Conflicts over Shared Rivers: Resource Wars or Fuzzy Boundaries?[1]

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Countries that share rivers have a higher risk of military disputes between them. Controlling for the length of the land boundary has shown that the shared river variable is not just a proxy for being neighbors and thus having a higher degree of interaction opportunity. A weakness of the earlier work is that the existing shared rivers data do not allow us to distinguish properly between dyads where the rivers run mainly across the boundary and dyads where the shared river runs along the boundary. Dyads with rivers running across the boundary should be expected to give rise to resource scarcity-related conflict scenarios, while dyads where the river forms the boundary may fight because river boundaries are fluid and fuzzy. Using a new dataset on shared water resources that is based on basin rather than river variables and two new measures of water scarcity, we test for the presence of these two scenarios. We find support for the neomalthusian theory of water conflict but not for the fuzzy boundary scenario. Shifting to the basin as the unit of analysis puts this research in line with the mainstream of research on water conflict and cooperation.

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1. Introduction

Most conflicts are over scarce resources of one kind of another, at least if territory is counted as a resource (Vasquez, 1993; Huth, 1996). With the decline of ideological conflict after the end of the Cold War some scholars, like Klare (2001a,b), argue that competition for access to vital resources increasingly drives international relations. According to Klare, the danger of international competition for adequate water resources will grow 'inevitably'. By 2050, the increased demand for water could produce 'intense competition for this essential substance in all but a few well-watered areas of the planet' (Klare, 2001a: 57).

The only published large-n study of water and interstate conflict is Toset et al. (2000), which showed that sharing a river increases the probability of a militarized interstate dispute in a dyad over and above mere contiguity. Water scarcity is also associated with conflict and a river shared across rather than along a border appears to be the form of shared river most frequently associated with conflict. Gleditsch & Hamner (2001) found, on the basis of events data for the period 1948–92, that shared rivers and water scarcity were associated with increased cooperation between countries, as well as conflict. Furlong & Gleditsch (2003b) investigated one of the caveats in Toset et al., the possibility that their findings might be spurious, as countries with long common boundaries are more likely to have a shared river and also to have more conflict, as argued theoretically by Wesley (1962: 388) and empirically by Starr (2002). Using a new dataset on international boundaries (Furlong & Gleditsch, 2003a,b) found that the relationship between shared rivers and conflict was not spurious with respect to boundary length.

Here we test another caveat in Toset et al. (2000). Most of the dyads with shared rivers in that study were mixed, in the sense that there were rivers that ran across as well as along the boundary. Due to these data limitations both studies could only reasonably test for the presence, rather than type, of shared rivers. This ambiguity leaves open another challenge to the resource scarcity perspective on conflict: the possibility that rivers cause conflict by being fuzzy borders. In this paper, we first review the water wars and fuzzy borders conflict scenarios. We then discuss a new dataset that moves from analysis of rivers to river basins, and, finally, we use this dataset to take a fresh look at the relationship between shared rivers and interstate conflict.

2. Resource Scarcity and Conflict: Water Wars?

The notion of an impending threat of 'water wars' has become quite common in academic and journalistic writing (Irani, 1991; New Scientist, 2001; Starr, J, 1991), as well as in the political rhetoric. In 1967, just before the Six-Day War between Israel and its Arab neighbors, Prime Minister Levi Eshkol declared that 'water is a question of survival for Israel', and therefore 'Israel will use all means necessary to secure that the water continues to flow' (Biliouri, 1997: 5). In the mid-1980s, US intelligence services are said to have 'estimated that there were at least ten places in the world where war could break out over dwindling shared water' (Starr, J, 1991: 17). Homer-Dixon (1999: 179–180) argues that war is more likely over non-renewable resources like petroleum and other minerals. But among the non-renewables water has the greatest potential for stimulating international war – although only under special conditions such as high dependence on water in a downstream country, a history of antagonism between the two countries, etc.

Water is a finite and fixed resource, and the rise of the global population has progressively reduced the world run-off per capita, from 40,000 m^3 per person in 1800 to 6,840 m^3 in 1995, estimated to fall further to 4,692 m^3 by 2025 (Beaumont, 1997: 358). Water resources are also enormously skewed geographically. North America has an annual run-off of 17,000 m^3 per capita per year, while Africa has 6,000, and Egypt has 50. Less than 1% of the world's usable freshwater is found in the Middle East or North Africa, although this region contains 5% of the world's population. Many countries with lower water availability today, particularly in Africa, have high rates of population growth, so that their water shortages may be exacerbated in the future. Increasing standards of living may lead to greater demands for water. In *Global Environmental Outlook 2000* the United Nations Environment Program expressed concern about how the increase in freshwater consumption is outpacing population growth and raised the prospect that in 2025 two out of three persons on Earth will live in water-stressed conditions (UNEP, 1999: 41–42). An expert survey identified freshwater scarcity and freshwater pollution as two of the four major emerging environmental issues, second only to climate change (UNEP, 1999: 339).

Neomalthusian writers foresee growing and increasingly serious water scarcities in a number of countries. 'Where water is scarce, competition for limited supplies can lead nations to see access to water as a matter of national security', 'an increasingly salient element of interstate politics, including violent conflict' (Gleick, 1993: 79). Many countries are highly dependent on water that originates outside their border – over 90% in the case of countries like Egypt, Hungary, and Mauritania (Gleick, 1993: 100, 103–104). Falkenmark (1990: 179), among others, claims that there is a serious risk of international conflict, especially in the Middle East and Africa, between upstream and downstream countries.[2] UNEP (1999: 8) also cites increasing concern that environmental degradation and resource shortages may cause armed conflict and lists water shortages as one of those issues. Finally, a recent authoritative report from the World Water Assessment Program views mankind as 'facing a serious water crisis' (UNESCO, 2003: 4).

On the other hand, there is also a more optimistic school of thought that argues that cooperation over water resources is more frequent than conflict (e.g. Beaumont, 1997; Lomborg, 2001; Wolf, 1999b). River resources can be shared in a cooperative manner, by means of treaties and joint river administrations. Such arrangements have been in force for decades on the Rhine and on the Danube, by a wide margin the river shared by most countries (Wolf et al., 1999: 424). Even the Mekong River Basin, an extremely conflict-ridden area, has had a regional commission with the participation of most of the key actors since 1957, and it survived the violence of the 1960s and 1970s.

