate conflicts. In line with this literature, this study analyzes the risk of a conflict between countries sharing freshwater. While some scholars claim that water-based conflicts can never occur, this analysis determines this risk by linking it to the size of a negotiation interval; the probability-to-conflict decreasing with this size. In fact, we are going to show that the size of this interval diminishes with scarcer resources and with the degree of the heterogeneity of countries measured by their productive efficiency. Then, in a peace scenario, we determine by bargaining the optimal allocation and we study its variation according to the parameters of the model. These theoretical results will be confirmed by an econometric approach.

Keywords: *Conflict Theory, Water-based Conflict, Nash-Bargaining, Dyadic Analysis*

Introduction

For a few decades, a growing literature has examined the role of water resources in interstate conflicts. In line with this literature, this study analyzes the risk of a conflict between countries sharing freshwater. While some scholars claim that water-based conflicts can never occur, this analysis determines this risk by linking it to the size of a negotiation interval; the probability-to-conflict decreasing with this size. In fact, we are going to show that the size of this interval diminishes with scarcer resources and with the degree of the heterogeneity of countries measured by their productive efficiency. Then, in a peace scenario, we determine by bargaining the optimal allocation and we study its variation according to the parameters of the model. These theoretical results will be confirmed by an econometric approach.

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In fact, this question is embedded in a wider relationship between resource scarcity and conflict that can be traced back to early 1970. In a nutshell, during the 1970s and the 1980s, resource-based security revolved around three issues, namely Middle Eastern oil, Soviet natural gas and Southern African minerals. According to Choucri and North [8], internal demand push states toward expansion, increasing the propensity for conflicts. The Gulf wars witness that the West always tries to safeguard access to oil and the recent (2005-06) Russia-Ukraine gas disputes illustrate that tensions are not finished. Today, water scarcity fans tensions and is expected to be a source of possible future conflict due to the increasing stress on the resource.

As a consequence, a large literature on water-based conflicts was developed opposing the Neomalthusians to the Cornucopians. The former predicts that conflicts over scarce resource are likely to become more prevalent (Bächler [3], Homer-Dixon [23], Klare [25]), especially in poorer regions more dependent on land and agriculture. More specifically, Miguel and *al.* [28] find a strong negative effect of economic growth on the likelihood of outbreak of civil war among 41 African countries, using rainfall variation as an exogenous instrument. Water is an essential resource for human life as well as for agriculture and industry and, consequently, stresses the attention of a substantial literature describing water both as an historic and, by extrapolation, as a future cause of interstate warfare. For instance, Furlong and *al.* [13] claim that if one of the riparian nations within a basin is water-short then there is a greater risk of interstate conflict. Besides, Gleick [16] proposes a classification to outline the role of water in different conflicts.

On the other side, the Cornucopians are more optimistic, outlining the cooperative aspects. Aaron Wolf [37] listed more than 3600 agreements along the history and shows that the lone water-based conflict took place between the two Sumerian city-states. According to him, international rivals sharing waters such as the Jordan River, the Nile, the Ganges have generally favored cooperation over conflict. "The simple explanation is that water is simply too important to fight over" said Aaron Wolf. "Nations often go to the brink of war over water and then resolve their differences." Indeed, some disagreements have been managed more peacefully such as the Mexican-American dispute over pollution in Rio Grande and damming on the Colorado River [20]. In fact, the majority of studies has actually focused on dispute resolution. By the way, Carraro and *al.* [6] review the applications of non-cooperative bargaining theory to water issues or other studies wonder how riparian states can reach cooperative outcomes in conflicts over water sharing (Barret [4], Kilgour and Dinar [26], Ambec and Sprumont [2], Dinar and Wolf [10]).

However, hydrological matters represent an additional dimension in many conflicts. For instance, the Six-Day war is presented as the first contemporary conflict over water [27]. This event could stem from the Israeli decision to finish the aqueduct to divert waters from the Tiberiade lake in 1957 which preceded a series of other one-sided decisions which hardened the tensions in this area until the Six-Day war. This claim is supported by recent empirical studies which highlight a strong positive relationship between shared rivers and dyadic militarized conflict (Sowers [32], Toset, Gleditsch and Hegre [34]). Moreover, the historical argument can be challenged because the absence of historical contests does not mean that any conflict will occur in the future. On the contrary, the fiercer competition due to a growing population and an increasing water demand might lead to a malthusian backlash (Cooley [9], Homer-Dixon [23], Hensel, Mitchell, Sowers [20]). By the way, Leif Ohlsson [30] says that “as long as more water in the hands of one country is perceived by another as a loss of the same amount (...) conflict and violent annexation of common water resources is a viable strategy”.

Despite these evidences, the attempts to tackle this topic within the economic theory are quite few. To this end, this paper aims at contributing in the reduction of this gap and to investigate how an interstate conflict can spark off. In fact, the purpose of this study is three-fold. First, we investigate the issue of water-related tensions through the conflict theory. At a theoretical level, as Garfinkel and Skaperdas [14] claim, conflict is difficult to comprehend from a traditional economic perspective because of the existence of imperfectly enforced property rights which represent a crucial motivation to engage in conflict and appropriate the resource of the opponent. In our study, countries want to grab the resource for its productive-use. The main contribution consists of outlining the existence of a negotiation interval by comparing the well-being of each country in a peace scenario with their well-being in a conflict scenario. The analysis of the variation of the size of this set will put forth the role of water scarcity in a water-based conflict. In fact, this study follows conflict models spearheaded largely by Hirshleifer ([21] and [22]) and Grossman ([17] and [18]). Within this literature, Janmaat and Ruijs [24] analyze the same debate by explicitly examining the role of leadership rather than the role of water scarcity. They explore the difference between a simultaneous and sequential move game.

In a second step, we propose to analyze the Nash-bargaining solution in order to exhibit the optimal cooperative solution when such an interval exists. Effectively, water-based conflicts may be a riddle insofar economic agents are likely to waste resources in order to fight over abundant resources such as territories or markets. From this point of view, the suggestion of determining the optimal allocation on the basis of the negotiation interval is interesting. Ansink and Weikard [1] also conduct a Nash-bargaining analysis to shed light on the question under which conditions countries will jointly define property rights to contested water to promote international water trade. However, their study is not based on this kind of negotiation set.

In a last step, we introduce consistent empirical investigations with our theoretical results. The empirical analysis is based on a dyadic approach, the common way to study countries' interactions.

The outline of this paper is as follows. Section 2 starts with some supporting facts. The conflict model is introduced in section 3. Through comparative statics, we can define a negotiation interval where countries may cooperate. This result motivates the following section where we turn to a bargaining game. The optimal solution depends on the quantity of water. Section 5 yields the empirical investigation to test our theoretical approach. Finally, a brief discussion and concluding remarks are offered in section 6.

