Supporting Information for

International Agreement Design and the Moderating Role of Domestic Bureaucratic Quality: The Case of Freshwater Cooperation

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This supporting document contains additional information and tables mentioned in the main text. All data and code required to reproduce the results in this study are available in a replication package posted at https://dataverse.harvard.edu/dataverse/jkarreth.

This supplementary document (to be made available online) contains supporting information on:

- The spatial distribution of river treaties
- Summary statistics
- The variance of water-related cooperation across time and across pairs of states
- The distribution of river treaty institutionalization and the bureaucratic quality measure
- Details on the bureaucratic quality measure
- Regression equation and predictions for coefficients
- Full results and marginal effects for all robustness tests discussed in the main text
- Seemingly unrelated regression results
- Details on estimating the instrumental variable solution
- Details on motivation, sources, and findings for control variables
- References used in the discussion of case evidence
- References cited in the supporting information

The spatial spread of river treaties

In 1960, the typical treaty in most regions outside of North America and Western Europe had 0 or 1 institutionalized feature on average. In 2000, in all regions of the world, including the developing world, the typical number of treaty features was higher than 2 in most regions. Figure A1 shows this spread of river treaty institutionalization especially in Asia and Africa.

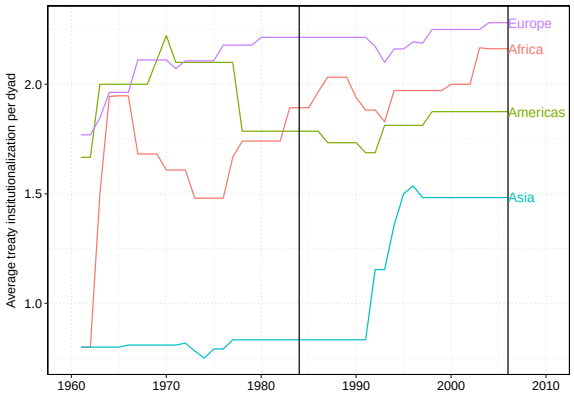


Figure A1. The evolution of river treaty institutionalization. The figure shows the average number of institutionalized treaty features in riparian dyads in each continent from 1960 to 2013. The area between the two black vertical bars is the time period we study in our analyses.

The map below shows the presence of river treaties across the world in 2000. This illustrates that river treaties are now present in all parts of the world.

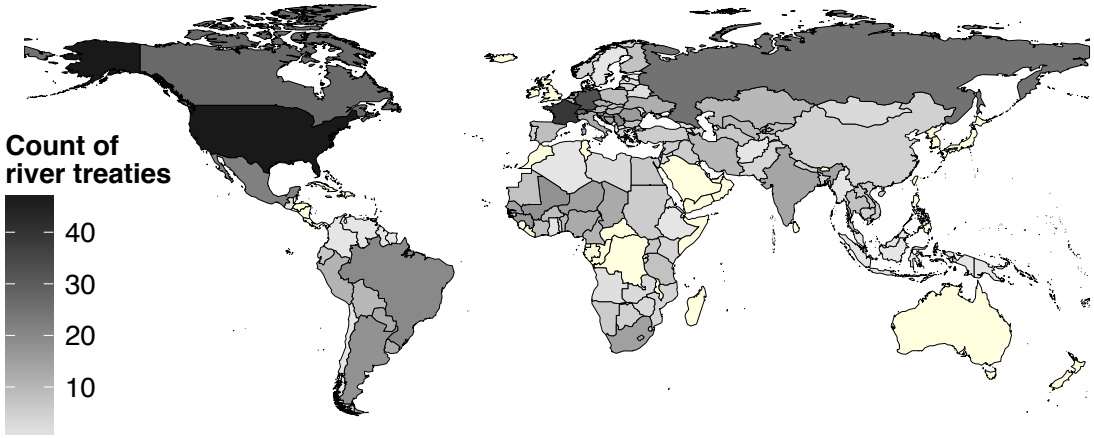


Figure A2. Freshwater cooperation treaties across the world in 2000. Darker shades indicate that a country is party to more freshwater cooperation treaties. Yellow shading indicates that the country has signed no such treaties at all.

Summary statistics

Table A1. Summary statistics

Variable	Mean	SD	Min	Max	N
Water-related cooperation (all years)	0.19	0.85	-5.00	6.00	11197
Water-related cooperation (years with events only)	1.91	1.98	-5.00	6.00	1110
At least one cooperative event	0.07	0.26	0	1	11197
Treaty institutionalization	0.72	1.20	0	4	11197
Treaty institutionalization (no treaties separate)	1.09	1.61	0	5	11197
Treaty created IGO	0.22	0.42	0	1	11197
Treaty provides Monitoring	0.26	0.44	0	1	11197
Treaty provides Enforcement	0.12	0.33	0	1	11197
Treaty provides conflict resolution	0.24	0.43	0	1	11197
Bureaucratic quality (lower)	0.40	0.29	0	1	11197
Water availability (lower)	7.65	1.54	3.24	12.33	11197
Treaty count	1.15	2.38	0	25	11197
Democratic dyad	0.23	0.42	0	1	11197
GDP p.c. (higher, logged)	8.53	1.29	5.71	11.24	11197
Power ratio	1.74	1.51	0	10	11197
Alliance	0.25	0.43	0	1	11197
Rivalry	0.06	0.24	0	1	11197
Shared IGO memberships	42.77	16.86	0	108	10982
Number of treaty members	2.64	3.49	0†	10	11197

†0 is the number of treaty members for dyads with no treaty.