There is also no scarcity of water for the globe as a whole. Many areas have water shortages relative to their present needs, and this problem may increase unless changes are made in the patterns of supply or consumption. However, securing adequate and plentiful water for human objectives is a political and economic issue rather than one of absolute physical constraints. UNEP (1999: 43–44), while emphasizing the dangers of impending water scarcities, also recognizes that 'good water management can solve many of the problems of pollution and scarcity', citing Israel and Jordan, two of the most water-scarce countries, as examples of successful irrigation strategies. Liberals argue for more realistic pricing as a way of regulating the use of water. The World Commission on Water for the 21st Century advocates 'full-cost pricing of water with equity' (Serageldin et al., 1999: 284).

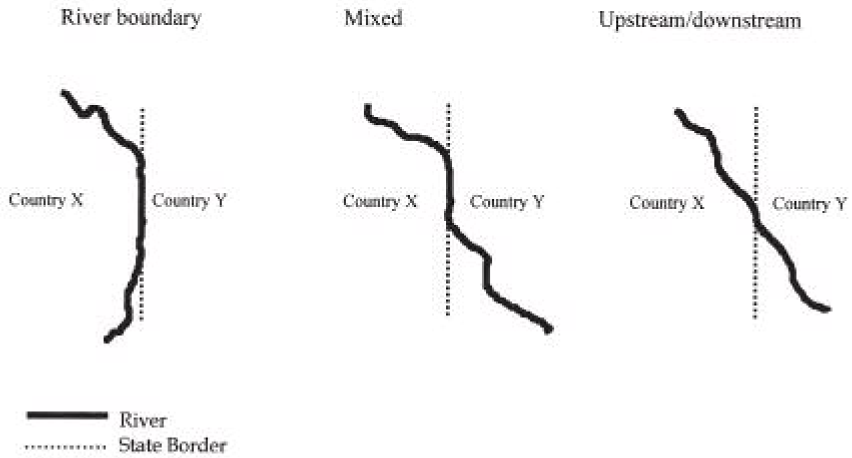
3. Rivers as Fuzzy Borders

The two earlier large n-studies of rivers and conflict incidence (Toset et al. 2000 and Furlong & Gleditsch 2003) both use a dataset coded largely from a 1978 study from the Center for Natural Resources, Energy, and Transport of the Department of Economics and Social Affairs of the United Nations (CRNET, 1978), which attempts to distinguish between three categories of river relations – upstream/downstream (i.e. shared across a border), border demarking, and mixed. This has, however, proved problematic. Only 9% of all coded rivers have a clear upstream/downstream categorization and 39% have a fourth, 'mixed' category. While both studies show that the upstream/downstream type of river was most significant for risk of conflict, that coding was not robust when disaggregated from the large and ambigu-

[2] A number of other examples are cited by Wolf (1999b: 253).

ous ‘other’ river type configurations. These data limitations have made it difficult to test for the presence, rather than type, of shared rivers.

Figure 1: Typology of Shared Rivers



Source: Toset et al. (2000: 980).

This ambiguity leaves open a challenge to the water wars hypothesis: the fuzzy boundary scenario. In this situation, countries sharing large amounts of river boundary are not fighting over the direct control of the resource per se, but rather over the political boundary. Rivers are notoriously fickle boundaries. Normally, the boundary follows the Thalweg, the deepest channel in the river. But this is not the only possible principle. Some boundaries follow a river bank, the median line between the banks, or lines drawn between turning-points (Gleditsch, 1952; Salman, 2000). For opportunistic reasons, two countries could come out in favor of two different legal principles for determining the position of the border. Even after the border has been fixed, erosion can change the banks, the median, or the Thalweg, to the detriment of one country and the benefit of one other.

An example of the fuzzy boundary conflict scenario is the Sino-Soviet border dispute of 1969. A dispute generally over the boundary line crudely demarcated by the Ussuri river and specifically over the ownership of Chenpao island (Lewis, 2004) led to intense fighting over the period of several months killing three thousand Soviet and Chinese troops (Clodfelter, 2002: 700).

Of course, a river may also serve as a border but be contested primarily because it is a water resource. For example, a 1989 conflict between Mauritania and Senegal which took place along the Senegal River, serious interethnic violence claimed perhaps 400 lives and led to small border skirmishes between the two nations. Although the Senegal River formed a boundary, the dispute was ultimately one over water resources:

> The trouble began ... over competing claims to farming rights on the common border, the Senegal river, where irrigation projects had increased the value of land and made the Mauritanians, traditionally herdsmen, less inclined to allow Senegalese to cultivate both sides of the border. (Bercovitch & Jackson, 1997: 240)

It is the aim of this paper to test the fuzzy boundaries and resource wars scenarios by moving from the Toset measure of rivers to the variable preferred in most water resource literature, the river basin.

4. The New Dataset: From Rivers to Basins

Recent work on cooperation and conflict over water resources has focused on the basin rather than on individual rivers (Wolf, Yoffe & Giordano, 2003; Wolf & Hamner, 2000; Wolf et al., 1999; Wolf 1999a,b). Whereas early work in this area outlines scenarios where acute conflict resulted from competition over the flow in a single river, new studies suggest a more nuanced threat from the management of basin areas. Of course this could include the standard upstream/downstream conflict scenario, but also broader concern about watershed management, pollution, and a more subjective notion of scarcity.

A river basin is a 'topographically delineated area drained by a stream system – that is, the total land area above some point on a stream or river that drains past that point' (Brooks et al., 1997: 000). This means that it encompasses all of the fresh and ground water in a large geographical area. Often encompassing a unique ecosystem, it is frequently used as a spatial unit for socio-economic management.