1 Cooperation versus Conflict

The debate between the defendants of cooperation and the defendants of conflict often sets forth the existence of the numerous agreements over water resources. Effectively, the history of water dispute resolution, in contrast to that of conflict, is much more impressive. The Food and Agriculture Organization of the United Nations has identified more than 3 600 treaties relating to international water resources, dating between 805 and 1984. Moreover, several institutions and/or commissions have been created for several years such as the Mekong Committee in 1957, the Indus Commission in 1960 or, more recently, the Nile Initiative Basin in 2001. All these facts and figures witness that a treaty can have beforehand defined water allocations between riparian states. Nevertheless, this peaceful situation could be challenged for many reasons.

First, the majority of these treaties deal with aspects of navigation and not with consumptive-use. If we adopt the restriction proposed by Aaron Wolf, himself, to treaties signed from 1870 and later that deal with water *per se* and excluding those which deal only with boundaries or fishing rights, it remains only 145 treaties in the Transboundary Freshwater Dispute Database at the University of Alabama. Most of them focus on hydropower and water-supplies, respectively 39% and 37%. Nevertheless, a first remark leads us to observe that there are less treaties than the 260 existing river basins and, furthermore, there are several agreements for one basin like for the Jordan basin where there were a succession of plans. Therefore, cooperation is not the prerogative of all the river basins. Under the assumption of Wolf claiming that such agreements guarantee a peaceful cooperation, there exist some areas not protected by an agreement.

Secondly, turning to the existing water allocation treaties, there are for instance the 1959 Nile Plan or the Johnston Plan for the Jordan River. The two following tables describe these allocations.

Table 1: Plan for the Nil basin, 1959

	Thousand m^3	Percent
Egypt	55	66
Sudan	18	21
Others	11	13
Total	84	100

Table 2: Johnston plan for the Jordan River System, 1954[1]

	Thousand m^3	Percent
Lebanon	35 (0)	2.75 (0)
Syria	132 (22)	10.25 (4.55)
Jordan	720 (100)	56 (20)
Israel	400 (375)	31 (75.45)
Total	1287 (497)	100 (100)

[a]In brackets, specific allocation from the Jordan river.

Then, in addition to the limited number of water-sharing treaties, these allocations can be challenged because they were defined accordingly an old self-interest theory giving the utilization right to the downstream countries : *the absolute integrity of the river*, i.e. the upstream riparian states can do nothing that affects the flow of the river.

In fact, there exist opposite doctrines which used to be employed to share transboundary water in practice. To this end, in response to the absolute integrity principle, there is *the absolute territorial sovereignty* which allocates the right to the most upstream nation. For instance, Turkey hid behind it to justify its hydrological project.

Both sorts of property-rights regimes had been contested for a long time and remain at the core of some interstate disputes. In effect, the evolution towards new water division approaches come later. Today, the most important trend is the shift in principle adoption, namely in position from "rights-based" criteria to "needs-based" criteria. On this basis, the UN Watercourse Convention - signed in 1997 - consecrates the rule of *equitable utilization* based on the international basin unit and, therefore, recognizes the obligation to manage their uses so as not to interfere with its neighbors. This is a real evolution in this poorly-developed international law context. Nevertheless, this rule remains quite unprecise about of what amounts are "equitable". Besides, some treaties specify equal portions whereas others provide a specific means of allocations. Moreover, countries such as Turkey or China continue to advocate extreme and self-interest theories even if efforts to codify international law are made. In fact, only one-fifth treaties define enforcement mechanism. Historically, force or the threat of force have ensured that a water treaty will be followed as it was the case with Egypt or Israel because of their respective power in terms of institutions and military organizations. Today, the Helsinki Rules are not binding and the UN Watercourse Convention are binding upon ratifying countries. This convention was to come into force once ratified by 35 countries. However, it has languished in limbo, with only 16 so far signing up[1]. Namely, Burundi, China and Turkey voting against it and refuse to sign it. Egypt and Israel abstained from voting.

Even if signs of cooperation are more numerous than actual conflicts, the way to stable peaceful cooperation is still fraught with pitfulls as long as countries expect more benefits by engaging in conflicts. Moreover, other push factors like the increasing global demand does not make the task easier. By the way, the U.N Secretary-general Kofi Annan said, in 2001, "fierce competition for fresh water may well become a source of conflict and wars in the future"

2 The Theoretical approach

The setting of the model is described within the framework of Hirshleifer ([21], [22]). He proposes an approach akin to rent-seeking and contest models but he introduces a trade-off between productive and unproductive activities which generalizes previous models. Namely, his study is based on four steps [7].

First of all, assume that two countries share a common water resource. Moreover, we propose an inaugural picture where initial allocations are given exogenously, for instance predefined by a treaty, such that total water W is split in two parts : $W = w_1 + w_2$. Thus, each country can allocate its endowment between two activities, i.e. a share y_i is allocated to produce consumption goods and a part h_i is spent in "guns" production. Thus, the *partition equation* is as follows :

$$w_i = y_i + h_i \tag{1}$$

Then, these quantities are used as a production factor. To keep the model as simple as possible, we assume that water is the only input for both activities. On one hand, we use a linear production function for consumption goods. On the other hand, contrary to the literature converting directly water into "guns", we choose a strictly concave production function for the coercive activity. Thus, denoting respectively by F_i and g_i the consumption goods production function and the guns production function, we have :

$$F_i(y_i) = \mu_i y_i \tag{2}$$

$$g_i(h_i) = g_i(h_i) = (\lambda_i h_i)^\alpha \text{ with } \alpha \in]0,1] \tag{3}$$

with $i = 1; 2$, $\mu_i > 0$ and $\lambda_i > 0$ the productive capacity of both countries.

[1] Finland, Germany, Hungary, Iraq, Jordan, Lebanon, Libya, Namibia, Norway, Portugal, Qatar, South Africa, Sweden, Syria and Uzbekistan

The resources allocated to productive activities will determine a total contestable output. In effect, this contestable output is defined as the *aggregate production* of both countries :

$$\sum_{i=1}^{2} F_i(y_i) \tag{4}$$

Thirdly, the outcome of the conflict is, its turn, determined through the *contest-success function*. Hirshleifer [22] and Garfinkel and Skaperdas [14] provide the well-known form where the ratio of inputs to fighting is considered important for the captured portion :

$$p_i(g_1, g_2) = \frac{g_i}{g_1 + g_2} \qquad \text{with } g_i \equiv g_i(h_i) \tag{5}$$

This function defines the probability to win the conflict for country i. Symmetrically, its probability to loose the conflict corresponds to the probability to win the conflict for country 2, $(1 - p_i(g_i, g_j)) = p_j(g_1, g_2)$. Under this remark, this contest function has the standard assumptions, i.e. $\partial_{g_i} p_i > 0$ and $\partial_{g_j} p_i < 0$. Additionally, this ratio implies that if one of the two opponents does not allocate any resource to "guns" production, then the other's probability is equal to 1; $p_i(g_i, 0) = p_j(0, g_j) = 1$ and $p_i(0, g_j) = p_j(g_i, 0) = 0$. Under the assumption that countries have full information, then both have an incitation to invest in contesting technology if its rival does.