Variance of water-related cooperation across time and across pairs of states

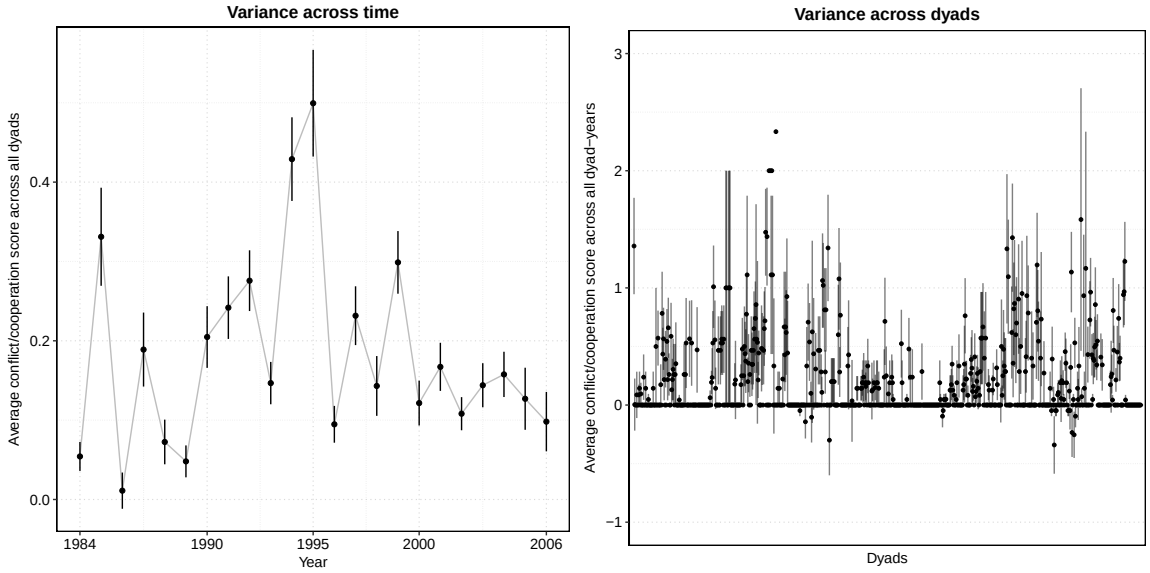


Figure A3. Variance of yearly average BAR scores across time (left) and dyads (right). Each dot represents the mean BAR score across dyads for each year (left) and across years for each dyad (right); whiskers represent standard deviations.

Distribution of river treaty institutionalization and bureaucratic quality

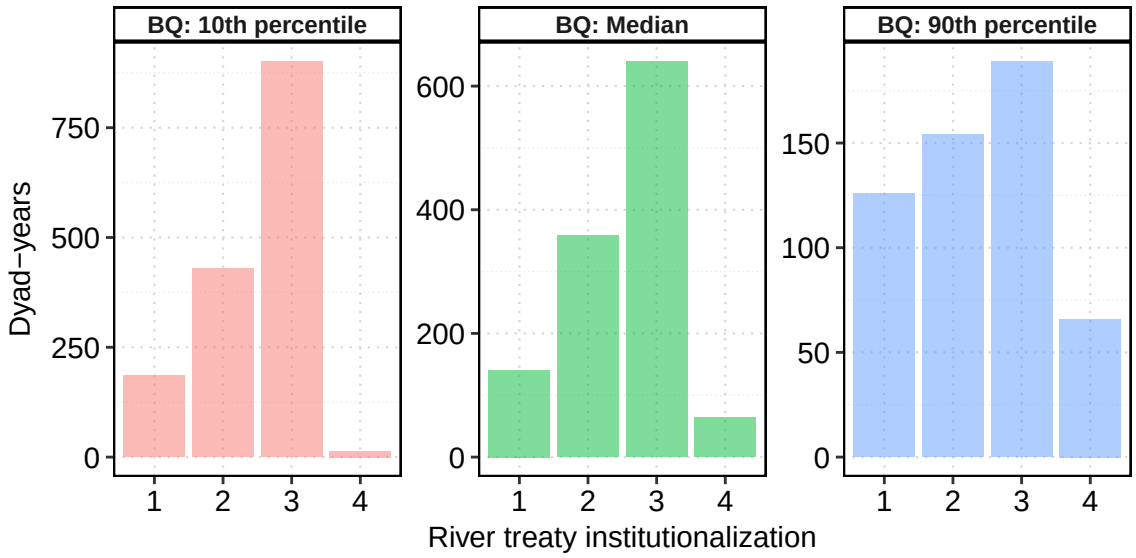


Figure A4. The distribution of institutionalized features of river treaties at low, median, and high levels of domestic bureaucratic quality (measured as the lower value of the two states in the dyad).