In the most comprehensive study on river basins and conflict, Wolf, Yoffe & Giordano (2003) have used a large global GIS database of biophysical, socio-economic, and geopolitical data to identify basins at risk of political stress. Their project uses events data to code a 20 point nominal range of actions (from treaties to war) over water. These data are then historically matched with the GIS data using the river basin as the spatial unit of analysis to come up with indicators of possible river stress. From this, 17 basins were identified with 'red flags'. Briefly, they found that nations generally cooperate about water, particularly if they cooperate in general, that the higher the per capita GDP or the lower the population density the greater the cooperation, that water stress is not a significant indicator of dispute, and that neither government type nor climate show any impact on water disputes.

Qualitative studies of basins and conflict have pointed to the importance of geographic scale (Ashton, 2002; Sneddon 2002). Both argue that the size of a basin, particularly in the context of the relative national water scarcity, plays a very important role in the potential for conflict escalation. Where

Ashton paints a dire picture of African scarcity as a precursor to conflict, Sneddon points out that the geographic importance of certain basins makes them ideal for co-management.

Indeed, the vast majority of research into river basins is in the realm of watershed management. In much of this work, the potential stresses of a basin a far outweighed by their potential as a catalyst for cooperative political engagement. Bakker (1999), Giordano & Wolf (2003), and Lubel et al. (2002) have shown how seemingly conflict-prone basins have become arenas of remarkable cooperation, including not only treaties but also the development of collective action institutions.

This paper presents a new dataset on shared rivers that better suited to answer the question posed above – shared resources or fuzzy boundaries – by moving from rivers to basins. This corrects for the problem of categorizing certain rivers as either upstream/downstream or borders on the basis of the Toset et al. (2000) data. Another limitation is that the Toset database does not accurately reflect the relative magnitude of the water resource. Importance of the water available in each dyad is only measured by water scarcity in either country and by the number of rivers. While the relevance of scarcity was demonstrated by Furlong & Gleditsch (2003)b, the number of river crossings provides no greater clarity than the dichotomous shared river variable. Third, the old dataset was somewhat incomplete. The database used to code the river relations included little information for either Asia or Africa. It left out 51 river basins and many prominent rivers. There seems to be little systematic reasoning to the river selection. For example only seven river crossings and three basins were listed for the Canada–US border, no rivers east of Quebec were included.

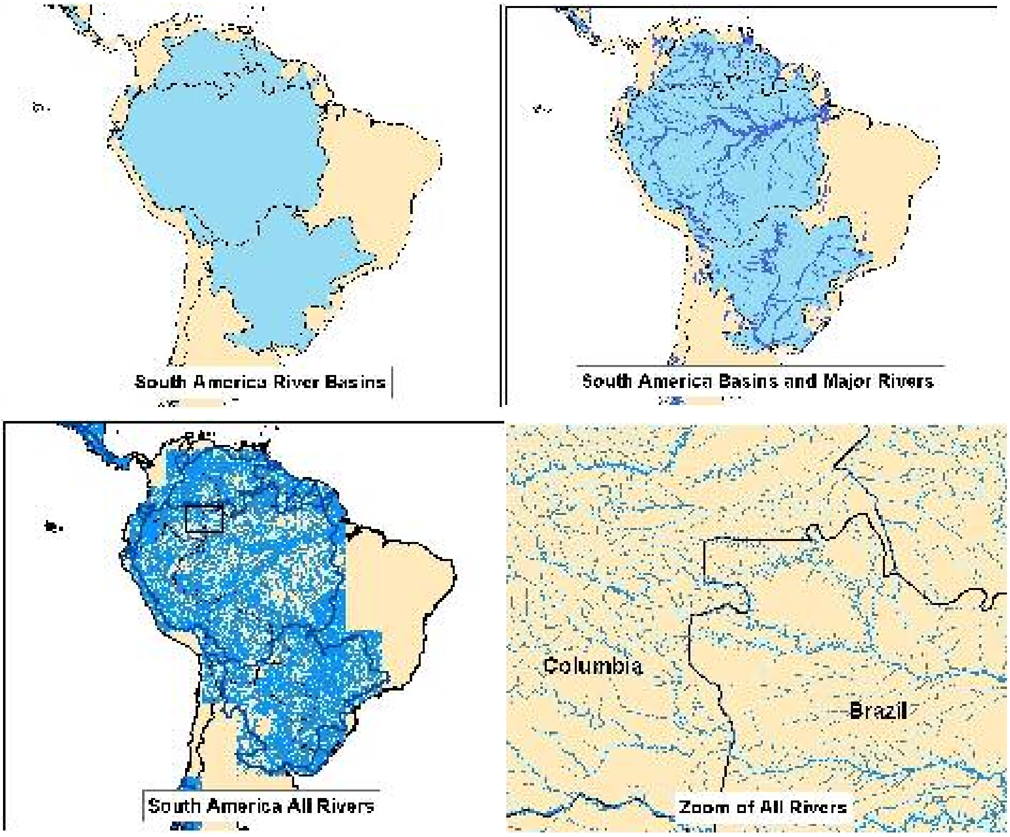
In order to address these shortcomings and inaccuracies of the Toset data, we have created a new dataset with three principle ambitions: to recode the shared river dyads so that the ratio between upstream/downstream and border demarcating rivers was clear, to recode the dataset based on river basins to get a measure of total water magnitude and of dyadic parity, and to add non-contiguous basin-sharing country dyads to the database.

In order to achieve the level of detail necessary to calculate these new variables a Geographic Information System was used. We began by doing a systematic test of the Toset dataset with the most up to date data on transboundary river basins – Aaron Wolf's Transboundary River Basin Registry[3]. We first used his GIS layer for all 250 world basins to determine the number of missing basins in Toset's set. 51 basins were missing and many others were named and coded differently so redoing the data based on new basins

[3] See the Transboundary Fresh Water Dispute Database at Oregon State University on www.transboundarywaters.orst.edu/.

was deemed necessary. As we were interested in coding all of the rivers that cross borders within Wolf's river basins we first created a very detailed rivers layer to cover the area under each of the 251 basins. This river layers was taken from the 1997 Digital Chart of the World. Below is an example of the Wolf Basin Layer and the two levels of river detail extrapolated from the DCW data.

Figure 2: Four Levels of Detail for GIS Basin Measurement, 1997



Source:

For each contiguous boundary crossing river basin we counted the number of river crossings and measured the length of each boundary-demarcating river. The non-contiguous river-sharing countries within each basin were then identified and separate dyads created. For all entries, the upstream state, and the percentage and size of basin in both and each countries were calculated[4].