The last step of this setting consists of specifying the *income distribution equation*. Here, we characterize two scenarios. On one side, we outline a "peace" scenario which is defined as the condition in which no resource is allocated to "guns" production, i.e. $h_i = 0$ and therefore $w_i = y_i$. This situation is held as we assume that there exists a prior treaty securing the peace between both countries. Thus, the payoff is defined by the production function (2). Since the function is linear, it is straightforward that each country will use all their available water. Therefore, the payoff functions depend on the initial allocation w_i.

$$\begin{aligned} P_i(w_i) &= F_i(w_i) \\ &= \mu_i w_i \text{ with } i = 1; 2 \end{aligned} \tag{6}$$

On the other side, the second scenario corresponds to the conflict where countries contest the aggregate outcome. We consider the conflict as a *winner-take-all* mechanism. In other words, the winner will appropriate all the outcome and the other will loose all its production. Thus, the income is given by the following expected payoff :

$$C_i(y_1, y_2, g_1, g_2) = p_i(g_1, g_2) \left[\sum_{i=1}^{2} F_i(y_i) \right] \tag{7}$$

Since it is explained in the previous section, allocation rules are often defined in old treaties without considering the interest of all riparian states. Moreover, these repartitions do not take into account neither the population growth or the economic development of states in the sense that treaties specify only fixed portions as in examples 1. Thereby, this kind of water assignment can be challenged by one of both countries. It was the case for the 1959 Nil agreement signed only between Egypt and Sudan. In fact, this agreement followed a first one signed in 1929 between Egypt and Great Britain who represented its colonies Sudan, Tanzania, Kenya and Uganda. Both treaties shared the flow between the most downstream countries without consulting other riparian states. Thus, Ethiopia has challenged their validity and has expressed its disagreement inasmuch as its contribution to the Nile river rises up more than 80%. The threat became more serious such as in 1979 when the Egyptian President Sadate has affirmed that "the only factor that could spark off a conflict is water". Today, even if all riparian countries has engaged in the *Nil Initiative* since 2001, the Nil basin is already a risky area and any such claims can be still settled due to imperfect institutions of governance and the lack of enforcement.

Therefore, given the increasing trend towards competitive utilizations, it is credible that countries deviate from the initial scenario peace in order to increase their withdrawals that will incite its neighbor to contest the resource and to expend some resources to produce "guns".

3 Towards Water Conflicts

The previous model allows us to analysis under which conditions a water-based conflict could spark off. In order to achieve this objective, we need to rewrite the payoff (7) by computing with equations (2), (3) and (5). Thus, we obtain a function depending only on the quantity of weapons :

$$\begin{aligned} C_i(g_1, g_2) &= \frac{g_i}{g_1+g_2}\left[\mu_1\left(W - w_2 - \frac{g_1^\beta}{\lambda_1}\right) + \mu_2\left(w_2 - \frac{g_2^\beta}{\lambda_2}\right)\right] \\ &= \frac{g_i}{g_1+g_2}\left[\mu_1 W + w_2(\mu_2-\mu_1) - (b_1 g_1^\beta + b_2 g_2^\beta)\right] \end{aligned} \quad (8)$$

with $\beta = \frac{1}{\alpha}$ and $b_i = \frac{\mu_i}{\lambda_i}$.

This setting allows us to study the water allocation of both countries and, beyond, to determine conditions to maintain a peace stability. We approach the water-based conflict as a two-stage game. Actually, in a first step, each country decides to enter the contest or not. Based on its choice, it acts accordingly in stage 2 and optimally allocates its resource between both productions. This structure allows us to solve the game by backward induction, i.e. to solve the problem in stage 2 and with this knowledge go back to stage 1.

3.1 The second stage

Given the initial endowment, adversaries make decisions on guns g_i and implicitly on their water allocation between both productions. They choose simultaneously and non cooperatively their optimal amount of weapons. Thus, each country maximizes its payoff (8) with respect to the constraint $w_i - \frac{g_i^\beta}{\lambda_i} \geq 0$.

Before going further, let us remark the two following points :

- there is no interest in studying the case where both countries decide to bind their constraint, $w_i = \frac{g_i^\beta}{\lambda_i}$, because it means that they do not produce any consumption good and the payoff (8) will be zero.
- it is obvious that the case where only one country decides to invest all its resources in arming leads to an asymmetric probability-to-win which is a quite ambiguous case. Moreover, this discussion is not relevant for our further objective, i.e. the discussion of the existence of a negotiation interval. Actually, we are going to observe that this interval belongs to the interval defined by the interior solution.

Lemma 1 *Under the assumption that there is not comparative advantage, i.e.* $b_1 = b_2$*, both countries produce the same quantities of guns :*

$$g_1^* = g_2^* = g^* = \left(\frac{\mu_1 W + w_2(\mu_2 - \mu_1)}{2b(1+\beta)}\right)^\alpha \quad (9)$$

which implies that each opponent has an equal probability to win the conflict, $p_i^*(g_1, g_2) = \frac{1}{2}$.

The optimal conflict payoff is as follows :

$$\begin{aligned} C_i(g_1^*, g_2^*) &= \frac{\beta}{2(1+\beta)} \left[\mu_1 W + w_2(\mu_2 - \mu_1)\right] \\ &\equiv C_i^*(w_2) \qquad i = 1, 2 \end{aligned} \tag{10}$$

***Proof* 1** *Under the assumption* $b_1 = b_2 = b$*, we obtain :*

$$\begin{cases} \frac{\partial C_1(g_1,g_2)}{\partial g_1} = g_2[a - b(g_1^\beta + g_2^\beta)] - \beta b g_1^\beta (g_1 + g_2) = 0 \\ \frac{\partial C_2(g_1,g_2)}{\partial g_2} = g_1[a - b(g_1^\beta + g_2^\beta)] - \beta b g_2^\beta (g_1 + g_2) = 0 \end{cases} \Rightarrow g_1 = g_2$$

with $a = \mu_1 W + w_2(\mu_2 - \mu_1)$.
The equilibrium[2] *is given by* $g_1^* = g_2^* = g^* = \left(\frac{a}{2b(1+\beta)}\right)^{\frac{1}{\beta}} = \left(\frac{a}{2b(1+\beta)}\right)^{\alpha}$.
Consequently, the optimal conflict payoff of each country is $C_i^*(w_2)$, $i = 1, 2$ ■

Since we said previously, we concentrate only on the interior solution. However, we have to define the interval where this result is valid. Thus, we obtain that

$$\begin{aligned} W - w_2 - \frac{g_1^\beta}{\lambda_1} > 0 &\Rightarrow w_2 < \frac{W\mu_1(1+2\beta)}{\mu_1(1+2\beta)+\mu_2} \equiv \overline{B} \\ w_2 - \frac{g_2^\beta}{\lambda_2} > 0 &\Rightarrow w_2 > \frac{W\mu_1}{\mu_1 + \mu_2(1+2\beta)} \equiv \underline{B} \end{aligned}$$

Therefore, over all the interval $\left[\underline{B}; \overline{B}\right]$, we know that both rivals have the same probability to grab the consumption goods production as a whole.

