



## Demand, supply, and restraint: Determinants of domestic water conflict and cooperation

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### ABSTRACT

This article focuses on one of the most likely empirical manifestations of the “environment-conflict” claim by examining how demand for and supply of water may lead to domestic water conflict. It also studies what factors may reduce the risk of conflict and, hence, induce cooperation. To this end, the article advances several theory-based arguments about the determinants of water conflict and cooperation, and then analyzes time-series cross-section data for 35 Mediterranean, Middle Eastern, and Sahel countries between 1997 and 2009. The empirical results show that demand-side drivers, such as population pressure, agricultural productivity, and economic development are likely to have a stronger impact on water conflict risk than supply-side factors, represented by climate variability. The analysis also reveals that violent water conflicts are extremely rare, and that factors conducive to restraint, such as stable political conditions, may stimulate cooperation. Overall, these results suggest that the joint analysis of demand, supply, and restraint improves our ability to account for domestic water-related conflict and cooperation.

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### 1. Introduction

A number of recent studies have argued that there is a long-term trend toward a reduction of violence in human affairs, both at the international and the domestic level (Goldstein, 2011; Pinker, 2011). However, while there seems to be widespread agreement on this trend, we are far from reaching consensus about its causes (Blattman and Miguel, 2010) or on the prospects that it will continue (Gleditsch et al., 2013). In fact, a rather pessimistic view is found in the environmental-security literature, warning that the unsustainable use of natural resources and the ensuing environmental degradation may generate violent conflict over scarce natural resources (Bächler, 1999; Homer-Dixon, 1999; Kahl, 2006).

Inspired by the debate around the notion of “limits to growth” (Meadows et al., 1972), social scientists have picked up on a long-standing argument initiated by Malthus (1798/1993), who

focused on how increasing scarcities may lead to violent conflict (Buttel et al., 1990). As outlined in his *An essay on the principle of population*, Malthus primarily considered the impending gap between food production and population pressure. More recently, concerns have been voiced over social consequences of a broader range of scarcities and (human-induced) environmental degradation (Hauge and Ellingsen, 1998; Gleditsch, 2003). Increasing water scarcity has been a key element in this literature, provoking scholars and policymakers alike to foresee future “water wars” (see Ward, 2002; Katz, 2011; Theisen et al., 2011). Projections of severe, human-induced climate change with its effects on the water supply in many parts of the world have boosted such neo-Malthusian fears.

A contrasting view is offered by cornucopians, who argue that scarcities can be overcome by human ingenuity, technological progress, the wise use of market mechanisms, or social and political institutions that promote cooperation (Simon, 1989, 1996; Lomborg, 2001; Kenny, 2011). For example, Wolf (1998) analyzes the patterns of state interactions over international freshwater resources and contends that resource competition is more likely to be accompanied by cooperation rather than conflict.

Similar disagreements run through the recent literature on the security implications of climate change. Pessimists predict an increased frequency and severity of armed conflicts as global

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warming progresses (Burke et al., 2009), while others view the conflict potential of climate change as small or overshadowed by more traditional determinants of violent conflict (see Buhaug, 2010; Bernauer et al., 2012b; Gleditsch, 2012).

In this article, we re-examine this controversy within a broader theoretical framework. Specifically, we focus on the demand for and supply of water resources, while also considering factors that may be conducive to restraint between the actors involved. To empirically test our arguments, we rely on time-series cross-section data on domestic water conflict and cooperation in 35 Mediterranean, Middle Eastern, and Sahel countries for 1997–2009: the water-related intrastate conflict and cooperation (WARICC) data by Bernauer et al. (2012a). We show that demand-side drivers, such as population pressure, agricultural productivity, and economic development, are likely to have a stronger impact on water conflict risk than supply-side factors, represented by climate variability. We also find that violent water conflicts in the study region are extremely rare, and that factors conducive to restraint, such as stable political conditions, may lead to cooperation. Overall, our analysis suggests that the joint analysis of demand, supply, and restraint improves the ability to account for domestic water-related conflict and cooperation.

The next section briefly reviews the existing (mainly empirical) literature on environmental degradation and conflict/cooperation. We then present the theoretical framework, where we classify our explanatory factors as representing demand, supply, and restraint. Next, we outline the research design and describe the empirical tests of our hypotheses. After discussing the findings, we conclude with an assessment of remaining gaps and ideas for further research.

## 2. Existing research on environmental factors and domestic conflict or cooperation – a short overview

There is a long tradition of empirical work on the security implications of environmental change in general and water scarcity in particular. The evidence offered by this literature is mixed, however. Whereas some single or comparative case studies contend that environmental stress is likely to lead to violent conflict (e.g., Libiszewski, 1996; Suliman, 1996; Homer-Dixon, 1999; Kahl, 2006), others argue that resource scarcity plays only a minor role in generating conflict (e.g., Benjaminsen, 2008; Kevane and Gray, 2008; Witsenburg and Adano, 2009). The discrepancy in conclusions between these works may be understood in part as a result of which cases have been analyzed. A limitation of the case-study tradition is its near-exclusive selection of cases involving conflict: a research design that fails to shed light on the absence of violence in other countries with similar scarcities or environmental problems (Gleditsch, 1998). In turn, this makes it difficult to draw firm conclusions across a wider range of countries and to generalize results.

The recent emergence of climate change as a major issue on policy agendas has led to a revival of the neo-Malthusian argument and a wave of quantitative studies examining possible links between climate variability and domestic violence. The bulk of this research provides little evidence for a powerful direct link between climate change or variability and armed conflict (Bernauer et al., 2012b; Deligiannis, 2012; Gleditsch, 2012; Scheffran et al., 2012; Meierding, 2013; Theisen et al., 2011; however, see also Hsiang et al., 2013), however, and research that finds significant effects does not agree on the direction of the relationship (for contrasting examples, see Theisen, 2008; Burke et al., 2009; Buhaug, 2010; Ciccone, 2011; Fjelde and von Uexkull, 2012; Hendrix and Salehyan, 2012; Koubi et al., 2012; Raleigh and Kniveton, 2012; Wischnath and Buhaug, 2014).

There is less statistical work addressing the effects of environmental change on a broader spectrum of interaction types

and most of the relevant research concerns international river basins in interstate relations (e.g., Wolf et al., 2003; Furlong et al., 2006; Mitchell and Hensel, 2007; Brochmann and Hensel, 2009; Bernauer and Kalbhenn, 2010; De Stefano et al., 2010; Kalbhenn, 2011; Brochmann, 2012; Brochmann and Gleditsch, 2012). The predominant finding from this literature is that cooperative interactions are more prevalent than conflictive interactions and that water-related international interactions involving violence are rare. Yet, it remains unclear whether this pattern is detectable also at a domestic level of interaction. In contrast to mainstream comparative climate-conflict studies, which rely on binary indicators of conflict/no conflict or event counts, our work is based on data (Bernauer et al., 2012a) that consider cooperation and conflict as relative phenomena along a common continuum (see also Zeitoun and Mirumachi, 2008; Zeitoun et al., 2010) and use issue coding to identify the issue at stake in each case (e.g., the quality of water supply in a city). This approach allows conflict and cooperation over domestic water issues to co-exist.