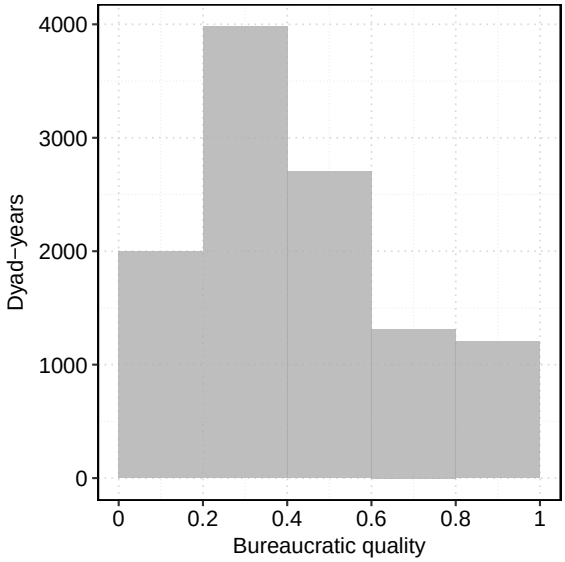


Figure A5. The distribution of bureaucratic quality, measured as lower of two values in a dyad.

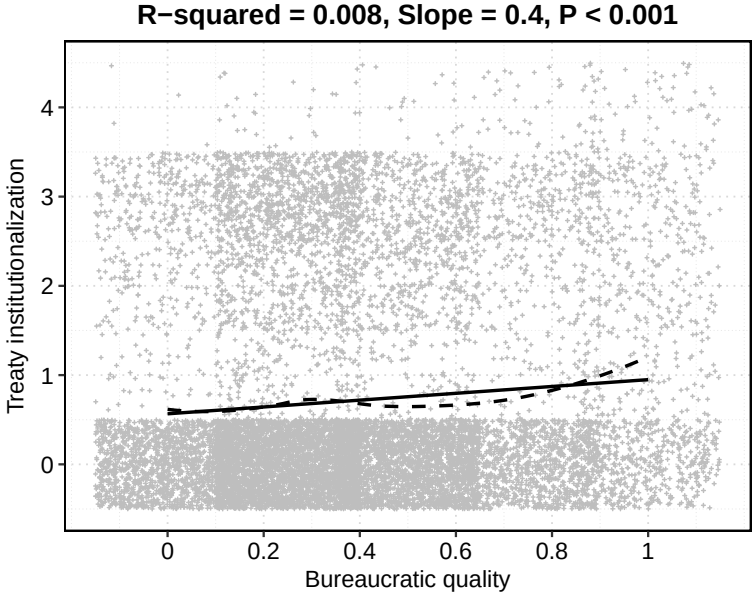


Figure A6. Scatterplot of bureaucratic quality (x-axis) and treaty institutionalization (y-axis), with linear and locally weighted regression lines. Estimates from a bivariate regression indicate a marginally positive, but substantively meaningless correlation between the (lower) bureaucratic quality in a dyad and the degree of treaty institutionalization between that dyad. In a comparison of two dyads with lowest and highest bureaucratic quality, the dyad with higher bureaucratic quality would exhibit, on average, 0.4 more institutionalized treaty features—one-third of a standard deviation of that measure. Points are jittered to avoid overplotting.

Details on the bureaucratic quality measure

This study uses a measure of bureaucratic quality provided by the International Country Risk Guide (PRS Group 2009). This measure captures the degree to which bureaucracies are well-trained and isolated from political influence and rapid disruptions; high scores are assigned to countries with strong bureaucracies with high levels of expertise. The original source defines high-quality bureaucracies as able to "minimize revisions of policy when governments change" and "somewhat autonomous from political pressure" (PRS Group 2009). Other work has used this measure in studies of economic growth or government performance, and also in the area of human and physical integrity rights (Sachs and Warner 1997, Knack 2001, Busse and Hefeker 2007, Rajkumar and Swaroop 2008, Papaioannou 2009, Cole 2015).