3.2 The first stage

Pursuing their self-interest, countries will compare their payoff in both scenarios and choose the best scenario. In fact, the choice is hardly dependent on the initial allocation between both countries.

Thus, it is first straightforward that the peace payoff of country 1 is decreasing with w_2 since, from equation (1) and (6), $P_1(w_2) = \mu_1(W - w_2)$ whereas the payoff of country 2 is increasing with w_2 because of $P_2(w_2) = \mu_2 w_2$.

Concerning the conflict payoff, we can observe that results are ambiguous. We have to distinguish two cases because the derivative is as following (see lemma 1) :

$$\frac{\partial C_i^*(w_2)}{\partial w_2} = \frac{\beta}{2(1+\beta)}(\mu_2 - \mu_1) \tag{11}$$

The sign of this derivative depends on the level of technology used by the states to produce their consumption goods. If country 2 has a better productive capacity then the payoff rises up with w_2. However, if country 1 has a better productive capacity then the payoff decreases with w_2. Obviously, if the amount of the water allocated to country 2 is more important whereas country 1 is more productive, the expected gain in conflict becomes smaller because the aggregate production becomes smaller.

Figure 1: Comparative Statics for country 1

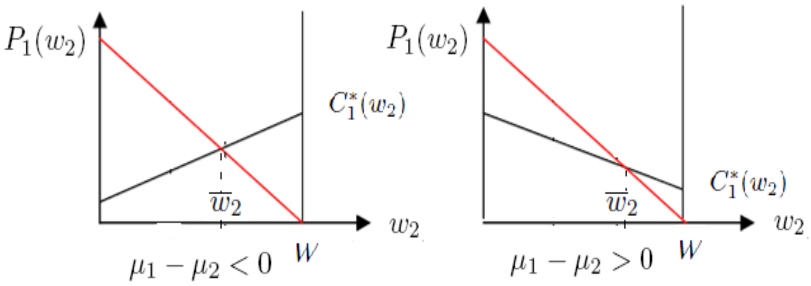

Figure 1 illustrates the situation in both cases for country 1. It is evident that there is an allocation where country 1 will have a better well-being in the peace scenario, respectively in the conflict scenario.

From Figure 1, we observe that over an interval $w_2 \in [0, \overline{w}_2[$, country 1 prefers the peace scenario. The upper-bound is defined by :

$$
\begin{aligned}
& P_1(w_2) > C_1^*(w_2) \\
\Leftrightarrow \quad & \overline{w}_2 \equiv \frac{(2+\beta)\mu_1 W}{(2+\beta)\mu_1 + \beta\mu_2} > w_2
\end{aligned}
\tag{12}
$$

Obviously, an increasing quantity w_2 prevents country 1 from producing as it could expect that leads to a higher payoff in the conflict scenario.

For country 2, we can also observe that there is an allocation where country 2 will have a better well-being in the peace scenario, respectively in the conflict scenario.

Figure 2: Comparative Statics for country 2

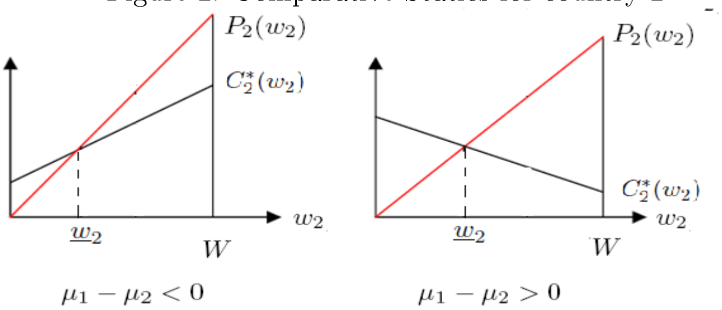

Figure 2 outlines that over an interval $w_2 \in [\underline{w}_2, W[$, country 2 prefers the peace scenario. The lower bound is defined by :

$$
\begin{aligned}
& P_2(w_2) > C_2^*(w_2) \\
\Leftrightarrow \quad & w_2 > \frac{\beta\mu_1 W}{\beta\mu_1 + (2+\beta)\mu_2} \equiv \underline{w}_2
\end{aligned}
\tag{13}
$$

Given these results, if we compute both interval where countries prefer the peace situation, we obtain a *negotiation interval*. Within this area, both countries have interest to allocate the adequate amount of water to insure peace and avoid wasting resources in coercive activities.

[2]The second order conditions are satisfied : $-b\beta g_i^{\beta-1}[g_j\beta(g_i+g_j)] - \beta b g_i^{\beta}$

Proposition 1 $\forall\, w_2 \in [\underline{w}_2; \overline{w}_2]$*, there exists an allocation* w_2 *where both countries are better-off in the peace scenario.*

***Proof* 2**

$$\begin{aligned} \overline{w}_2 &> \underline{w}_2 \\ \Leftrightarrow \frac{(2+\beta)\mu_1 W}{(2+\beta)\mu_1 + \beta\mu_2} &> \frac{\beta\mu_1 W}{\beta\mu_1 + (2+\beta)\mu_2} \\ \Leftrightarrow \beta + 1 &> 0 \end{aligned}$$

Therefore, we can conclude that $[0; \overline{w}_2] \bigcap [\underline{w}_2; W] = [\underline{w}_2; \overline{w}_2]$*.* ■

This proposition highlights a relevant result regarding the opportunity to achieve a peace scenario. Actually, there exists a water allocation between both countries that allows to reach a higher well-being when the peace scenario prevails. This interval can be interpreted as a conflict indicator in the sense that the more this interval is greater, the less a conflict may spark off. This deduction can have strong implications for an international sharing treaty.

Before going further, we verify that this interval is included in the interval of the interior solution $\left[\underline{B}; \overline{B}\right]$.

$$\begin{aligned} \underline{w}_2 \geq \underline{B} &\;\Leftrightarrow\; 2\mu_2(\beta+1)(\beta-1) \geq 0 \\ \overline{w}_2 \leq \overline{B} &\;\Leftrightarrow\; 2\mu_2(\beta+1)(\beta-1) \geq 0 \text{ because } \beta \in [1, +\infty[\end{aligned}$$

Therefore $[\underline{w}_2; \overline{w}_2] \subsetneqq \left[\underline{B}; \overline{B}\right]$.

3.3 Study of the size of the negotiation interval

Until now, we have proved that there exists a negotiation interval in which both countries can carry out the peace situation. This interval is defined as the difference between both switch points : $\overline{w}_2$ and $\underline{w}_2$.

$$D = \frac{4\mu_1\mu_2 W(1+\beta)}{\left[\beta\mu_1 + (2+\beta)\mu_2\right]\left[(2+\beta)\mu_1 + \beta\mu_2\right]} \tag{14}$$

As we can observe, the size of this interval depends on the crucial components which are the total quantity of water in the river W and the two productive capacities μ_i. In other words, it will vary when these factors will impact the probability of conflict.