## 3. A theory of domestic water conflict and cooperation: demand, supply, and restraint

Water is an essential resource for human beings and it always features high on lists of scarce resources that may be worth fighting for, particularly in dry areas such as the Mediterranean region, the Sahel, or the Middle East (Libiszewski, 1996; Bernauer and Kalbhenn, 2010). Most writings in the neo-Malthusian tradition assume that the balance between the supply of and demand for scarce resources is important in generating social conflict (e.g., Percival and Homer-Dixon, 2001, p. 14). Unfortunately, the literature remains vague on which of the two is more relevant in generating conflict, and few studies have assessed this dynamic empirically (see Beck and Bernauer, 2011). The third causal component that we will consider here, i.e., restraint, is mostly absent from this previous research or it is implicitly assumed to be working through the other two mechanisms.

Against this background, we define domestic-level water conflict as *unilateral actions* by individuals, firms, NGOs, or state authorities, or *interactions* between them over water-related issues that are likely to or actually worsen the water quality/quantity at the domestic level. Conversely, we define domestic-level water cooperation as *unilateral actions* by individuals, firms, NGOs, or state authorities, or *interactions* between them over water-related issues that are likely to or actually improve the water quality/quantity at the domestic level. While cooperation and conflict can co-exist, we expect that water conflict is more likely when the demand for water is high, its supply low, and restraint against conflict ineffective. In turn, we generally expect more cooperation over water issues to arise when there is lower demand, higher supply, and more effective restraint. This argument is partially based on the idea that actors increase cooperative actions in anticipation of conflict in the future and mirrors Zeitoun and Mirumachi (2008, p. 300): “tensions rising from the distributional nature of water conflicts – that is, scrambles for a larger share of the pie – would be reduced, as the pie itself is enlarged.”

### 3.1. Demand

A major driver of freshwater demand is population pressure, which is at the core of the original Malthusian model and remains central to today's scenarios of future water stress. The logic is simple: higher population density, all else held constant, increases the demand for water and may also amplify inequality in access to this resource (e.g., Matthew and Gaulin, 2001; Gizelis and Wooden, 2010). According to a recent UNEP (2008) report, one-third of the African population now lives in drought-prone areas, and almost all

Sub-Saharan countries are probable to experience water stress by 2025. Africa is projected to increase from 1 billion people today to over 4 billion in 2100 (UN, 2013) and population density grows with it. Lower population density is likely to be associated with lower water demand, less conflict, and with more cooperation, because conflict may be anticipated due to population growth in the future.

A second demand factor is agricultural productivity, which reflects the interaction between domestic institutions and environmental pressures. These processes are linked to domestic water-related conflict and cooperation (Matthew and Gaulin, 2001; Gizelis and Wooden, 2010). The agricultural sector competes with urban and municipal water users and higher agricultural productivity may to increase the pressure on local water resources (Gizelis and Wooden, 2010, p. 448). This may also apply to virtual water—water used in the production process of goods that are consumed in elsewhere (Allan, 1997; Hoekstra, 1998). Virtual water through imports might therefore decrease pressure on local water resources in dry areas, because the water for production is used elsewhere. On the other hand, virtual water might also increase the pressure on water resources in dry areas if products are exported and, hence, the area is deprived of some of its own water. However, increasing a country's food imports (i.e., importing virtual water) and drawing on an exogenous water source is only one side of the coin, since domestic agriculture is often a highly politicized topic and is rarely treated in a purely pragmatic way. Due to our sole focus on domestic demand factors and limitations in data availability on virtual water flows, we do not consider the concept of virtual water in our theoretical argument here.

Even in the absence of significant population pressure, the demand for freshwater in low- and middle-income countries is likely to increase with economic development and related processes, such as industrialization, energy production, health and sanitation developments, or changing food habits, including the expansion of irrigation systems in arid regions (Hoekstra and Chapagain, 2006; Gleick, 2011). Only in wealthy and technologically advanced societies is the net effect of additional development likely to lower the mean water consumption per capita (i.e., increasing efficiency and substitution strategies outweigh increasing demand from changing consumption habits). Note that economic development may also be seen as a supply and a restraint factor, which we discuss below.

This reasoning seems at odds with empirical research that finds low economic development, typically measured by a state's income level, to be a robust correlate of civil war (Hegre and Sambanis, 2006; Ward et al., 2010). Wealthier societies are on average less exposed to armed domestic conflict, whether because of individual opportunity costs (Collier and Hoeffler, 2004) or state capacity (Fearon and Laitin, 2003). But that literature only considers the extreme outcome of civil war and offers little insight into the dynamics within the especially heterogeneous sample of lower-level violence in this study. These rationales lead us to the first set of hypotheses:

**Hypothesis 1a.** Higher population density is more likely to increase the risk of domestic water conflict than the probability of water cooperation.

**Hypothesis 1b.** Higher agricultural productivity is more likely to increase the risk of domestic water conflict than the probability of water cooperation.

**Hypothesis 1c.** Higher economic development is more likely to increase the risk of domestic water conflict than the probability of water cooperation.

A corresponding argument can be made for domestic water cooperation. Factors such as population density, agricultural

productivity, and economic development increase pressure on water resources and the competition for these resources can create tensions between different water users. In turn, these tensions create pressure on water-managing institutions to find solutions for allocation problems in order to avoid conflicts over water. Provided that a state is equipped with functioning management institutions, water scarcity could lead to cooperative solutions (Ostrom, 1992; GWP, 2000; Baland and Platteau, 2003; Swyngedouw, 2004) for water allocation, innovative technologies, or new ways of water exploitation. Thus, increased competition for water provides a strong incentive for cooperation. This counterargument leads us to a second, and contradictory, set of hypotheses:

**Hypothesis 1d.** Higher population density is more likely to increase the probability of domestic water cooperation than the risk of water conflict.

**Hypothesis 1e.** Higher agricultural productivity is more likely to increase the probability of domestic water cooperation than the risk of water conflict.

**Hypothesis 1f.** Higher economic development is more likely to increase the probability of domestic water cooperation than the risk of water conflict.

Ultimately, however, whether the first set of arguments or the counterarguments are more influential on domestic water conflict and cooperation has to be assessed empirically.

### 3.2. Supply

The supply of water is usually determined by natural factors, the most prominent being seasonal variations and long-term changes in climate patterns. The Intergovernmental Panel on Climate Change (IPCC, 2007) defines climate as “average weather,” usually over a 30-year period. Given our focus on short-term changes in supply, we will refer to this factor as “climate variability” rather than “climate change.”