In order to calculate the historic boundaries two methods were used. First a series of GIS layers boundary changes between 1944 and 1996 for O'Loughlin et al. (1998) was used to recalculate the relevant dyads. The river-sharing dyads from 1816–1944 in the Toset dataset were for the most part identified using historic documentation to determine where the bound-

[4] A companion paper is in preparation that will describe the detailed description of the coding.

ary change occurs. For instance, when Egypt and Syria joined to form the United Arab Republic, Syria was replaced by Egypt in all Syria/Israel and Syria/Jordan dyads. Where this was not possible and the boundary could not be determined, Toset's reading of historical maps was assumed to be the best available method and his data were used.

5. Differentiating Conflict Scenarios

Using the newly compiled basin data, we perform regression analysis (with bivariate and multivariate logit models) to investigate earlier findings on rivers and interstate conflict. To measure conflict, our dependent variable, we have coded the onset of militarized interstate disputes (MID) with a minimum of one fatality from the Correlates of War project. We consider all system member dyads from 1880–2001.[5] The reason for limiting ourselves to fatal disputes is to minimize the potential attention bias inherent in data on low-level conflict (Toset et al., 2000: 984; Gleditsch, 1999). Our results remain consistent in tests considering fatal and nonfatal disputes.[6]

Our first hypothesis investigates the general relationship between rivers and conflict. A dummy variable (*Shared Basin*) notes whether or not the two states in a dyad share a river basin (where they may be contiguous or non-contiguous). The hypothesis reads:

> H1: Dyads that share a river basin experience more conflict between them[7].

Hypotheses two and three test the fuzzy borders and river crossings scenarios respectively. Although we use these as alternative scenarios, they are not exclusive. Two countries can have a river boundary as well as a number of river crossings and the new dataset permits to better sort out the two effects:

> H2: Dyads that have a boundary in a river experience more conflict between them.

[5] The MID data are now available from 1816 to 2001. However, one of the control variables, the level of economic development, is only available from 1880. The MID data were downloaded from EUGene (Expected Utility Generation and Data Management Program) (see Bennett & Stam, 2003). The most recent MID dataset is described by Ghosn & Palmer (2003). EUGene was also used to download data on years of peace, energy consumption per capita, population, major power status, alliances, and inter-capital distances for the control variables described below.

[6] There were two exceptions to this finding. First, the control variable for alliances was significant in some regressions including nonfatal MIDs. We also performed multivariate analysis of the impact of water variables on MIDs disaggregated by fatality level (non-fatal, 0-25 battle deaths, 26-999 battle deaths, 1,000 or more battle deaths), also discussed below.

[7] In all hypotheses we assume 'everything else being equal'.

H3: Pairs of countries that have a greater number of places where a river crosses their border experience more conflict behavior between them

The data used in Toset et al. (2000) and Furlong & Gleditsch (2003a,b), limited to immediate neighbors, whereas we now have data for non-contiguous countries sharing a river basin. Thus, we now analyze all dyads, instead of just contiguous dyads, with the length of boundaries included as a control variable. Hypothesis two is tested according to the logged length in kilometers of the boundary between contiguous dyads demarcated by a river (*River Boundary*). Hypothesis three considers the number of river crossings of a border between two countries, counted using the new GIS rivers database (*River Crossings*).

To investigate neomalthusian concerns of conflict over scarce resources and inequitably distributed resources, we test the following hypotheses:

H4: The greater the amount of water resources two countries share, the higher the probability of dyadic conflict.

H5: Where distribution of water resources is particularly unequal between two countries, there will be a higher the probability of dyadic conflict.

Hypothesis four is investigated using a variable for the log of the total size in square kilometers of the river basins shared by the dyad (*Basin Size*). To test hypothesis five we calculate the log of the size of the shared basins in the upstream state (*Basin Upstream*) as well as the percentage of the total basin area lying in the upstream state (*Percent Upstream*).[8] As is evident from Table 1, all of the basin-related variables designed to test hypotheses two through five are significantly correlated to conflict. Without multivariate analysis, it is not possible to differentiate between the resource scarcity and fuzzy borders scenarios.

In place of the water scarcity variable used by Toset et al. (2000) and Furlong & Gleditsch (2003b), we now use a measure of rainfall and a measure of drought. We interact our measures of water scarcity with water resource measures to obtain hypotheses six and seven:

H6: When two countries share a river basin and one or both has little rainfall, they will display greater risk of conflict.

[8] In dyads that share more than one river basin, the upstream state was taken to be the state with containing the greater total area of upstream river basin.

H7: When two countries that share a river basin and one or both has recently experienced drought, they will display greater risk of conflict.

Data collected to investigate hypothesis six gave us the mean national rainfall over a 30 year period, 1968–98 (data from Mitchell & Hulme, 2001). From this dataset, we defined water scarcity as values falling in the bottom 25th percentile of the world range. A dummy variable for a dyad with one or both countries falling into that category (*Dry*) was then interacted with the presence of a shared basin, with basin size, and with upstream basin size.

The second scarcity variable tested was the recorded the number of droughts – defined not biophysically but as a natural disaster (data from EM-DAT, 2001) – a country had experienced each year from 1975 to 2000. Thus, assumed in this variable is the capacity of a country to adapt and mitigate the harmful effects of drought. The drought measure is similar to the original water scarcity variable in that is represents a strain which could stimulate conflict. In addition however, the drought variable used can be disaggregated by individual drought years, where as the water scarcity variable was measured as the mean of a 30 year period. We transformed this variable into a dummy (*Drought*) which noted one or more droughts occurring in either or both states at any time during the past five years. In bivariate analysis, the rainfall measure for scarcity showed *Dry* nations have slightly more conflict, not surprising given the association between low development and adverse climate. The drought measure is negatively related to conflict, possibly because of a reduced capacity to wage disputes in years following a natural disaster.