Proposition 2 *The size of the negotiation interval is reduced by (i) an increasing water scarcity and (ii) an increasing heterogeneity between both countries.*

***Proof* 3** *(i) It is straightforward that the sign of the derivative (15) is positive.*

$$\partial_W D = \frac{4\mu_1\mu_2(1+\beta)}{\left[\beta\mu_1 + (2+\beta)\mu_2\right]\left[(2+\beta)\mu_1 + \beta\mu_2\right]} \tag{15}$$

(ii) The derivatives of 14 with respect to the productive parameters are

$$\partial_{\mu_1} D = \frac{4\mu_2\beta W(1+\beta)(2+\beta)\beta(\mu_2^2 - \mu_1^2)}{\left[\beta\mu_1 + (2+\beta)\mu_2\right]^2\left[(2+\beta)\mu_1 + \beta\mu_2\right]^2} \tag{16}$$

$$\partial_{\mu_2} D = \frac{4\mu_1 W\beta(1+\beta)(2+\beta)\beta(\mu_1^2 - \mu_2^2)}{\left[\beta\mu_1 + (2+\beta)\mu_2\right]^2\left[(2+\beta)\mu_1 + \beta\mu_2\right]^2} \tag{17}$$

- *If* $\mu_1 > \mu_2$ *then the derivative (16) is negative whereas the derivative (17) is positive.*

- *If $\mu_2 > \mu_1$ then the derivative (16) is positive whereas the derivative (17) is negative.* ■

Thus, this proposition highlights that an increasing water scarcity contributes to lower the cooperative possibility as well as the heterogeneity of countries. Actually, the scarcity of the resource stirs up tensions between riparian nations by reducing the size of the negotiation interval until this interval disappears which is synonymous of the outbreak of war. In addition, the heterogeneity of countries has the same impact on the size of the interval that challenges one argument of Wolf [37] claiming that it is strategically impossible that such events appear because of this heterogeneity. In fact, in an upstream/downstream scenario, Wolf outlines that the only possibility could appear when the aggressor is both the downstream state and the regional hegemon because the upper-state has no reason to launch an attack and is not incited to build a project which will decrease either quantity or quality to not annoy a stronger neighbor. By assuming that country 2 is the downstream country, this result is embedded in proposition 3. However, we demonstrate that tensions are also driven by the hegemony of country 1. When country 1 is more productive than country 2, an increasing in its productive ability leads to decrease the size of the negotiation interval. In fact, there are some observational evidences that support this result. Indeed, China decides unilaterally to build its dam on the upper reaches of the Mekong which is regulated only in its lower part by an agreement concluded between Vietnam, Cambodia, Laos and Thailand. China follows an uncoordinated development of project that affects the flow of the Mekong where most of the riparian states live from fishing and agriculture. In line with this example, Turkey has engaged in its Anatolia Projet, GAP, since 1977 which comprises about 20 dam projects with hydro-power plants. Both examples denote the economic incentive for the upper-state to derive water. Although China and Turkey are military and economically stronger than the other riparian countries, they stir up potential quarrels.

4 The Nash-Bargaining solution

The previous results insure that there exists an opportunity to achieve the peace. Moreover, it is economically more rationale to cooperate and share the surplus. Thus, it is interesting to analyze the cooperative solution within a Nash-bargaining framework like Ansink and Weikard [1]. Hence, we can analyze the possibility to prevent the contest where the contest payoff serves as the disagreement point.

Thus, if both countries agree that negotiations will be effectively conducted, the purpose consists of choosing the optimal allocation by determining the optimal w_2 in the negotiation interval $[\underline{w}_2; \overline{w}_2]$.

To reach this objective, we assume here an easier production function for more convenience. Set $\alpha = \frac{1}{2}$ in equation (3) which implies that $\beta = 2$. Thus, the maximization programm can be written as following :

$$\begin{aligned} &\max_{w_2} \frac{1}{3} \left(2\mu_1(W - w_2) - \mu_2 w_2\right)^{\gamma} \left(2\mu_2 w_2 - \mu_1(W - w_2)\right)^{1-\gamma} \\ &\text{w.r.t } \ w_2 \in]\underline{w}_2; \overline{w}_2[\end{aligned} \tag{18}$$

The optimal solution is therefore :

$$w_2^* = \mu_1 W \frac{(2\mu_1 + \mu_2(4 - 3\gamma))}{(2\mu_1 + \mu_2)(\mu_1 + 2\mu_2)} \tag{19}$$

This quantity depends also on the three previous relevant determinants, i.e. W and μ_i $(i = 1, 2)$ but also on the power of negotiation of country 1, i.e. γ. All these parameters will influence the quantity that would be allocated to country 2 in various ways.

Proposition 3 *The optimal bargaining allocation w_2^* is (i) decreasing with the bargaining power of country 1 γ, (ii) increasing with the total water amount W, (iii) increasing with the productivity of country 1 μ_1 and (iv) decreasing with the productivity of country μ_2.*

***Proof* 4** *The derivatives of the solution (19) with respect to the different arguments are*

$$\partial_W w_2^* = \frac{\mu_1 \left(2\mu_1 + \mu_2(4-3\gamma)\right)}{(2\mu_1+\mu_2)(\mu_1+2\mu_2)} \tag{20}$$

$$\partial_\gamma w_2^* = -\frac{3\gamma\mu_1\mu_2 W}{(2\mu_1+\mu_2)(\mu_1+2\mu_2)} \tag{21}$$

$$\partial_{\mu_1} w_2^* = \frac{2\mu_1^2\mu_2 W(1+3\gamma) + 8\mu_1\mu_2^2 W + 2\mu_2^3(4-3\gamma)}{(2\mu_1+\mu_2)^2(\mu_1+2\mu_2)^2} \tag{22}$$

$$\partial_{\mu_2} w_2^* = -2\mu_1 W \frac{\left[\mu_1^2(14-3\gamma) + 8\mu_1\mu_2\right]}{(2\mu_1+\mu_2)^2(\mu_1+2\mu_2)^2} \tag{23}$$

It is straightforward that

- *the sign of the derivative (20) is positive.*
- *the sign of the derivative (21) is negative.*
- *the sign of the derivative (22) is positive since* $4 - 3\gamma > 0$.
- *the sign of the derivative (23) is negative since* $14 - 3\gamma > 0$. ■

This proposition outlines some intuitive results. First, it is obvious that an increase of the total quantity of water in the river leads to increase the share allocated to country 2. Then, this amount will be lower with a stronger bargaining power of country 1. Effectively, the influence of both countries in a negotiation depends highly on their respective power. This influence can stem from a stronger militarized force or a stronger commercial power. In effect, a country can threaten to buy some goods in another country. This kind of threat is obvious credible if both countries have strong commercial relationships. Finally, the heterogeneity between both countries plays a role : when country 1 is more productive, the allocated amount of water to country 2 will be higher. This result captures the idea that it needs more resources to produce their goods. However, one can wonder whether it could be better to produce in the most productive state and then prefer exchanging. This could be more efficient to delocalize the production of water-intensive goods and concentrate the efforts in other production.