The level of precipitation and temperature from one year to the other are manifestations of climate variability. It affects evapotranspiration as well as snow cover, which in some regions acts as a natural reservoir of freshwater that eventually becomes available downstream during the summer months (Parry et al., 2007). While anthropogenic climate change will impact average levels of water availability in the longer term, the main human determinants of supply in a shorter perspective are found in the form of dams and reservoirs, which regulate water flow and make water supply more manageable and predictable (but may also create ecological problems and societal challenges downstream), as well as groundwater extraction and desalination of sea water. In most societies, including the study region of our analysis, temporal and spatial variations in precipitation and temperature patterns give a representative image of variations in local water supply. That being said, water supply is more than a simple function of deviations in rainfall and temperature patterns. Water storage capacities in the form of reservoirs or dams, river flows across water basins, and general water dependency are likely to matter as well. Hence, although we argue that temporal and spatial variations in precipitation and temperature patterns give a representative image of variations in local water supply, these variables might be somewhat crude proxies. We return to this issue in the conclusion.

Against this background, we examine the following supply-side hypothesis:

**Hypothesis 2.** More extreme climate variability is more likely to increase the risk of domestic water conflict than the probability of water cooperation.

### 3.3. Restraint

We add the notion of restraint to these (neo-) Malthusian hypotheses. Although resource scarcity of one kind or another is a widespread condition, scarcity by itself does not lead to open competitive confrontation and the eruption of armed conflict in most cases. Hence, “something holds us back from violence,” although this “something” does not necessarily mean that conflict is absent or that cooperation is given if we also consider non-violent conflicts. In principle, there may be a host of factors that determine a society’s restraint against escalating water conflicts, but we focus on what is arguably the most important contextual dimension, i.e., domestic institutional characteristics.

The “democratic peace” refers to the observation that democracies rarely, if ever, fight one another (e.g., [Oneal and Russett, 1999](#)). Democracies are superior providers of public goods and more likely to have stronger environmental policies to the extent that they cooperate in finding joint solutions to environmental problems (e.g., [Payne, 1995](#); [Lake and Baum, 2001](#); [Neumayer, 2002](#); [Bättig and Bernauer, 2009](#)). Thus, if water-related social problems are amenable to solutions, they are less likely to escalate to conflict in democracies. Indeed, [Gizelis and Wooden \(2010\)](#) find that democratic institutions mitigate the impact of water scarcity on intrastate-armed conflict.

However, it has also been suggested that authoritarian regimes are better able to address water allocation problems, because they can impose policies and suppress opposition more effectively. [Bernauer and Siegfried \(2007, 2012\)](#), for example, show that there was less water-related conflict in the Aral Sea basin under Soviet rule than in the somewhat more democratic post-Soviet environment. Furthermore, increasing levels of democracy are likely to open up more “political space” for people to express their grievances (see also [Payne, 1995](#)) and to engage in conflictive interactions with other water users or authorities that regulate water supply. Consequently, the democratic restraint against environmental conflict may in fact only kick in at relatively high (i.e., violent) levels of severity, implying that we may expect an overall higher degree of water conflict in democratic regimes than in non-democratic ones, although this degree is unlikely to escalate to the use of armed force in democracies. Based on this, we seek to test:

**Hypothesis 3a.** A higher level of democracy is more likely to increase the risk of domestic water conflict than the probability of water cooperation.

Another argument in the realm of political institutions concerns political stability. Numerous studies have shown that both highly authoritarian and highly democratic countries are more durable and less exposed to violent internal power struggles than so-called anocracies, i.e., unstable regimes located “between” pure autocracies and democracies ([Vreeland, 2008](#); [Gleditsch et al., 2009](#)). This dynamic is likely to influence how water scarcity and distribution challenges are handled ([Bernauer and Siegfried, 2007](#)). Our final hypothesis is then:

**Hypothesis 3b.** Higher political stability is more likely to increase the probability of domestic water cooperation than the risk of water conflict.

## 4. Research design

### 4.1. Data and dependent variables

To evaluate our hypotheses, we employ recently compiled event data on water-related conflict and cooperation in 35 Mediterranean, Middle Eastern, and Sahel countries for 1997–2009: the WARICC data by [Bernauer et al. \(2012a\)](#). In its original

form, the dataset is structured such that there is one observation per water-related event. As indicated above, an event is defined as *unilateral actions* by individuals, firms, NGOs, or state authorities, or *interactions* between them over water-related issues. The events were coded from media reports retrieved from BBC Monitoring. The potential for “media bias,” i.e., greater media attention in countries with a free press (see, e.g., [Li, 2005](#); [Drakos and Gofas, 2006](#)) is discussed in the appendix to the article presenting the dataset ([Bernauer et al., 2012a](#)). Examples of typical events are initial talks about the construction of a new water-supply network to improve the water quality of a region; an agreement on that new project that is signed a few months after the initial talks; and the construction of the water-network. Although these hypothetical events are obviously related, each event is considered separately and assigned a value for the intensity of conflict or cooperation. Events that do not result from human action, but are imposed by nature (e.g., extreme weather events) are not coded. A detailed description of the data is given in [Bernauer et al. \(2012a\)](#), but [Figs. 1 and 2](#) here provide a short overview of countries and events. The full dataset contains records of 10,352 water-related events.

The key variable in this dataset, the *Water Events Scale (WES)*, measures the intensity and impact of a domestic water-related event in an ordinal fashion. This scale consists of 11 points, ranging from –5 (most conflictive event) to +5 (most cooperative event). Events assigned to the +5-category imply a very extensive role for any kind of actor in trying to initiate or implement policies, programs, or actions that substantially improve the quality or quantity of water in the whole country. Only 70 events (0.68 percent of the sample) involve physical violence and are given the maximum conflictive score of –5. There are 1780 conflictive non-violent events (18 percent), while 3665 (35.40 percent) are cooperative. Finally, about 47 percent of recorded events are neither cooperative nor conflictive (i.e., neutral or the 0-category). Evidently, violent water-related events are extremely rare and studying only those would exclude the large majority of water-related social interactions. [Table 1](#) provides a more detailed overview of the WES, while [Table 2](#) illustrates the coding of this measure with some examples.

We aggregate these data to the country-year, which serves as our unit of analysis ( $N = 446$  country-years). For the first set of empirical tests, we use the yearly mean value of the WES for each country as the dependent variable. Note that median or weighted means also seem appropriate for aggregating the WES values for the single events into a country-year format. We carried out robustness checks using such measures (mean, median, weighted means/medians by cooperative and conflictive events, weighted means/medians by the standard deviation, raw counts of conflictive and cooperative events, and ratios of conflictive and cooperative events per country-year) to ensure that our results are not artifacts resulting from a specific aggregation strategy. We provide further details on these tests in the online appendix, but note the findings presented below are robust to using these alternative ways of aggregation.