Together, these variables, mean rainfall over a 30 year period (1968–98), and drought incidents in the past 25 years represent a significant improvement on the single year biophysical scarcity variable used in the past shared rivers studies (per capita freshwater availability). First, the old water variable only accounted for a biophysical scarcity. With the inclusion of droughts (which by definition include the capacity to adapt and mitigate), we can account for the socio-economic aspects of water management. Second, the original scarcity variable only included one year of data. Our new biophysical variable covers the mean of a 30-year period and our drought indicator has annually disaggregated data for a 25-year period.

Neomalthusian theorists also expect that resource conflict will be particularly common in poor states and in certain geographic regions. We test the hypotheses that the Middle East, North Africa, and Sub-Saharan Africa experience greater conflict over water resources:

H8: When a pair of countries shares a river and one or both of them lies in the Middle East/North Africa, they experience an increased risk of conflict.

H9: When a pair of countries shares a river and one or both of them lies in the Sub-Saharan Africa, they experience an increased risk of conflict.

We code a dummy variable for dyads in which one or both states was in the *Middle East/North Africa*, and another dummy for pairs in which one or both states lies in *Sub-Saharan Africa*.[9] These terms are each interacted with the presence of a shared basin. As a bivariate term, the Middle East/North Africa variable was related to less conflict, while the Sub-Saharan African variable was related to more. The ability to test the vulnerability to water wars of these two regions of special interest to resource conflict theorists is a major advantage over the Toset et al. data, which had relatively poor coverage of these areas.

Developed nations have technologies and wealth available to manage and conserve water resources, avoid wasteful irrigation practices, and to mitigate humanitarian impact in times of water scarcity. Therefore, when a pair of countries sharing a river basin also has a relatively high level of economic development, we would expect the overall strain on the water resources to be less. Thus:

H10: Among pairs of countries that share a river basin, those with higher levels of development will display lesser risk of conflict.

However, it may also be the case that states with relatively little economic activity do not put much stress on their water resources and have little reason to fight over them. This would lead to a Kuznets (or inverted parabola) relationship, with conflict most likely among states that have developed to the point of straining their resources but had not begun to implement water saving technologies.

H11: Stress on resources, and resource conflict, is least severe for states at the lowest and highest levels of development.

To test hypotheses ten and eleven, we first calculate a variable for the total level of development in a country dyad (*Dyad Development*), defined as the log of the total energy consumption of the dyad divided by its total population. In bivariate analysis, *Dyad Development* is negatively related to conflict, as was the *Development* term based on the weaker economic link in the dyad. The *Dyad Development* variable is interacted with the presence of a

[9] See Appendix 1 for regional definitions.

shared river basin. We also interact the *Shared Basin* variable with the square of our measure of the countries' development, to test for increasing returns to wealth, under which the very richest basin-sharing countries would experience little incentive at all for resource conflict.

In Table I we show the relationship between the conflict variable and the various independent variables (including the control variables). With the exception of the economic development variables, all the results are in the expected direction.

Table I. Bivariate Analysis of Conflict and the Independent Variables, 1880–2001

Variable	Parameter estimate	Standard error	Odds ratio	N
One democracy (yes/no)	–2.54***	0.08	12.7	693,529
Two autocracies (yes/no)	–2.42***	0.13	11.2	693,529
Shared basin (yes/no)	0.82***	0.08	2.27	692,677
River boundary (Ln of km)	0.001***	0.0001	1.00	693,529
River crossings (#)	0.01*	0.01	1.01	693,529
Basin size (Ln of km²)	0.06***	0.006	1.06	692,677
Upstream basin (Ln of km²)	0.07***	0.007	1.07	693,529
Percent upstream (%)	1.78***	0.29	5.93	692,677
Dry (yes/no)	1.00***	0.122	2.72	692,230
Drought (yes/no, during past 5 years)	0.16	0.21	1.17	679,558
Dyad development (Ln energy cons. per cap.)	–0.07**	0.02	1.07	649,549
Middle East/North Africa (yes/no)	–0.15***	0.02	1.16	693,529
Sub-Saharan Africa (yes/no)	0.10***	0.01	1.05	693,529
* p<0.05, ** p<0.01, *** p<0.001				

6. A Model for Interstate Conflict

In Table II, we show the results from a multivariate model with just the control variables. These controls perform very consistently throughout our tests, and at very high levels of significance, suggesting that we have a good underlying model for interstate disputes. Again, the only exception is economic development, to which we return below.

The strongest predictor of peace within a dyad is *Peace History*, a variable generated using a decay function containing the number of previous years without a militarized dispute in the dyad.[10] Variables representing the

[10] The variable was defined as –(2^(-years of peace)/c), where c=1 was chosen to maximize the log likelihood in Model 1 (See Toset et al., 2000: fn. 14). We also estimated the model using the cubic spline correction for temporal dependence, but found that this did not change the model results and had a lower goodness of fit (Beck et al., 1998). Years of peace in the dyad were taken from the COW data downloaded through EUGENE (Bennett & Stam, 2003) and

political make-up of the dyad as compared to a reference dyad of two democracies were the next most important factors in determining conflict; regime type is taken from the Polity IV scale of democracy and autocracy (Marshall & Jaggers, 2003). As has been documented extensively (e.g. in Russett & Oneal, 2001), the political make-up of a dyad tell us a great deal about its propensity for conflict. The regime type with the greatest positive correlation to conflict is that of *Unconsolidated Regimes*. We define this as a case in which both states have either a combined score that is either missing or in the unconsolidated range (falls between –5 and +5), or the combination of an autocracy (with a score of –6 or less) and a state with either a missing or transitional coding. Our results agree with a number of studies that find that transitional or weak regimes are especially prone to both external and internal violence (Hegre et al., 2001; Mansfield & Snyder, 2002). The second most dangerous situation was that of a *Single Democracy*, in which one and only one state is a consolidated democracy, defined as having a combined score of 6 or more (its dyadic partner's score may be missing, unconsolidated, or authoritarian). Finally, a dyad of *Two Autocracies* is also at greater risk of a fatal military dispute than the reference group, two democracies. All these findings are in line with the well known hypothesis of a liberal peace between democratic regimes.