The measure uses expert assessments of a country's bureaucracy in general. Countries were evaluated annually. Specifically, these assessments cover the following dimensions:

- Whether "the bureaucracy has the strength and expertise to govern without drastic changes in policy or interruptions in government services" (PRS Group 2009: 34)
- whether the bureaucracy "tends to be somewhat autonomous from political pressure and to have an established mechanism for recruitment and training" (PRS Group 2009: 35)
- "The ICRG staff collects political information [...], converting these into risk points for each individual risk component on the basis of a consistent pattern of evaluation. The political risk assessments are made on the basis of subjective analysis of the available information [...]." (PRS Group 2009: 28)

A recent collection of data on the quality of government summarizes the ICRG bureaucratic quality measure as follows: "The ICRG data, which are based on the assessments of a variety of locally produced information, are both a highly valued market service and an established indicator for the quality of government in economics and political science." (Dahlström et al 2015: 9).

Regression equation and predictions for coefficients

Following our hypotheses:

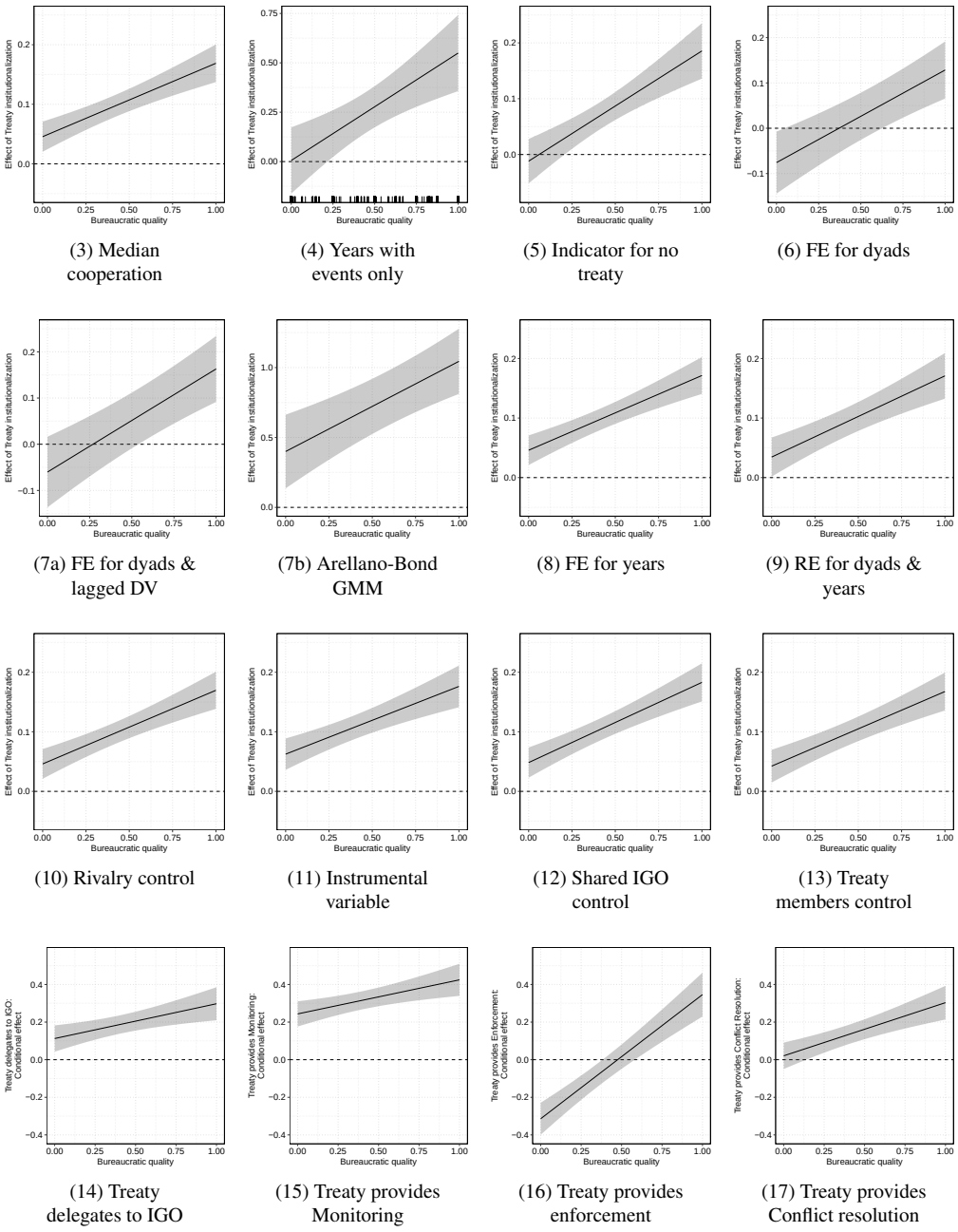
> The positive impact of institutionalized river treaties on freshwater-related cooperation between riparian states is contingent on the quality of domestic bureaucracies: states sharing the same river will cooperate most when they are part of treaties with institutionalized features and when they have domestic bureaucracies with high quality. We expect cooperation to be higher in this scenario compared to one where only one factor (either treaty institutionalization or high-quality bureaucracies) is present.