To conclude, this analysis shows that there exists an optimal allocation when an interval of negotiation exists. This bargaining game allows countries to define property rights over water and can be used to achieve an agreement. Some examples support this idea. For instance, Thailand helped fund a hydroelectric project in Laos in exchange for a proportion of the power to be generated.

5 Empirical Analysis

This section aims at testing our theoretical results described in proposition 3 through a standard empirical approach. Namely, in this section, we assimilate negotiation as the contrary of conflict. Therefore, an increase in the size the negotiation interval means a decline in the probability of conflict. Thus, we want to analyze if a growing water scarcity enhances the probability of a conflict between two countries sharing a river basin. From the analysis of Gleditsch and *al.* [15], we know that there is a higher risk of military disputes between countries sharing rivers. This variable performs a similar role as a contiguity dummy and intuitively increases the probability. However, it does not give any information on the effect of water quantities on military conflict. Thus, one can wonder whether the water endowments influence interstate disputes within a river basin. Therefore, we perform a regression analysis to investigate the actual relationship between the probability of interstate outbreak and water scarcity.

Since the seminal work of Bremer [5], the dyadic analysis has become the analytical cornerstone of interstate conflict studies. More precisely, the common way consists of using undirected dyadic analysis where interactions ij or ji are not distinguished because the empirical question is not to identify the aggressor and the victim but the existence of a conflict within a dyad. Consequently, the dyads ij and ji are identical and only one of them is kept to avoid double counting. Moreover, this approach allows us to take into account variations in both the individual and the dyadic level that allows comparisons between pairs. Some pairs may share many international rivers but each dyad is considered as a different observation because the interaction between both countries can vary from one basin to another according to the area of the basin located in countries.

To achieve this analyze, we may distinguish various scenarios.
H1 : *The greater the amount of water resources two countries share, the smaller the probability of dyadic conflict.*
H2 : *Pairs of countries that share many basins experience less conflict between them.*
These two hypothesis are based on the first result outlined in proposition 3. In other words, we aim at testing the effect of scarcity on the probability of a dyadic conflict. The scarcity of water is either captured directly by the available quantities or approximated by a dummy variable scored 1 whether the dyad shares many basins.

These hypothesis can be related to the fundamental economical problem which is that individuals require even more resources to fulfill their needs. In effect, as long as water resources can fulfill these needs, we can expect that the probability of conflict is low. However, as its was explained previously, the growing human requirements increase the competition for this resource which is finite. Therefore, the amount of water that is shared by a pair of countries reduces and an interstate conflict may spark off.

H3 : *The unequal water repartition is positively correlated with the probability of a dyadic conflict*
This hypothesis captures the water endowment heterogeneity and outlines the idea illustrating in figures 1 and 2 where a country with few resources prefers engaging in conflict. Thus, the unequal allocation would be an incitation to enter conflict.

5.1 Data

The database contains information on all pairs of countries between 1950 and 2002 that gives 22,819 observations. It consists of a collection of various variables assembled from different databases either related to international basins or individual countries. To measure conflict, we take our dependant variable from the database developed by the PRIO staff[3]. They have coded the onset militarized interstate disputes with a minimum of one fatality from the Correlates of War project. This limitation to "fatal disputes" allows us to minimize the potential bias inherent in data on low-level conflict [13].

Then, the explanatory variables are presented in more details in table 3.

[Table 3]

In order to accurately test our theoretical model, we include some control variables. They highlight how water-related variables impact the probability of conflict independently of generally accepted explanations on the causes of conflict.

[3]International Peace Research Institute Oslo

First, we introduce dummy variables representing political make-up of the dyad as compared to a reference dyad of two democracies. Those variables come from the PRIO database and are taken from the Polity IV scale of democracy and autocracy. Actually, the political regime is a crucial factor driving interstate conflicts. On this basis, a dyad with unconsolidated regimes have a greater propensity for conflict. Thus, we have three dummies to take into account dyads containing at least one consolidated regimes, dyads containing two unconsolidated regimes and dyads containing two autocracies.

Then, as Gleditsch and *al.* [15], we consider a variable outlining the number of previous years without a militarized dispute in the dyad. This variable may be a strong indicator of peace.

Next, we form the dyad size variable, i.e. the log of the combined population of the states that make up a dyad. This variable could be used as a proxy for a demand-measure. Actually, dyad with large population should need greater amounts of resources and therefore increase their withdrawals.

In order to test the heterogeneity of both countries, we perform a differential wealth measure which is the ratio of the richer over the poorer country in terms of income per capita (in log). This variable is used as a proxy to capture the development difference between both countries composing the pair.

Finally, we insert some geographical measures such as the contiguity which is scored 1 if the dyad shares a border and 0 otherwise, the distance between the capitals and the length of their boundaries. This variable is based on the assumption that adjacency may enhance the likelihood of conflict.

Concerning the water-based variables, the literature provides two approaches to test the relationship between water and conflicts. First, we can use state-level data such as the studies of Hensel, Mitchell and Sowers [20]. In this case, we use the standard scarcity measure defined by Falkenmark and Widstrand [12], that is the the per capita population pressure on the freshwater supply. This variable comes from the FAO's information system on water and agriculture : AQUASTAT. This is a ratio between the available freshwater over the total population. From this variable, some dummies are created by confronting the measure to available thresholds. For instance, shortages started to be considered when a country reaches the point of water-stressed conditions below 1,700m^3 per capita and per year. Below 1,000m^3 per capita and per year the resource is considered scarce and begin to hamper human health and economic activities. To this end, we choose to score the dyad to 1 if one of both countries is water-scarce and 0 otherwise. This variable will allow us to test our hypothesis H1 by adding the total water available in the dyad and hypothesis H2 by inserting scarcity thresholds. The second hypothesis can be investigated through the variable that represents the percentage of the total basin area lying in the upstream state.

The second approach consists of using basin-level data such as Hensel and Brochman [19]. These data include namely one supply-measure : water discharge and one demand-measure such as the area of the basin located in the dyad in percent. This approach will also allow to investigate the role of these variables on the likelihood of a conflict in a different way.

Finally, we add a dummy variable scored 1 if the pair of countries share more than one basin and zero otherwise.