The second set of empirical assessments, which builds on in-sample and out-of-sample predictions, employs two dichotomous variables: the first (cooperation) receives a value of 1 if the mean WES score in a given country year is positive (0 otherwise); the second (conflict) receives a value of 1 if the mean country-year WES score is negative (0 otherwise).

### 4.2. Explanatory variables – demand side

According to our theory, the following three demand facets are likely to affect water resources and, therefore, also cooperation and conflict: population density, agricultural productivity, and economic development. Population density is measured as the midyear population divided by land area in square kilometers. Additionally,



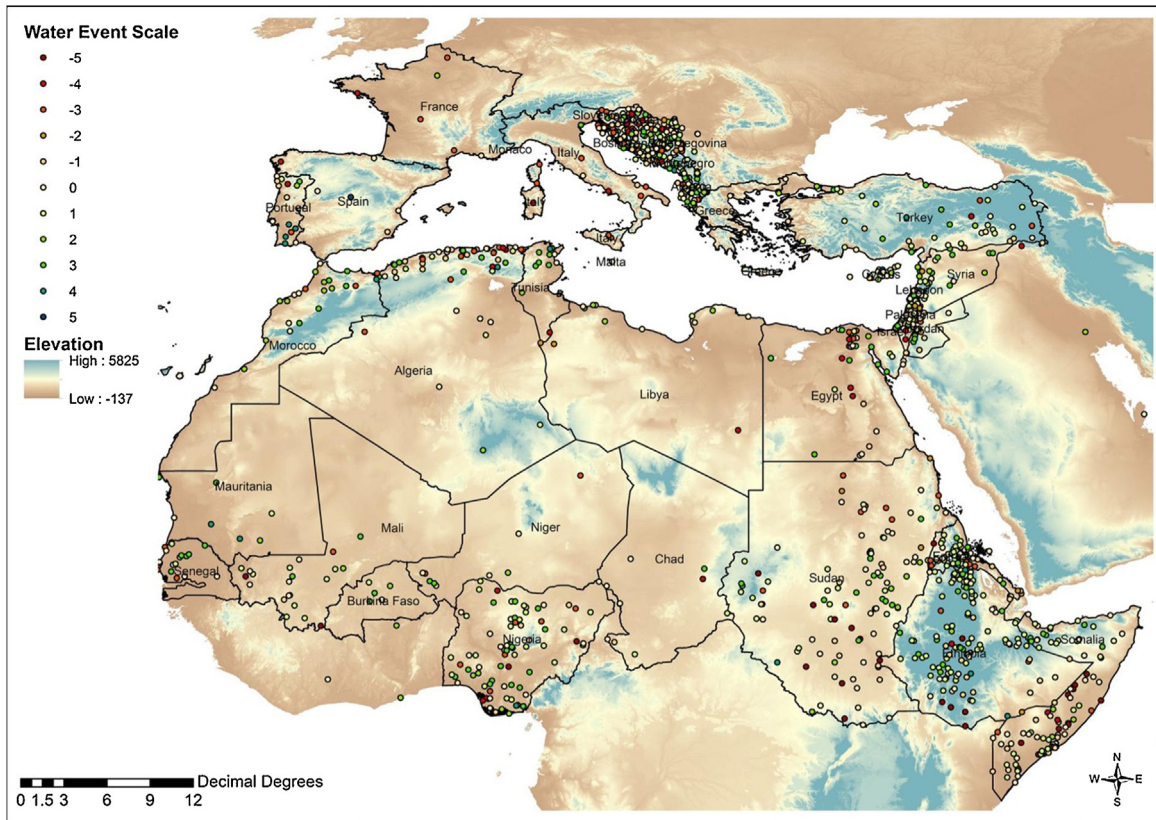


Fig. 1. Events coded by location in data, 1997–2009.

we incorporate a measure of agricultural productivity. [Gizelis and Wooden \(2010, p. 448\)](#) note that a country’s degree of agricultural productivity measured as the ratio of the crop production index to the percentage of agriculture land “captures demand-side water use

and indicates how productive a country’s agriculture is relative to the amount of land being used” for this purpose. Finally, to operationalize a country’s overall level of economic development, we use *GDP per capita*. While the data for all demand-side variables

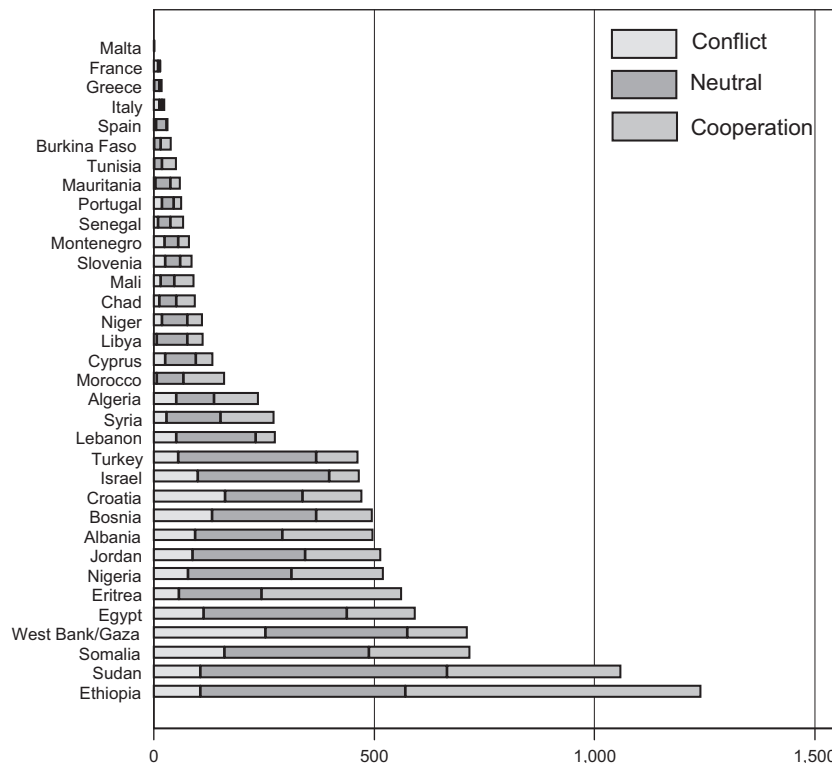


Fig. 2. Events coded per type and (state) entity/country in data, 1997–2009.