we estimate variants of the following regression model:

$$\text{Cooperation}_{it} = \beta_0 + \beta_1 \times \text{BQ}_{it} + \beta_2 \times \text{Treaty}_{it} + \beta_3 \times \text{BQ}_{it} \times \text{Treaty}_{it} + \gamma \cdot \mathbf{X}_{it} + \varepsilon_{it}$$

where *BQ* stands for the bureaucratic quality indicator, *Treaty* stands for treaty institutionalization, $\mathbf{X}$ is a matrix of control variables, and i and t indicate dyads and years, respectively. Central to our argument is that β_3 be positive and big enough to increase the conditional effect of treaty institutionalization ($\beta_2 + \beta_3 \times \text{BQ}$) across the range of bureaucratic quality; in other words, the effect of treaty institutionalization should be significantly larger at high levels of domestic bureaucratic quality than at low levels.

Full results and marginal effects for all models discussed in the main text



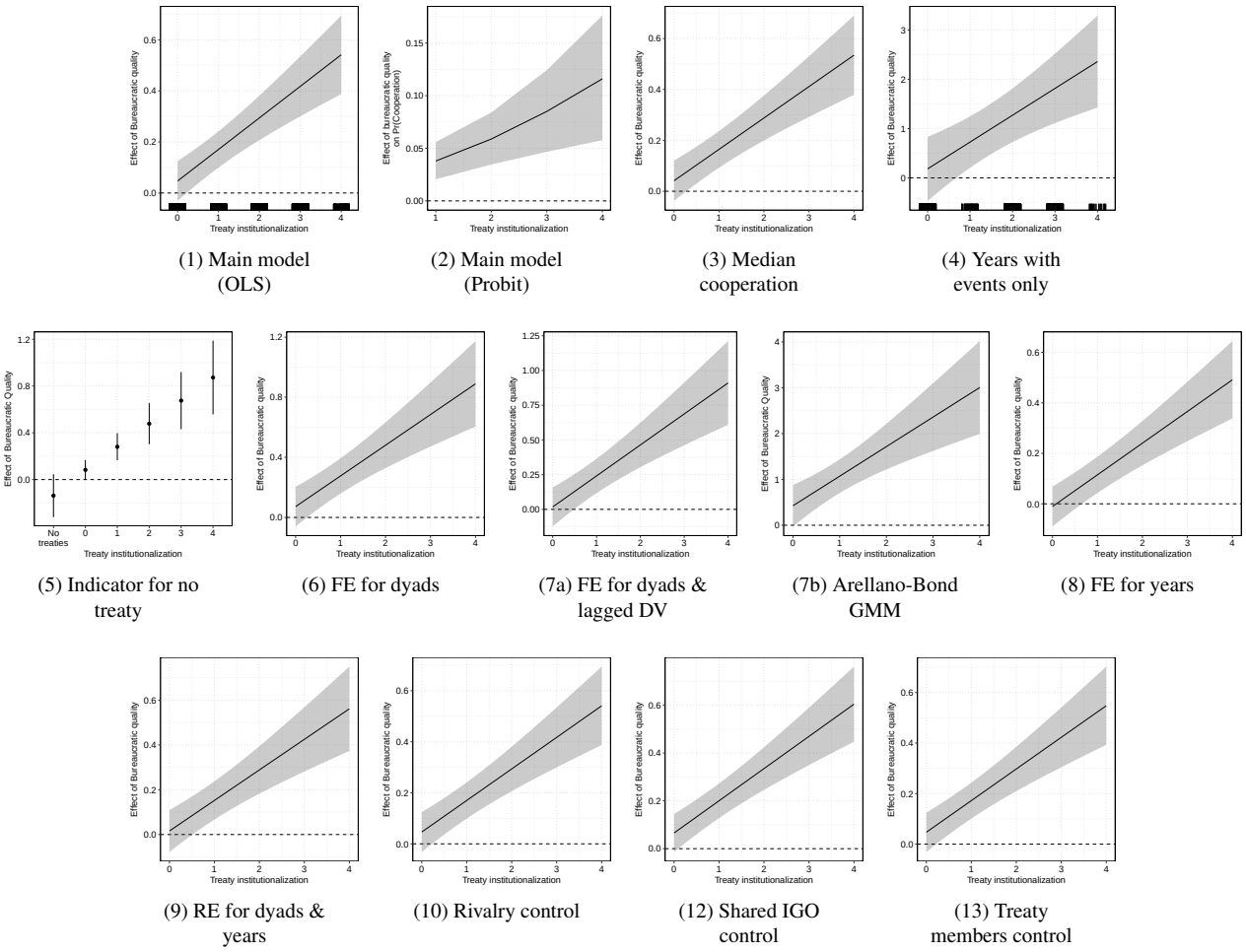
(3) Median cooperation | (4) Years with events only | (5) Indicator for no treaty | (6) FE for dyads