5.2 Model Specification and Results

A multivariate logit model is proposed to analyze the relationship between international rivers and military disputes taking into account some control variables.

$$\begin{aligned} FMIDonset_{ij} &= \alpha + \beta_1 Onedemocratie_{ij} + \beta_2 Twoautoccraties_{ij} + \beta_3 Unconsolidated_{ij} \\ &+ \beta_4 Peacehistory_{ij} + \beta_5 Dyadsize_{ij} + \beta_6 PowerGDP_{ij} \\ &+ \beta_7 Contiguity_{ij} + \beta_8 LnDist_{ij} + \beta_9 LnLengthBound \\ &+ \beta_{10} LnDischarge_{ij} + \beta_{11} OtherBasin + \beta_{12} Water_{ij} + \varepsilon_{ij} \end{aligned} \tag{24}$$

This equation allows us to test various models by replacing the variable $water_{ij}$ by one of its equivalent defining our different scenarios. Some expectations for the sign of parameters are yielded. First, in line with the study of Marshall and Jaggers, a negative sign is expected for the three political regimes $\left(\beta_1 > 0;\ \beta_2 > 0;\ \beta_3 > 0\right)$. Actually, these expectations are based on the well known hypothesis that a liberal peace is achieved between two democratic regimes whereas the more important propensity for conflict would be a dyad formed by two *unconsolidated regimes*. The historical variable is expected to be negatively correlated with the conflict probability $\left(\beta_4 < 0\right)$. Then, according to our assumption that a large population can be a proxy for capturing the pressure on the resource, the sign of the estimator of the dayd size should be positive $\left(\beta_5 > 0\right)$. Next, on the basis of our theoretical model, the heterogeneity with respect to GDP per capita should contribute to increase the probability of a dyadic conflict $\left(\beta_6 > 0\right)$. Turning to the geographical variables, we expect that they are positively correlated with the probability because geographical proximity contributes to yield a positive increase in conflict probability $\left(\beta_7 > 0;\ \beta_8 < 0;\ \beta_9 > 0\right)$. Finally, concerning water-based variables, we expect to have a negative sign with the discharge of the basin $\left(\beta_{10} < 0\right)$ and a positive one with the dummy related to the existence of other shared basins $\left(\beta_{11} > 0\right)$ as well as for the sign of the total water shared by the dyad $\left(\beta_{12} > 0\right)$.

Table 4 contains main empirical results for the conflict model.

[Table 4]

In a first overview, we can observe that almost all standard variables have expected sign. Briefly, the political regime are positively correlated with the probability of conflict and highly significant. Thus, political instabilities increase the likelihood of conflicts. At the opposite, historical series of years of peace decrease the probability to an outbreak. As usual, this is the most important factor driving peace. Turning to the total population of the dyad, we can observe that this determinant increases the probability and is highly significant. Contrary to our intuitive, the likelihood of interstate disputes is not impacted by the heterogeneity within the dyad in terms of GDP. Finally, only the distance variable plays its role in influencing negatively the likelihood of the conflict between both countries within the dyad. Globally, most of these variables fit with prior research.

A perusal observation of parameters related to water specific variables will allow us to confirm or not our theoretical results. Thus, **Model I** tests the discharge of the basin but does not provide significant results. This suggests that the total amount of water in the basin does not influence the relationship between two countries. Thus, this result suggests us to perform another variable that is the total quantity of water shared by both countries instead of the basin discharge. **Model II** confirms our theoretical intuition with a significant negative effect of the total quantity of water shared by the dyad. This result is sustained when we test the total water per capita rather the total water. Table 5 presents the new estimation results.

[Table 5]

Therefore, this result supports our theoretical result where the total water shared by two countries W is a crucial component impacting the size of the negotiation interval. By extrapolation, it suggests that if we can consider all riparian nations within the basin then the discharge would be a crucial determinant to analyze the tension within a basin. Therefore, results in Model I can be lessened and would be worth considering a more global framework.

Model III tests the situation when dyads share many basins and provides interesting results. Actually, this variable is highly significant and decreases the probability of conflict. In fact, sharing many basins is synonymous of increasing the amount of water. This result is therefore another way to prove that as long as there is lots of resources, peace can be achieved.

However, **Model IV** and **Model V** do not provide expected results with both non significant estimations. Both variables, i.e. the presence of a water-scarce country and the area of the basin located in the upstream state are probably not appropriated to test the uneven distribution of water.

Nevertheless, as Gleditsch and *al.* [15] suggested, the analysis of regional impacts can bring more insights in this issue. Thus, we propose to study the interaction of these variables with the regional location, especially by taking into account if one or more nations are in Sub-Saharan Africa (SSA) or in the MENA region. The latter region remains one of the tensest area of the world and water resources are scarce by nature. Table 6 gives results for both regions.

[Table 6]

We observe that both variables remain insignificant for nations in Sub-Saharan Africa but, at the opposite, become significant with expected signs for the MENA region. In other words, the interaction between a country facing with absolute scarcity and a country located in the MENA regions increases the probability-to-conflict. This region is still a potential area for conflict between countries and more advanced research should be conducted to improve the understanding of the specific factors driving conflicts. Concerning the area of the basin in the upstream state, the result is also significative. It confirms that the uneven distribution is also a key determinant but, only, in an arid region. Actually, the MENA region faces with high water scarcity. Thus, this disparity can reinforce the likelihood of conflicts because countries are more vulnerable.

With respect to these models, we can conclude that globally the malthusian scenario is supported by our empirical analysis. First, we outline the total amount shared by a dyad is an important driving force. On this basis, one can deduce results for river basins containing several countries. The more are there are countries, the more the probability-to-conflict should increase. Second, more regional analysis allows us to affine results to observe that disparities in water endowments may be also a key determinant.

6 Conclusion

Talks of water-based conflicts disseminate around the globe these years. A recent report of the U.S. National Intelligence Council concludes that the likelihood of interstate outbreak will increase during the next 15 years "as countries press against the limits of available water". Nonetheless, some dismiss these warnings as alarmist. A lot of arguments are advanced to support one side or the other. However, the theoretical literature is still rare. This analysis contributes in the reduction in this gap.
In fact, the contribution is two-fold. First, the study explores the relationship between water and conflict into a game-theoretical framework. This approach is based on the conflict model outlining a trade-off between production and appropriation. This model allows us to take into account the opportunity cost when an economic agent engages in contest. By comparing this scenario with a benchmark case where both countries use all their resources for production, we obtain an interesting result. Indeed, cooperation is a possible outcome only if there is enough water and countries are quite similar. According to these factors, arid and semi-arid areas are therefore the most potential water-related disputes. UN figures suggest there are around 300 potential conflicts over water. For instance, the Central Asia is a high risk area where Uzbekistan, Kazakhstan, Kyrgyzstan and Tadjikistan meet tensions over the Amu Daria and Syr Daria rivers. By 2015, nearly 40% of the estimated world population will live in countries that find difficulties to meet their demand. Therefore, the increasing competition for this natural resource seems to be convincing.
The second step consisted of testing this primary results using an empirical analysis. This study is build in line with empirical studies. The econometric analysis confirms that the water scarcity is an important determinant in water-based interstate conflicts contrary to the heterogeneity of countries. On the basis of this result, the question of to what degree water scarcity is likely to affect interstate relations can be raised. Even if there exists some scarcity measures but the answer is still ambiguous.

Given these results, a lot of policy implications can be drawn. Indeed, we can wonder what governments and international agents can do to prevent the eruption of violence and political instability. A first implication is related to the renegotiation of existing treaties. Since we discussed previously, most of them are not well-defined anymore and do not take into account all the co-riparian states. Efforts have already been done such as the creation of the Nile Initiative Basin in 2001. However, in other international basins, it is more difficult because some political entities are not represented such as the Palestinians along the Jordan or the Kurds along the Euphrates. Second, efforts can be done at the internal level to increase the productivity of water use, namely in irrigation techniques. This seems to be a good pattern to reduce water pressure. Today, several solutions can be thought such as recycling or reusing waste water, desalination or rainwater harvesting. Finally, a more conventional solution is also suitable. Stronger policies have to be drawn to regulate water use in order to encourage thriftiness otherwise freshwater suffers from the tragedy of commons.