**Table 1**  
Water events scale (WES).

Value	Description	Events recorded
5	Events that are likely to or do result in substantial improvement with respect to water quality/quantity in the country as a whole.	31
4	Events that are likely to or do result in substantial improvement with respect to water quality/quantity at the regional level within the respective country.	111
3	Events of moderate intensity that may result in an improvement with respect to water quality/quantity at the regional or national level within the respective country.	1138
2	Agreements signed or other measures formally adopted that signal commitment to improvement with respect to water quality/quantity at the regional or national level.	985
1	Events that are likely to or do result in a very small improvement with respect to water quality/quantity at the local level.	1400
0	Routine and purposive actions on water issues that have no identifiable positive or negative impact on water quality/quantity.	4837
-1	Events that are likely to or do result in a very small negative impact on water quality/quantity at the local level.	639
-2	Tensions within government (intrastate) or between countries (inter-state) that may affect water quality/quantity at a domestic level.	425
-3	Large-scale and general opposition of the public toward policies and actions that have negative implications for water quality/quantity at the regional to national level.	328
-4	Events that are likely to or do result in a deterioration with respect to water quality/quantity at the regional level within the respective country.	293
-5	Events that are likely to or do result in a deterioration with respect to water quality/quantity at the national level; physical violence associated with water problems.	165
Total		10,352

Reproduced from Bernauer et al. (2012a, p. 537).

are taken from the World Bank Development Indicators, we use the natural log for the first and third of these variables to deal with skewed distributions and expected non-linear effects.

#### 4.3. Explanatory variables – supply side

We measure climate variability with data for temperature and precipitation. To this end, we include the absolute deviation of the current level of precipitation and temperature, respectively, from past long-run levels, i.e., the 30-year moving average (see IPCC, 2007; Koubi et al., 2012). Hence, we treat climate variability as a large-scale phenomenon that is beyond human control at the local level and within the short to medium term. The precipitation data, measured in mm per year, are taken from the Global Precipitation Climatology Center (GPCC) (Beck et al., 2004); the temperature data are measured in degrees Celsius and stem from the University of Delaware's Global Surface Air Temperature Database (Matsuura and Willmott, 2009). Both climate indicators are derived from high-resolution statistics that were aggregated to the country level using the PRIO-GRID framework (Tollefsen et al., 2012). Missing climatological data for Malta and Monaco were replaced by data for nearby areas in Italy and France, respectively.

#### 4.4. Explanatory variables – restraint factors

For democracy, we rely on the *polity2* variable from the Polity IV dataset (Marshall and Jaggers, 2013). This item captures a state's

degree of democracy along three dimensions (Marshall and Jaggers, 2013, p. 14): “the presence of institutions and procedures through which citizens can express effective preferences about alternative policies and leaders. Second, the existence of institutionalized constraints on the exercise of power by the executive. Third, the guarantee of civil liberties to all citizens in their daily lives and in acts of political participation.” The final variable taken from this dataset ranges between –10 (full autocracy) and +10 (full democracy). Data for Bosnia and West Bank/Gaza are missing in these data and we imputed values of zero to mitigate potential consequences of missing data.

Second, political (in-) stability is measured by an indicator that counts the number of years since a country entered the Polity IV dataset in 1800 or had a three-point change (“most recent regime change”) in the *polity2* score in either direction of the scale over a period of three years or less (Marshall and Jaggers, 2013, p. 17). This coding rule also applies to the end of a transition period, i.e., “the lack of stable political institutions” (Marshall and Jaggers, 2013, p. 17). As soon as such a change occurs, this count item is reset to 0 and the count starts again. Hence, the higher the values on this variable, the more politically stable a country.

#### 4.5. Descriptive statistics and methodology

All right-hand-side variables are lagged by one year to minimize endogeneity. Table 3 summarizes the descriptive statistics and variation inflation factors (VIFs) of all variables in

**Table 2**  
WES with examples from data.

Value	Description	Country	Year
5	National emergency water plan is implemented – comprises mini stations for desalination, drillings, transfers from other dams, etc.	Algeria	2002
4	Ministerial meeting agrees to reduce price of water per cum. for Sheikh-Zayed canal and pumping station	Egypt	1999
3	Lebanon inaugurates water project	Lebanon	2002
2	Jordan and Italy sign agreement to finance water network project	Jordan	2001
1	Workshop organized by ministry of mines, energy, and water resources on the provision of potable water	Mali	2003
0	Algerian and Yugoslav business men discuss cooperation in different sectors – including water supplies and dams	Algeria	1997
-1	Janjawid militia controls water wells – residents of camp run out of water	Sudan	2008
-2	Syrian-Israeli talks on reaching an agreement on water in Golan region – talks fail	Israel	2000
-3	Niger delta rebel group complains about lack of water supply – explicit warning against president	Nigeria	2008
-4	Water supply is interrupted on island of Vis	Croatia	2001
-5	People killed in tribal clashes over water points	Ethiopia	2001

Reproduced from Bernauer et al. (2012a, p. 538).

**Table 3**  
Basic information on variables.

	Obs.	Mean	SD	Min	Max	VIF
WES – country-year mean	446	0.25	0.92	–4	3	
WES – cooperation dummy	446	0.56	0.50	0	1	
WES – conflict dummy	446	0.25	0.43	0	1	
Population density	446	4.22	1.65	0.83	9.78	1.41
Agricultural productivity	442	3.93	5.32	0	36.25	1.12
GDP per capita	430	7.89	1.74	4.73	12.13	2.81
Temperature – 30-year MA	446	0.25	0.44	–1.12	1.34	1.08
Precipitation – 30-year MA	446	0.10	102.72	–383.74	325.56	1.05
Democracy	446	2.50	6.43	–9	10	2.12
Political stability	420	18.10	17.45	0	61	1.67

Note: “MA” in this and all subsequent tables refers to “moving average.”

the analysis. The VIFs demonstrate that the explanatory factors have low levels of multicollinearity. All items display a VIF that is well below the threshold level of 5. However, to control for any remaining multicollinearity and to ensure the robustness of our findings, we also run models where we introduce the variables on demand, supply, and restraint separately into our estimations.

Our main empirical estimation strategy is based on a widely used method for analyzing panel data, i.e., Prais–Winsten regression models with panel-corrected standard errors and an AR1 autocorrelation structure (Beck and Katz, 1995, 1996). This approach controls for panel heteroskedasticity and contemporaneous as well as serial correlation. Tests indicate that country-fixed effects are unnecessary in our case, and we also leave out a lagged dependent variable. In sensitivity tests, however, we estimated models with a lagged dependent variable that may model temporal dynamics more accurately or year-fixed effects that control for exogenous system-wide shocks that are common to all countries in our dataset. These results are virtually the same as the ones reported below. This alternative specification and other tests that are not reported in the text are documented in the web appendix and can be replicated with our replication data files.

Ward et al. (2010) remind us that drawing inferences from statistically significant results might be misleading in that they tell us little about the predictive power of a covariate or an entire model. To address this point, we assess the ability of our full model (Model 4) to actually predict countries' level of water-related

cooperation or conflict by using in-sample and out-of-sample prediction techniques that rely on the binary dependent variables of water conflict and cooperation.