(7a) FE for dyads & lagged DV | (7b) Arellano-Bond GMM | (8) FE for years | (9) RE for dyads & years

(10) Rivalry control | (11) Instrumental variable | (12) Shared IGO control | (13) Treaty members control

(14) Treaty delegates to IGO | (15) Treaty provides Monitoring | (16) Treaty provides enforcement | (17) Treaty provides Conflict resolution

Figure A7. Marginal effects of river treaty institutionalization, conditional on domestic bureaucratic quality, on water-related cooperation between countries. The solid line shows the effect of treaty institutionalization at different levels of domestic bureaucratic quality. The gray area marks the 95% confidence intervals. Results based on the Models in Table A2 and A3; Model numbers in parentheses.



(1) Main model (OLS) | (2) Main model (Probit) | (3) Median cooperation | (4) Years with events only

(5) Indicator for no treaty | (6) FE for dyads | (7a) FE for dyads & lagged DV | (7b) Arellano-Bond GMM | (8) FE for years

(9) RE for dyads & years | (10) Rivalry control | (12) Shared IGO control | (13) Treaty members control

Figure A8. Marginal effects of bureaucratic quality, conditional on river treaty river treaty institutionalization, on water-related cooperation between countries. The solid line shows the effect of bureaucratic quality at different levels of river treaty institutionalization. The gray area marks the 95% confidence intervals. Results based on the Models in Table A2 and A3; Model numbers in parentheses.

Table A2. Robustness tests for estimates of water-related cooperation, 1984–2006.

Model Robustness test	3 Median cooperation	4 Years with events only	5 Indicator for no treaty	6 Fixed effects for dyads	7a FE for dyads & lagged DV	7b Arellano-Bond GMM	8 Fixed effects for years	9 Random effects for dyads & years	10 Rivalry control	11 Instrumental variable	12 Shared IGO control	13 Treaty members control
Treaty institutionalization	0.046*	0.006	−0.012	−0.076*	−0.060	0.400*	0.046*	0.034*	0.046*	0.062*	0.048*	0.042*
	(0.013)	(0.086)	(0.020)	(0.035)	(0.039)	(0.134)	(0.013)	(0.017)	(0.013)	(0.013)	(0.013)	(0.014)
Bureaucratic quality (lower)	0.041	0.183	0.083	0.072	0.018	0.426	−0.011	0.016	0.046	0.050	0.066	0.047
	(0.040)	(0.331)	(0.043)	(0.067)	(0.072)	(0.231)	(0.040)	(0.048)	(0.040)	(0.041)	(0.041)	(0.040)
Treaty institutionalization	0.123*	0.544*	0.197*	0.204*	0.223*	0.645*	0.125*	0.136*	0.124*	0.114*	0.135*	0.125*
× Bureaucratic quality (lower)	(0.022)	(0.151)	(0.038)	(0.041)	(0.044)	(0.155)	(0.022)	(0.027)	(0.022)	(0.023)	(0.022)	(0.022)
Water availability (lower)	−0.006	0.258*	−0.010	−0.131*	−0.124*	−0.018	−0.005	−0.006	−0.006	−0.005	−0.005	−0.006
	(0.005)	(0.043)	(0.006)	(0.037)	(0.040)	(0.065)	(0.005)	(0.008)	(0.005)	(0.005)	(0.005)	(0.005)
Treaty count	−0.011*	−0.098*	−0.014*	0.029	0.033	−0.069	−0.010*	−0.008	−0.011*	−0.015*	−0.005	−0.012*
	(0.005)	(0.019)	(0.005)	(0.020)	(0.023)	(0.067)	(0.005)	(0.006)	(0.005)	(0.005)	(0.005)	(0.005)
Democratic dyad	−0.083*	0.115	−0.083*	−0.146*	−0.165*	−0.253*	−0.058*	−0.089*	−0.084*	−0.089*	−0.009	−0.084*
	(0.025)	(0.171)	(0.025)	(0.038)	(0.040)	(0.074)	(0.026)	(0.030)	(0.025)	(0.025)	(0.027)	(0.025)
GDP p.c. (higher, logged)	−0.008	−0.270*	−0.011	−0.046	−0.076	−0.282*	−0.003	0.002	−0.007	−0.005	0.000	−0.007
	(0.008)	(0.064)	(0.008)	(0.043)	(0.050)	(0.111)	(0.008)	(0.011)	(0.008)	(0.009)	(0.008)	(0.008)
Power ratio	0.011*	0.005	0.008	−0.036	−0.022	−0.140	0.010	0.006	0.010	0.013	−0.009	0.011
	(0.006)	(0.047)	(0.006)	(0.041)	(0.044)	(0.084)	(0.005)	(0.008)	(0.006)	(0.006)	(0.006)	(0.006)
Alliance	0.001	0.082	−0.008	0.040	0.048	0.061	−0.021	−0.016	0.003	−0.002	0.036	0.000
	(0.020)	(0.142)	(0.019)	(0.032)	(0.033)	(0.055)	(0.020)	(0.024)	(0.019)	(0.02)	(0.020)	(0.019)
No treaties			0.185*									
			(0.049)									
No treaties			−0.221*									
× Bureaucratic quality (lower)			(0.100)									
Average cooperation (prior year)					−0.014							
					(0.010)							
Rivalry									−0.020			
									(0.033)			
Shared IGO memberships											−0.005*	
											(0.001)	
Number of treaty members												0.002
												(0.003)
Intercept	0.228*	2.093*	0.260*	2.090*	2.154*		0.078	0.163	0.221*	0.189*	0.348*	0.218*
	(0.079)	(0.609)	(0.079)	(0.774)	(0.871)		(0.088)	(0.107)	(0.078)	(0.079)	(0.081)	(0.078)
Dyad-years	11197	1110	11197	11197	10536	10005	11197	11197	11197	10981	10982	11197