As with Toset et al. (2000) and Furlong & Gleditsch (2003b), we find no evidence of the level of *Development* as a contributing factor to conflict, with development defined as the lower of the values of logged energy consumption per capita in states 1 and 2 (i.e., that for the 'weak link' state). Because development is highly correlated to regime type, the non-result is not entirely surprising. By contrast, *Dyad Size*, defined as the log of the combined population of the states, is positively related to conflict and highly significant, as is the presence of one or more major powers within the dyad. These findings are explained by the fact that big states and major powers have both more resources and capabilities to pursue military disputes, and more diverse and widespread international interests.

Other realist factors do not perform as well in our model. The presence of an *Alliance*[11] is not a significant predictor of conflict. However, as expected, the *Distance* between the capitals of states 1 and 2 significantly reduces the probability of conflict while, as reported initially in Furlong & Gleditsch (2003b), the opportunity for conflict, defined by logged *Boundary*

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used the Werner's adjusted values (2000), which document pre-1816 years of peace in the dyad.

[11] Defined as the presence of an entente or a defense pact between the states. These results did not change when we also considered neutrality pacts.

length yields a small positive increase in conflict probability.[12] Finally, a dummy variable for *Post Cold War* (defined as 1990 or later) indicates decreased risk of conflict. This result confirms most conflict data monitoring projects' finding of decreasing levels of international and internal conflict since the depolarization of the international system (Eriksson, 2003; Gleditsch et al., 2002; Gurr & Marshall, 2003).

Table II. Multivariate Analysis of Conflict and Control Variables, All Dyads, 1880–2001

Variable	Parameter estimate	Standard error
Peace history[14]	–3.94***	0.07
Unconsolidated regimes (yes/no)	2.01***	0.27
Single democracy (yes/no)	1.84***	0.26
Two autocracies (yes/no)	1.69***	0.29
Development (Ln energy consumption per cap.)	0.02	0.02
Dyad size (Ln population)	0.41***	0.04
Major power (yes/no)	1.1***	0.13
Alliance (yes/no)[15]	–0.1	0.13
Distance (Ln km)	–0.72***	0.07
Boundary length (Ln km)[16]	0.13***	0.02
Post-Cold War (yes/no)	–0.48***	0.11
N	583,031	
Pseudo-R^2	0.4	

* p<0.05, ** p<0.01, *** p<0.001

7. Conflict over Basins or Borders?

In Table III we show the results of a series of tests designed to analyze the ambiguities of previous models of the relationship between rivers and military disputes. First, using the dummy variable (*Shared Basin*) for the presence of a shared basin we affirm the earlier conclusion that there is a positive and significant relation between countries sharing water and incidence of conflict.

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[12] Contiguity is a standard control in models of interstate conflict. That information is captured in our boundary length variable, as non-contiguous states have a boundary length of zero. The two variables are highly correlated (r =0.987) and perform similarly in our models. Using both in the same model, however, results in each appearing insignificant.

Table III. Shared Basins, Shared Borders and Conflict: Multivariate Analysis, All Dyads, 1880–2001

	Model 1		Model 2		Model 3		Model 4		Model 5		Model 6	
Variable	**Parameter estimate**	**St. error**	**Parameter estimate**	**St. error**	**Parameter estimate**	**St. error**	**Parameter estimate**	**St. error**	**Parameter estimate**	**St. error**	**Parameter estimate**	**St. error**
Control variables												
Peace history	–3.94***	0.07	–3.94***	0.07	–3.94***	0.07	–3.96***	0.07	–3.93***	0.07	–3.94***	0.07
Unconsolidated regimes	2.01***	0.27	2.02***	0.27	2.01***	0.27	2.01***	0.27	2.01***	0.27	2.04***	0.27
Single democracy	1.84***	0.26	1.83***	0.26	1.84***	0.26	1.86***	0.26	1.85***	0.26	1.86***	0.26
Two autocracies	1.68***	0.3	1.69***	0.29	1.7***	0.29	1.67***	0.3	1.68***	0.3	1.72***	0.3
Development	0.03	0.02	0.02	0.02	0.02	0.02	–0.03	0.02	–0.03	0.02	0.02	0.02
Dyad size	0.4***	0.04	0.41***	0.04	0.41***	0.04	0.39***	0.04	0.39***	0.04	0.41***	0.04
Major power	1.10***	0.13	1.12***	0.13	1.1***	0.13	1.11***	0.13	1.11***	0.13	1.11***	0.13
Alliance	–0.1	0.13	–0.1	0.14	–0.11	0.13	–0.1	0.13	–0.09	0.13	–0.09	0.14
Distance	–0.66***	0.06	–0.72***	0.07	–0.72***	0.07	–0.671***	0.07	–0.69***	0.07	–0.73***	0.074
Length of boundary	0.02	0.04	0.13	0.03	0.12***	0.02	0.15***	0.04	0.04***	0.04	0.11***	0.03
Post-Cold War	–0.59***	0.12	–0.48***	0.12	–0.49	0.11	–0.59***	0.12	–0.56***	0.12	–0.5***	0.12
River variables												
Shared basin (yes/no)	0.94***	0.24										
River boundary			–0.0001	0.0003								
River crossings					0.003	0.004						
Basin size							0.07***	0.02				
Basin upstream									0.06**	0.02		
Percent upstream											0.68	0.51
N	582,659		583,031		583,031		582,659		583,031		582,659	
Pseudo-R^2	0.34		0.4		0.4		0.4		0.4		0.4	

* p<0.05, ** p<0.01, *** p<0.001

In order to differentiate between the resource scarcity and the fuzzy boundary scenarios, we then test the length of the boundary demarcated by a river (*River Boundary*). This proves to have no relation to conflict. Neither does *River Crossings*. The shared river variable may be explaining something other than the presence of contentious river crossings or fuzzy boundaries.

Our first test of the resource wars scenario, the variable *Basin Size*, obtains a positive and significant relationship to conflict, as does *Basin Upstream*. These results strongly suggest that it is the basin, or the shared water resources, rather than the course of the individual rivers over which countries fight. This finding is in line with most prevailing water theories. The combined resources present in a basin, including both fresh and groundwater, are a potential source of conflict. While acute conflicts over single rivers are rare, the presence of a large shared river basin provides far more to fight over.