## 5. Empirical findings

Table 4 shows the results of our first estimation strategy. Model 1 focuses on the demand-side variables. Model 2 and Model 3 employ the same approach, but for the supply-side and restraint factors, respectively. Model 4 is the full model with all explanatory variables.

The model-fit statistics alone indicate that some of our hypotheses are unlikely to hold. In particular, Model 2, which exclusively looks at the supply-side variables, has virtually no explanatory power and we cannot reject the null hypothesis that all coefficients in that model are jointly indistinguishable from 0. This is mirrored by the coefficients on climate variability as expressed by temperature and precipitation deviations from the 30-year moving average. While these coefficients are negative, suggesting a conflict-increasing effect of climate variability, they are not statistically significant in any model. We conclude that the impact of the supply-side items is low at best. Despite our “more nuanced” focus on domestic water-related conflict (most of which is non-violent) and cooperation, our result is in line with previous research (e.g., Koubi et al., 2012), which finds that there is little evidence for a direct impact of climate variability on armed conflict onset.

With regard to the demand-side indicators, all three variables have a negative sign, which corresponds to our theoretical expectations. Most of their significance levels are sensitive to model specifications, though, and we cannot place much faith in the revealed substantive impact of either *population density* or *agricultural productivity*. Put differently, the significance levels depend on which explanatory variables we consider simultaneously in our models. These results are not surprising when considering the two contradictory theoretical arguments relating water demand to conflict and cooperation, though. Both explanations have valid arguments for the occurrence of conflict and cooperation, but it is difficult to assess this question empirically without data on water-management institutions. Nevertheless, the demand-side variables do seem to perform better on average than

**Table 4**  
The determinants of domestic water-related conflict and cooperation.

	Model 1 (Demand)	Model 2 (Supply)	Model 3 (Restraint)	Model 4 (Full)
Population density	–0.036 (0.023)			–0.039 (0.046)
Agricultural productivity	–0.008 (0.007)			–0.017 (0.006)***
GDP per capita	–0.138 (0.033)***			–0.133 (0.054)**
Temperature – 30-year MA		–0.060 (0.084)		–0.081 (0.091)
Precipitation – 30-year MA		–0.001 (0.001)		–0.001 (0.001)
Democracy			–0.046 (0.010)***	–0.029 (0.012)**
Political stability			0.002 (0.003)	0.008 (0.003)**
Constant	1.541 (0.313)***	0.256 (0.046)***	0.307 (0.067)***	1.477 (0.480)***
Obs.	426	446	420	400
Wald $\chi^2$	21.44***	0.83	20.36***	50.91***
R <sup>2</sup>	0.05	0.00	0.05	0.09

Note: Panel-corrected standard errors in parentheses. A negative sign on a coefficient indicates a conflict-promoting effect with higher values on the covariate.

\* Significant at 10%.

\*\* Significant at 5%.

\*\*\* Significant at 1% (two-tailed).

the supply-side items. The fit of Model 1 is higher than the fit of Model 2 and at least one of the demand-side influences reaches conventional significance levels in any model of Table 4.

The relatively stronger result for demand factors is primarily driven by economic development as measured by *GDP per capita*. Although *GDP per capita* has been identified as one of the most robust negative influences on civil war (Hegre and Sambanis, 2006; Ward et al., 2010), our models indicate that economically developed countries are more likely to see water-related conflict. A one-unit increase on this variable is associated with an increase of about 14 percent on the *WES* variable. This finding supports our theoretical argument that more economic development is associated with increased consumption of natural resources in general and freshwater resources in particular (Rock, 1998). In turn, while more economic development may decrease the risk of high-intensity civil conflict, it actually increases the probability that a country experiences more low-intensity (non-violent) disputes over water resources.

Coming to the restraint factors, these variables largely perform as expected and reveal robust effects on domestic water-related conflict and cooperation. Adding or suppressing variables from the models does not alter these findings. According to Models 3 and 4, the democracy impact is negative and significant. A one-unit increase on the democracy index is associated with a 3.75 percent decrease on the *WES* on average. It seems that authoritarian regimes can indeed solve water allocation problems more effectively than democracies by imposing solutions and suppressing opposition (Bernauer and Siegfried, 2007, 2012). This interpretation is also in line with the claim that there is more “political space” in democracies for people to express their grievances and engage in conflictive interactions with the government (Payne, 1995).

It has been suggested that the conflict-increasing effect is likely to fade or reverse at high levels of democracy and that democracy is likely to confine water conflict to non-violent forms. Hegre et al. (2001) conclude that the relationship between democracy and civil conflict follows an inverted U-shaped relationship, with the highest risk of conflict in the semi-democratic (or anocratic) zone. While such a curvilinear relationship is not detectable in our data, we do find that the apparent conflict-inducing effect of democracy is reserved for non-violent water conflicts. Violent conflict over water resources is overwhelmingly a non-democratic phenomenon; only three of the 31 country-years in our data that saw at least one violent event over water took place in democratic regimes – in Italy, Croatia, and Israel. These descriptive statistics are further supported by unreported regression estimations using either violence onset in a country year or the number of water-related casualties per year as dependent variables: democracy has a negative, i.e., violence-dampening, and statistically significant impact.

*Political stability* has a conflict-reducing effect: the coefficient of this variable is positive and significant in one out of two models, meaning that higher levels of stability are associated with more cooperative outcomes. The substantial impact of this item is rather low, however. On average, we only see an increase of about 1 percent in domestic water-related cooperative behavior. Since this item only approaches statistical significance in one model, its impact is also likely to depend on model specification.

## 6. In-sample and out-of-sample predictions

We conducted a wide range of robustness checks to assess whether our findings are sensitive to changes in model specifications or estimation procedures. Here, we focus on in-sample and out-of-sample predictions of domestic water-related conflict and

cooperation. First, we replicated Model 4 from above in a probit regression setup with different sets of cubic splines for temporal correction (Beck et al., 1998). For these two models, we used the dichotomous indicator of cooperation and conflict, respectively. As demonstrated in Table 5, the results of these estimations do not reveal substantial changes over Model 4. Thus, we proceed with Fig. 3 that builds on the models in Table 5.