*$p < 0.05$. Standard errors in parentheses.

Table A3. Estimates of water-related cooperation, disaggregating treaty institutionalization.

Model	14	15	16	17
Bureaucratic quality (lower)	0.104*	0.076	0.064	0.075
	(0.039)	(0.040)	(0.037)	(0.040)
Treaty delegates to IGO	0.113*			
	(0.036)			
Treaty delegates to IGO	0.185*			
× Bureaucratic quality (lower)	(0.063)			
Treaty provides Monitoring		0.244*		
		(0.034)		
Treaty provides Monitoring		0.181*		
× Bureaucratic quality (lower)		(0.060)		
Treaty provides Enforcement			−0.314*	
			(0.043)	
Treaty provides Enforcement			0.660*	
× Bureaucratic quality (lower)			(0.080)	
Treaty provides Conflict Resolution				0.021
				(0.036)
Treaty provides Conflict Resolution				0.283*
× Bureaucratic quality (lower)				(0.062)
Water availability (lower)	−0.010	−0.005	−0.016*	−0.010
	(0.005)	(0.005)	(0.005)	(0.005)
Treaty count	0.003	−0.015*	0.028*	0.006
	(0.004)	(0.005)	(0.004)	(0.005)
Democratic dyad	−0.079*	−0.080*	−0.070*	−0.076*
	(0.025)	(0.025)	(0.025)	(0.025)
GDP p.c. (higher, logged)	−0.005	−0.006	−0.008	−0.007
	(0.008)	(0.008)	(0.008)	(0.008)
Power ratio	0.006	0.009	0.000	0.005
	(0.006)	(0.006)	(0.005)	(0.006)
Alliance	0.006	−0.010	0.012	0.001
	(0.019)	(0.019)	(0.019)	(0.019)
Intercept	0.229*	0.183*	0.343*	0.256*
	(0.078)	(0.078)	(0.079)	(0.078)
Dyad-years	11197	11197	11197	11197

*$p < 0.05$. Standard errors in parentheses.

Seemingly unrelated regression results

Table A4. Seemingly unrelated regression estimates of treaty institutionalization and average cooperation

Outcome	Treaty institutionalization	Cooperation
Bureaucratic quality (lower)	0.007	0.047
	(0.037)	(0.040)
Treaty institutionalization		0.046*
		(0.013)
Treaty institutionalization		0.124*
× Bureaucratic quality (lower)		(0.022)
Water availability (lower)	−0.085*	−0.006
	(0.005)	(0.005)
Treaty count	0.344*	−0.011*
	(0.004)	(0.005)
Democratic dyad	0.114*	−0.083*
	(0.025)	(0.025)
GDP p.c. (higher, logged)	0.011	−0.008
	(0.009)	(0.008)
Power ratio	−0.085*	0.011
	(0.006)	(0.006)
Alliance	0.018	0.002
	(0.020)	(0.019)
Intercept	1.000*	0.220*
	(0.078)	(0.078)
Dyad-years	11197	11197
Estimated correlation between residuals	0.00	

*$p < 0.05$. Standard errors in parentheses.

Details on estimating the instrumental variable solution

This solution requires an instrumental variable Z that predicts both the endogenous X (the institutionalization of river treaties) and Y (water-related cooperation) variables. In addition, the exclusion restriction means that the relationship between Z and Y must go solely through X.We use as an instrument Z the number of states in the basins shared by the dyad members. This variable predicts the institutionalization of river treaties (see Table A5). We also have a good theoretical reason to assume that its impact on water-related conflict and cooperation exclusively comes from the (potentially) endogenous variable. The rational design literature has emphasized that states turn to institutional solutions under scenarios such as a high number of states in a collaboration problem (Koremenos et al. 2001: 797). The more states in a basin, the more difficult it is for all basin members to ascertain others' behavior (due to the multiplicity of strategic options), and the more difficult it is to enforce behavior bilaterally. Following this rational design logic, states in these situations are more likely to turn to institutional solutions with the features we measure in the river treaty institutionalization index: centralization and delegation via monitoring, enforcement, conflict resolution, and international organizations. Thus, the empirical and theoretical justifications for using the number of states in river basins (and, in addition, fixed effects for years to address temporal effects) are both strong.