To conclude this study, water may be an important source of future conflicts. However, public policymakers can mitigate this risk by implementing policies which target the relevant determinants.

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Appendix 2 : Definition and Descriptive statistics

Table 3: Summary statistics

Variable	Database	Mean	Std. Dev.	N
FMIdonset	0.072	PRIO	0.258	22819
onedemoc	PRIO	0.236	0.425	22819
twoautoc	PRIO	0.242	0.428	22819
unconsolidated	PRIO	0.34	0.474	22819
peacehistory	PRIO	-0.178	0.334	22256
dyadsize		10.717	1.468	22256
contiguity		0.701	0.458	22819
lndistance	PRIO	6.363	0.86	22819
lnboundary	PRIO	4.623	3.144	22819
PowerGdp		2.382created	3.642	21197
LnDischarge	AQUASTAT[12]	376.079	1127.342	20111
shareotherbasin	created	2.666	46.139	20609
TotalWaterShare	created	6.326	1.641	20559
DyadOneScare	created	0.888	0.315	22819
percupstream	PRIO	0.192	0.202	22819

[12]FAO's information system on water and agriculture

Table 4: Estimation results : logit

	Ref. Model		Model I		Model II		Model III		Model IV		Model V	
Variable	**Coeff.**	**(Std.) (Err.)**	**Coeff.**	**(Std.) (Err.)**	**Coeff.**	**(Std.) (Err.)**	**Coeff.**	**(Std.) (Err.)**	**Coeff.**	**(Std.) (Err.)**	**Coeff.**	**(Std.) (Err.)**
onedemoc	1.83**	(0.58)	1.86**	(0.63)	1.65**	(0.54)	1.80**	(0.60)	1.82**	(0.58)	1.89**	(0.61)
twoautoc	2.00**	(0.63)	2.07**	(0.68)	1.75**	(0.61)	2.03**	(0.66)	1.98**	(0.63)	2.04**	(0.65)
unconsolidated	2.26**	(0.59)	2.23**	(0.63)	2.05**	(0.56)	2.20**	(0.60)	2.25**	(0.58)	2.31**	(0.61)
peacehistory	-3.28**	(0.19)	-3.21**	(0.20)	-3.23**	(0.20)	-3.18**	(0.20)	-3.28**	(0.19)	-3.27**	(0.19)
dyadsize	0.41**	(0.09)	0.45**	(0.09)	0.58**	(0.11)	0.45**	(0.09)	0.41**	(0.09)	0.40**	(0.09)
PowerGdp	0.00	(0.01)	0.00	(0.01)	0.00	(0.01)	0.00	(0.01)	0.00	(0.01)	0.00	(0.01)
contiguity	0.23	(0.58)	0.31	(0.54)	0.04	(0.46)	0.18	(0.51)	0.20	(0.59)	0.35	(0.58)
lndistance	-0.66**	(0.14)	-0.71**	(0.14)	-0.52**	(0.14)	-0.65**	(0.13)	-0.66**	(0.14)	-0.69**	(0.13)
lnboundary	-0.05	(0.10)	-0.08	(0.09)	-0.02	(0.08)	-0.05	(0.09)	-0.04	(0.10)	-0.06	(0.10)
lndischarge			0.00	(0.00)								
totalsharewater					-0.30**	(0.09)						
shareotherbasin							-0.51**	(0.19)				
OneScarce									-0.11	(0.26)		
lnbasinupstream											0.04	(0.04)
Intercept	-6.53**	(0.84)	-6.51**	(0.90)	-7.39**	(0.92)	-7.22**	(0.95)	-6.39**	(0.87)	-6.69**	(0.91)
N	20674		18222		18146		18660		20674		20674	
Log-likelihood	-2726.47		-2457.28		-2353.18		-2453.66		-2726.04		-2721.67	
$\chi^2_{(9)}$	410.56		384.51		402.13		381.23		425.92		416.29	

Significance levels : † : 10% ∗ : 5% ∗∗ : 1%

Table 5: Extension of Model II

Variable	Coefficient	(Std. Err.)
onedemoc	1.59**	(0.52)
twoautoc	1.63**	(0.60)
unconsolidated	1.96**	(0.55)
peacehistory	-3.12**	(0.21)
dyadsize	0.29**	(0.10)
PowerGdp	0.00	(0.01)
contiguity	-0.17	(0.49)
lndistance	-0.53**	(0.15)
lnboundary	0.03	(0.08)
TotalWaterCapShare	-0.31**	(0.09)
Intercept	-6.89**	(0.93)
N	18337	
Log-likelihood	-2355.76	
$\chi^2_{(10)}$	387.07	

Significance levels : † : 10% ∗ : 5% ∗∗ : 1%

Table 6: Regional Estimation

Variable	Coefficient	(Std. Err.)	Coefficient	(Std. Err.)	Coefficient	(Std. Err.)	Coefficient	(Std. Err.)
onedemoc	1.82**	(0.59)	1.73**	(0.58)	1.82**	(0.60)	1.77**	(0.59)
twoautoc	1.96**	(0.65)	1.91**	(0.65)	1.93**	(0.65)	1.93**	(0.65)
unconsolidated	2.25**	(0.60)	2.21**	(0.59)	2.24**	(0.60)	2.22**	(0.60)
peacehistory	-3.29**	(0.19)	-3.24**	(0.19)	-3.29**	(0.19)	-3.25**	(0.19)
dyadsize	0.44**	(0.10)	0.43**	(0.10)	0.45**	(0.10)	0.43**	(0.09)
PowerGdp	0.00	(0.01)	0.00	(0.01)	0.00	(0.01)	0.00	(0.01)
contiguity	0.24	(0.57)	0.02	(0.51)	0.25	(0.56)	0.13	(0.53)
lndistance	-0.68**	(0.14)	-0.65**	(0.14)	-0.70**	(0.14)	-0.68**	(0.14)
lnboundary	-0.04	(0.10)	-0.01	(0.09)	-0.04	(0.09)	-0.03	(0.09)
ScareSSA	0.15	(0.29)						
ScareMENA			0.67**	(0.21)				
ssa_lnbasinupstream					0.02	(0.03)		
mideastnaf_lnbasinupstream							0.05*	(0.02)
Intercept	-6.67**	(0.93)	-6.86**	(0.86)	-6.77**	(0.93)	-6.62**	(0.88)
N	20674		20674		20674		20674	
Log-likelihood	-2725.4		-2701.97		-2723.27		-2715.06	
$\chi^2_{(10)}$	407.87		438.7		408.01		430.57	

Significance levels : † : 10% ∗ : 5% ∗∗ : 1%