This figure summarizes one possible avenue of in-sample prediction, i.e., the ordered grouping of the predicted probabilities of either *WES – cooperation dummy* or *WES – conflict dummy* by quintiles and comparing these with the actual instances of water cooperation and conflict in our data. Using quintiles instead of terciles seems more suitable with our events, since this reflects the long tail in the distribution of the predicted probabilities more accurately. We refer to the fifth quintile as the “most likely” group, the fourth quintile as the “moderately likely” group, and the bottom three quintiles as the “least likely” group. The predictive power of our full model is relatively high, regardless of whether we focus on water conflict (right panel) or cooperation (left panel). The fifth and the fourth quintiles combined, i.e., the most and moderately likely groups comprise 135/241 cooperative and 67/98 conflictive events. Put differently, those predicted probabilities that form these particular forecasting categories already predict 56 percent of water-cooperation years and 68 percent of water-conflict years correctly. Consequently, only 106 country-years that actually saw more cooperation than water-related conflict are characterized as least likely cases, i.e., our model would not predict that we observe a mostly cooperative behavior over domestic water issues – although we did in reality. We find a similar pattern for conflict: 31 country-years that actually saw more conflict than water-related cooperation are characterized as least likely cases. In sum, this initial check of the in-sample predictive power seems promising.

In Fig. 4, we show Receiver Operator Characteristic (ROC) plots based on Table 5. Generally, models with more predictive power generate “true positives at the expense of fewer false positives” (Ward et al., 2010, p. 366). A perfectly predictive model would correctly classify all actual cases of water-related conflict or

**Table 5**

The determinants of domestic water-related conflict and cooperation – probit analyses.

	Model 5 ( Cooperation)	Model 6 (Conflict)
Population density	0.007 (0.084)	0.120 (0.099)
Agricultural productivity	−0.005 (0.013)	0.030 (0.009)***
GDP per capita	−0.151 (0.075)**	0.105 (0.091)
Temperature – 30 year MA	−0.107 (0.139)	0.208 (0.184)
Precipitation – 30 year MA	−0.001 (0.001)	−0.001 (0.001)
Democracy	−0.046 (0.018)**	0.040 (0.020)**
Political stability	0.004 (0.006)	−0.013 (0.007)
Constant	1.762 (0.445)***	−1.636 (0.618)***
Obs.	400	400
Wald $\chi^2$	107.37***	61.00***
Pseudo $R^2$	0.19	0.18

Note: The table entries are probit coefficients. Standard errors clustered on country in parentheses. Cooperation (conflict) years variable and cubic splines included in both models, but not reported.

\* Significant at 10%.

\*\* Significant at 5%.

\*\*\* Significant at 1% (two-tailed).



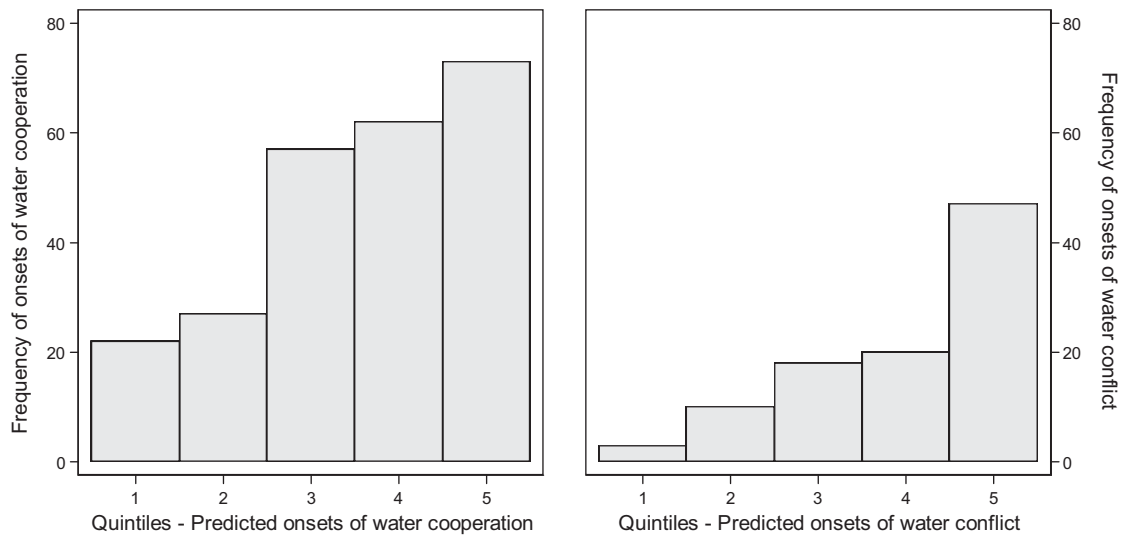


Fig. 3. Frequency of water cooperation and conflict by prediction quintiles.

cooperation and never generate false positives, i.e., cases of conflict or cooperation predicted by our model, but not actually occurring. Our models predict water-related conflict or cooperation by no means perfectly, but they do have a higher predicted probability for a randomly chosen positive event than for a non-event (represented by the diagonal). This is mirrored by the area under ROC curve statistic (AUC), which theoretically varies between 0.5 (no predictive power) and 1.0 (perfect predictive power). As demonstrated by Figs. 3 and 4, our models that distinguish between water cooperation and conflict perform well above average in this regard, i.e., above an AUC of 0.5.

Finally, the question remains whether this conclusion holds for the harder test of an out-of-sample prediction. We use a four-fold cross validation quasi-experimental setup that was repeated ten times (Ward et al., 2010, p. 370) – both for the full model that employs *WES – cooperation dummy* as the dependent variable and for a similarly specified model that examines *WES – conflict dummy*. The exact procedure for this cross-validation is described in Ward et al. (2010) and can be replicated with our data files. In short, however: cross-validation relies on dividing existing data

into subsets, using random assignment of the cases to the different sets. All except one of the subsets are then pooled together and routinely estimated by applying the preferred model specification. Fig. 5 depicts our findings. As one would expect the predictive power of either model decreases as compared to the in-sample values. Nevertheless, the power of the models remains quite high (AUC = 0.755 on average for left panel; AUC = 0.735 on average for right panel).

In addition to these prediction tests, a number of additional sensitivity tests were carried out, which are described in the online appendix. These tests included, among others, corrections for possible endogeneity between political institutions and domestic water cooperation and conflict, alternative climate variability indicators, or two-stage regressions estimating the effect of climate variability on conflict/cooperation via economic performance. In total, the online appendix refers to more than ten pages that are comprised of nine tables and two graphs. While we would like to refrain from emphasizing one over the other robustness checks, all of them are explained in detail in this appendix. That said, please note that neither of these additional