Presence of a shared basin, total basin size, and size of basin located upstream are significant predictors of MIDs disaggregated by fatality level (including nonfatal MIDs). The magnitude of the coefficients obtained is greatest for MIDs with 1–25 deaths, roughly equal for MIDs with either 0 or 26–999 deaths, and smallest for conflicts with 1,000 or more dead. This finding suggests that water resources are quite important and can lead to serious conflicts between states, but have not been less often related to international war on the largest scale. The number of rivers crossing the border does not become a significant indicator of any conflict level of conflict, except for those with 26–999 deaths; and here the coefficient is very small (0.0083). The length of the boundary demarcated in rivers is not a significant indicator of fatal conflicts, but is a marginal risk factor for nonfatal conflicts (with a coefficient of just 0.0005). This suggests that fuzzy river boundaries on rare occasions may lead to political posturing, but will rarely cause interstate violence.

We also test the percentage of shared river basin in the upstream state, but did not obtain significant results. This suggests that the absolute size of the available resources rather than the disparity in their distribution is a risk factor for conflict. That result is intuitively plausible and reflects a common view in the literature. An upstream state has an incentive to alter the landscape of the basin and siphon off greater water resources (e.g. by means of a dam or extensive irrigation channels), while a downstream state has an incentive to oppose such actions, regardless of where most of the basin currently lies. For example, although much of the Nile river basin is located in Sudan, that nation's use of the water resources is mitigated by limitations placed on them by their downstream riparian neighbor, Egypt. In this case, the threat of force (the bombing of dam projects), may be used by the downstream partner to limit water extraction upstream. The overall size of the basin signifies its importance to Egypt and any redirection of the upstream flow may result in hostile action.

Wolf, Yoffe & Giordano (2003) found no significant relationship between water stress and conflict events. We test this in Table IV using two measures of water stress. The dummy variable (*Dry*Basin Size)* for a river-sharing dyad in which one or both countries also have relatively little rainfall does not perform as expected.[13] *Basin Size* and *Dry* continue to be positive and significant predictors of conflict, but the interaction term has a negative relationship to dispute onset. This finding may indicate that countries with endemic water scarcity and shared basins have long-term incentives to invest in water management measures and avoid conflict that other basin-sharing dyads do not.

Table IV. Water Scarcity and Shared River Basins: Multivariate Analysis, All Dyads, 1880–2001

	Model 7		Model 8	
Variable	**Parameter estimate**	**St. error**	**Parameter estimate**	**St. error**
Peace history	–3.29***	0.12	–4.03***	0.16
Unconsolidated regimes	1.61***	0.35	1.82***	0.43
Single democracy	1.18***	0.35	1.58***	0.43
Two autocracies	1.4***	0.37	1.81***	0.45
Development	–0.05*	0.03	–0.01	0.05
Dyad size	0.37***	0.08	.39***	0.07
Major power	–0.40	0.21	0.36	0.32
Alliance	–0.47**	0.16	0.46*	0.21
Distance	–0.56***	0.1	–0.75***	0.12
Length of boundary	0.004	0.32	0.15**	0.05
Post-Cold War	0.19	0.21	0.92***	0.19
Shared basin			1.0**	0.35
Basin size	0.12*	0.06		
Dry	3.9**	1.22		
Dry*Basin size	–0.28**	0.09		
Drought			–0.32	0.25
Drought*Shared basin			0.2	0.3
N	16,020		307,053	
Pseudo-R^2	0.31		0.41	

* p<0.05. ** p<0.01. *** p<0.001

The socio-political measure of water scarcity, *Drought*, does not yield significant results on its own or for any of the interaction terms with basin variables. One explanation may be that drought, a measure here of ability to cope with water shortage, is already controlled for with several of the other variables included in the regression such as development, democracy, and major power status. Similarly, poor nations and minor powers (which also tend to be autocratic) are more likely to require international aid in times of drought.[14] These results replicate the findings by Wolf, Yoffe & Giordano (2003).

8. Regional Impact

In Table V we include a model with test for different regions. The Middle East/North Africa dummy is not itself a significant predictor of conflict; the *Shared Basin* variable continues to be positively correlated to conflict. The significance of the interaction term shows that countries in this region that also share a river basin experience a risk for conflict greater than similar

Table V. Dyad Development, Regional Dummies and Conflict: Multivariate Analysis, All Dyads, 1880–2001

	Model 9		Model 10		Model 11	
Variable	**Parameter estimate**	**St. error**	**Parameter estimate**	**St. error**	**Parameter estimate**	**St. error**
Peace history	–3.9***	0.07	–3.92***	0.07	–3.9***	0.07
Unconsolidated Regimes	2.93***	0.26	1.98***	0.27	2.00***	0.26
Single democracy	1.81***	0.25	1.8***	0.26	1.82***	0.26
Two autocracies	1.64***	0.29	1.62***	0.3	1.75***	0.29
Development			0.035	0.02	0.006	0.02
Dyad size	0.42***	0.04	0.4***	0.04	0.37***	0.04
Major power	1.04***	0.12	1.13***	0.13	1.04***	0.12
Alliance	–0.08	0.13	–0.11	0.13	–0.15	0.13
Distance	–0.7***	0.07	–0.65***	0.06	–0.61***	0.06
Length of boundary	0.03	0.03	0.02	0.04	0.07	0.04
Post-Cold War	–0.5***	0.11	–0.02	0.04	–0.54***	0.13
Shared basin	0.81**	0.03	0.79**	0.25	0.74**	0.23
Dyad development	0.08**	0.03				
Dyad development squared	–0.03	0.03				
Dyad development*Shared basin	–0.19***	0.04				
Dyad development Sq.*Shared basin	–0.06	0.04				
Middle East/North Africa			0.13	0.12		
MENA*Shared Basin			0.59*	0.27		
Sub-Saharan Africa					–1.02***	0.2
Sub-Saharan Africa*Shared basin					1.33***	0.27
N	631,886		582,659		582,659	
Pseudo-R^2	0.4		0.4		0.4	

* $p<0.05$, ** $p<0.01$, *** $p<0.001$

[13] *Dry*SharedBasin* could not be analyzed due to multicollinearity. The interaction of *Dry*BasinUpstream* produces similar results to those reported for the interaction with *Basin Size*.
[14] The correlation between *Drought* and *Development* is –14%.

basin-sharing countries elsewhere. In the case of Sub-Saharan Africa, the regional dummy on its own yields *less* conflict! This may seem counterintuitive, but most conflict in this region is internal rather than international. Also, we have controlled for some of the factors that might have predicted conflict here, notably, regime type. The interaction term, *Sub-Saharan Africa*Shared Basin*, has a positive and highly significant relationship to dispute onset. As neomalthusian literature expects, basin-sharing countries in water scarce regions are at higher risk for dispute than basin-sharing countries elsewhere. Africa is indeed at the center of the shared basin and conflict question.