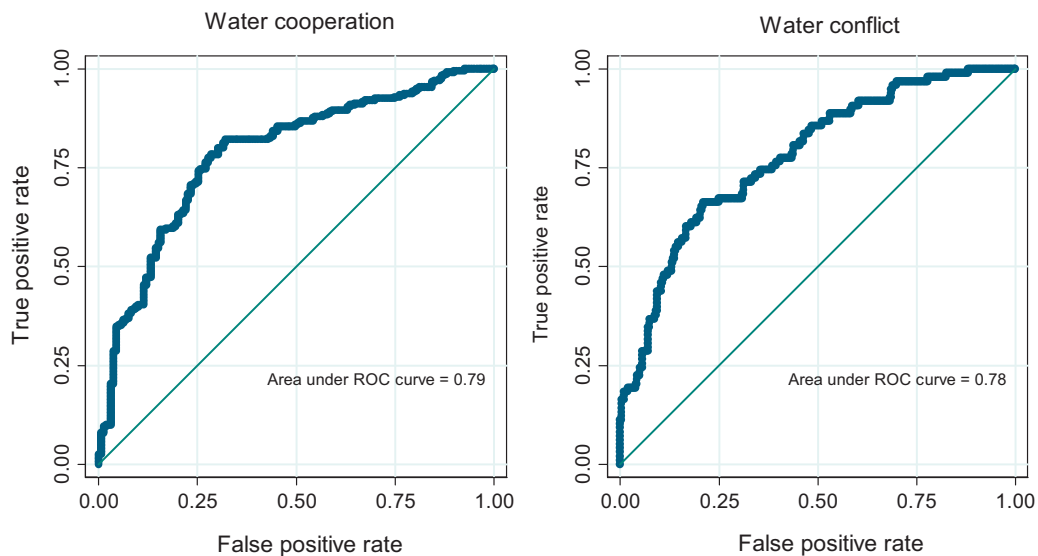
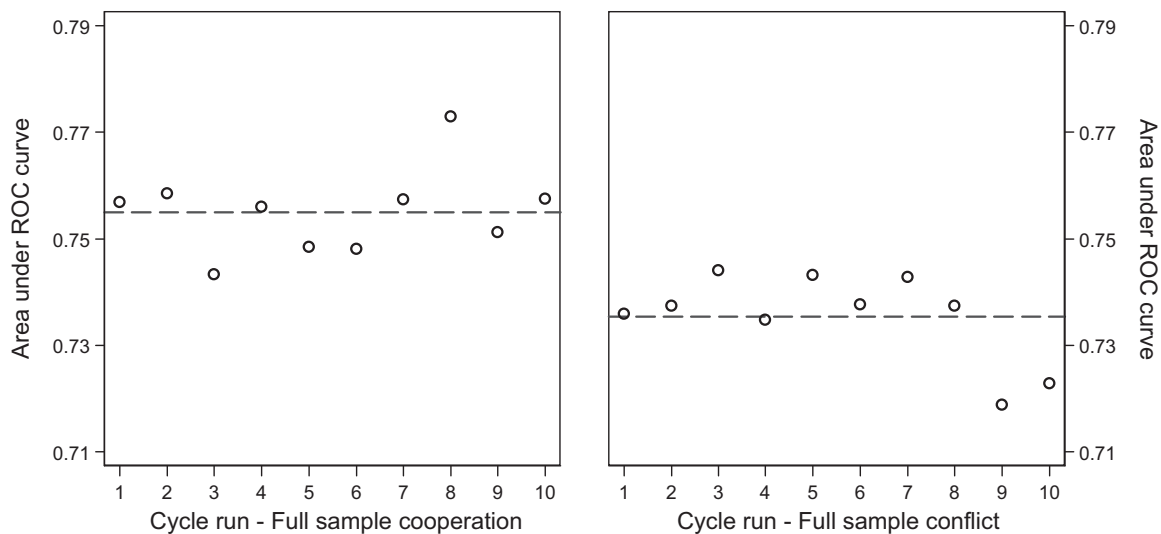


Fig. 4. In-sample prediction: area under ROC curve for cooperation and conflict.



**Fig. 5.** Out-of-sample prediction: four-way cross-validation exercise. *Note:* Left panel pertains to estimates of AUC for WES – Cooperation Dummy. Right panel pertains to estimates of AUC for WES – Conflict Dummy. Four-way cross validation estimates are shown by dots, dashed horizontal line signifies mean estimate AUC over all four-way cross-validations that were repeated for 10 different random partitions of the data.

tests produced findings that deviate substantively from those reported here.

## 7. Conclusion

In this study, we ask which factors drive domestic water-related conflict and cooperation. Is it the supply of, the demand for water resources, or institutional restraints against overt social conflict? The empirical analysis provided evidence that demand (primarily, economic development; to a smaller degree *agricultural productivity* and *population density*) as well as institutional restraint (primarily, *democracy*; to a smaller degree *political stability*) influence domestic water-related interaction. But we did not find any indication that short-term variations in water supply, as captured by precipitation and temperature patterns, matter for domestic water-related conflict/cooperation dynamics. This finding speaks to the broader debate on climate security and appears to substantiate other research that fails to find a systematic relationship between climate variability and more severe forms of conflict, notably armed conflict. Social interaction is shaped by opportunities and restraints determined in large part by the qualities of the societies themselves – not by nature.

The analysis also revealed that whereas economic development and democracy seem to tilt the balance of water-related interaction toward more conflictive behavior, this is the case only for non-violent events; violent conflict over water is almost exclusively a non-democratic phenomenon. Accordingly, democratic systems may provide opportunities for protest (and a free press is also more likely to pick up and report conflict events), and development-related processes may put increasing strains on scarce water resources, thus increasing the conflict potential. Nonetheless, the political institutional mechanisms of these systems ensure that such conflictive interactions are kept at a manageable, non-violent level.

Drawing on recently compiled data on water-related events across a broad spectrum of interaction types, from overt violent conflict to high-impact cooperative initiatives (Bernauer et al., 2012a,b), this analysis provides a significant extension to the literature's habitual dichotomous treatment of such events. However, our study has only scratched the surface of understanding drivers of such interactions, and future research should invest more in modeling, theoretically as well as empirically, when, how,

and what kind of cooperation may provide the optimum solution to imminent water scarcities.

More research is also needed to better understand local dynamics. This analysis is based on aggregated country-level data, but it is not unlikely that a more nuanced high-resolution assessment (see Cederman and Gleditsch, 2009; Fjelde and von Uexkull, 2012; Wischnath and Buhaug, 2014) may uncover new dynamics of supply, demand, and restraint-side drivers of water- and environment-related interaction. Similarly, the variables we employed in order to capture climate variability should have given a representative image of variations in local water supply. However, these proxies may be too abstract. Next to the discussion we provide in Section 3.2, also consider that water supply may also be based on groundwater in our sample's region, which depends on precipitation levels, but not exclusively. For example, years might be considered as drought-years due to crop failures caused by a deleterious distribution of rainfall – despite normal or average yearly precipitation levels. Other factors – at a more disaggregated level – are likely to matter as well and could have very different characteristics and consequences, e.g., floods, droughts, water storage capacities, freshwater derived from river basins, or general water dependency.

## Conflicts of interest

The authors declare no conflicts of interest.

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## Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at [doi:10.1016/j.gloenvcha.2013.11.018](https://doi.org/10.1016/j.gloenvcha.2013.11.018).

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