9. The Impact of Economic Development

Economic development was found to be significantly related to less conflict in the bivariate analysis, but unrelated to conflict in all the multivariate analysis, with or without rivers and basin data. This is consistent with what was found in Toset et al. (2000), but inconsistent with other dyadic work on conflict (Bremer, 1992). We have accounted for it by pointing to the correlation between development and democracy. Others, however, have found both to be significant (Russett & Oneal, 2001) and some (Hegre, 2000) have found the democracy variable to be less robust than development when both are included. This puzzle led us in the direction of the argument about the environmental Kuznets curve (Cole, 2003), which suggests that countries at low levels of economic development do not suffer much from pollution or resource scarcity because of their limited economic activity. At very high levels of economic development, the problem of resource scarcity is also smaller, partly because the political priorities change and a clean environment is valued more highly, partly because rich countries can afford to invest in new technology that economizes with the resources. The environmental Kuznets curve has been found for some common forms of pollution, such as SO_2 in cities, but not for all (e.g. not for greenhouse gas emissions). It underlies the corncucopian argument that economic development will improve the environment rather than destroy it (Simon, 1996; Lomborg, 2001).

We test this argument here by creating a joint development variable, which measures the total economic activity in the pair of nations (the variable *Dyad Development* is defined as the log of the total energy consumption in the dyad divided by its total population) and square it to look for the inverted U suggested by the environmental Kuznets curve. If the environmental Kuznets curve hypothesis fits this dataset, rich and poor countries should be less stressed by resource scarcity and therefore presumably less inclined to fight over it. In Table V we test this argument by including both the linear and the squared term for economic development[15] and the same two terms interacted with Shared Basin. Only the coefficient for *Dyad Development*Shared Basin* is significant, and it is negative. This indicates that among countries sharing rivers, more developed pairs will suffer less conflict, most likely because these states have sufficient wealth available to cope with resource crises and to utilize water management technology. The non-significance of the squared terms, however, indicates that the Kuznets curve relationship does not hold. The benefits to development are linear: resource conflict neither accelerates as states develop nor do the benefits of wealth accelerate for the richest states. The results suggest that strategies of resource and scarcity management can develop early in the development process and thus mitigate conflict as basin usage intensifies. They also confirm the hypothesis that it is the very poorest river sharing dyads, rather than those at middle income levels, that are most at risk of resource conflicts.

10. Conclusions

The neomalthusian concerns are supported to some extent by our empirical analysis. The presence of a shared basin does indeed have a significant relation to conflict, just as a shared river was found to relate to conflict in earlier studies. However, with the new and improved dataset, the number of rivers crossings, length of border as river, and percentage of border as river are not significantly related to conflict.

The fuzzy boundary scenario does not seem to provide an important explanation for the increased conflict found by both Toset et al. as well as Furlong & Gleditsch. The fact that shared basins proved significant while the more detailed data on number of rivers and river boundary did not, suggests that conflict is not dependent on the number of rivers, but rather over the overall importance of a basin. This is supported by the significance of the size of the river basin variable. This is not surprising, as river basins clearly represent more both in physical output of water, and in land use potential, than do individual rivers. This finding puts the study shared rivers and conflict in line with most academic work on freshwater, i.e. organized by basin rather than by individual river. Indeed, as discussed above, most of the recent qualitative literature on 'water wars' as well as water cooperation, uses the river basin as a single entity – as the area of significance and reference.

The interaction of water scarcity and shared water resources did not perform as expected or yield conclusive results. However, the expectation that the risk of water-related conflict will be influenced by income level and

[15] Hibbs (1963) found that the squared economic development term predicted internal violence. The argument seems reasonable for interstate violence, too, but we are not aware of any empirical application of it.

geographic region was born out. Poorer states and states in the water-scarce regions of the Middle East/North Africa and Sub-Saharan Africa experience more conflict than comparable basin-sharing dyads.

We conclude, using the new basin based river data, that the earlier studies of neomalthusian conflict over water are upheld. It is not fuzzy boundaries but shared resources that make rivers flashpoints for conflict. This is not evidence for 'water wars', but shared waters resources can stimulate low-level interstate conflict. That in no way excludes cooperation, and indeed the low-level conflict may be an important incentive for more cooperation. That relationship, however, remains to be investigated.

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Appendix 1: Regional Definitions

Middle East and North Africa: Algeria, Bahrain, Egypt, Iran, Iraq, Israel, Jordan, Kuwait, Lebanon, Libya, Morocco, Oman, Qatar, Saudi Arabia, Sudan, Syria, Tunisia, Turkey, United Arab Emirates, Yemen (Arab Republic), Yemen (Peoples Republic).

Sub–Saharan Africa: Angola, Benin, Botswana, Burkina Faso, Burundi, Cameroon, Cape Verde, Central African Republic, Chad, Comoros, Congo, Democratic Republic of Congo (Zaire), Cote d'Ivoire, Djibouti, Equatorial Guinea, Eritrea, Ethiopia, Gabon, Gambia, Ghana, Guinea, Guinea–Bissau, Kenya, Lesotho, Liberia, Madagascar, Malawi, Mali, Mauritania, Mauritius, Mozambique, Namibia, Niger, Nigeria, Rwanda, Senegal, Sierra Leone, Somalia, South Africa, Swaziland, Tanzania, Togo, Uganda, Zambia, Zanzibar, Zimbabwe.

Definitions taken from Mack (2004).

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