In the first stage, we estimate the relationship between the endogenous variable X (treaty institutionalization) and the original instrument, the number of states in the basin:

$$\text{Treaty institutionalization}_{it} = \alpha_0 + \beta_1 \times \text{Number of states}_i + \gamma_i + \delta_t + \varepsilon_{it} \quad (1)$$

Table A5. First stage estimates of river treaty institutionalization, used in the IV solution shown in Model 11 (Table A2).

	First stage
Number of states in basin	0.05*
	(0.005)
R^2	0.92
F-statistic	201.9
Dyad-years	10981
Dyads	740
Dyad fixed effects	✓
Year fixed effects	✓

Outcome: River treaty institutionalization (higher numbers denote more institutionalized features).

*$p < 0.05$. Standard errors in parentheses.

The results are shown in Table A5. Next, following Wooldridge (2010: 942-945), we construct two instruments based on the model in Table A5: the predicted values for treaty institutionalization and the interaction between domestic bureaucratic quality and the predicted values for treaty

institutionalization.

$$Z_{it} = \widehat{\text{Treaty institutionalization}}_{it} \tag{2}$$

$$Z_{it} \times X_{it} = \widehat{\text{Treaty institutionalization}}_{it} \times \text{Bureaucracy}_{it} \tag{3}$$

Finally, we estimate the IV regression, using the above instruments we just constructed:

$$\text{Cooperation}_{it} = \alpha_0 + \beta_1 \times Z_{it} + \beta_2 \times X_{it} + \beta_3 \times Z_{it} \times X_{it} + \gamma \cdot \mathbf{C}_{it} + \varepsilon_{it} \tag{4}$$

where $\mathbf{C}_{it}$ is a matrix of the remaining control variables discussed above.

Just as in the previous analyses, we then calculate conditional effects and their variances σ^2 using the formulae:

$$\frac{\partial \text{Cooperation}}{\partial \text{Treaty institutionalization}} = \beta_1 + \beta_3 \times \text{Bureaucracy}_{it} \tag{5}$$

$$\sigma^2 = var(\hat{\beta}_1) + \text{Bureaucracy}_{it}^2 \times var(\hat{\beta}_3) + 2 \times \text{Bureaucracy}_{it} \times cov(\hat{\beta}_1 \hat{\beta}_3) \tag{6}$$

Details on control variables

Motivation

The regressions in this study control for potential influences on cooperation patterns drawn from the water politics and international relations literature.

- We capture the stress related to water scarcity by measuring water availability for the water poorer dyad member, using data on renewable water per capita found in the FAO Aquastat database (Food and Agriculture Organization of the United Nations 2012).
- In order to verify that the observed freshwater politics outcomes are not simply a function of the quantity of treaties signed, we control for the number of treaties in effect between the dyad members, using data from the TFDD (Wolf 2014).
- The next set of control variables reflects (neo)liberal international relations scholarship:
  - The models include a binary indicator for joint democracy, operationalized as a joint score of 7 or higher on the net regime score from the Polity IV data (Marshall and Jaggers 2009).
  - A state's level of economic development affects water affordability (Feitelson and Chenoweth 2002) and is considered by some to shape relations between riparian states; wealthier states might be able to compensate for water-induced stress factors for cooperation (Biswas 2001). This variable is measured by the wealthier dyad member's gross domestic product per capita (Heston, Summers, and Aten 2009).
  - A separate robustness test (Model 12 in Table A3) accounts for the number of joint memberships in intergovernmental organizations (IGOs). Sharing many IGO memberships may lead to a more cooperative behavior regarding water issues due to preference alignment, better social relations, or other factors. Other work suggests that more opportunities to interact in IGOs might set up opportunities for discord and disagreements over resource distribution (Fausett and Volgy 2010), which might spill over into water relations. We include as a control variable the count of shared memberships in IGOs, taken from the Correlates of War IGO data version 2.3 (Pevehouse et al. 2004).
- One robustness test (Model 13 in Table A3) controls for the number of states in a treaty to account for possible differences in behavior between dyads in bilateral versus multilateral treaties.
- The final two control variables reflect arguments growing out of the realist literature on obstacles to cooperation.
  - The models account for the influence of relative power distribution in the riparian dyad, which we measure as the natural logarithm of the stronger divided by the weaker state's capabilities, based on the Correlates of War Material Capabilities composite index (Singer, Bremer, and Stuckey 1972).
  - From the Correlates of War Alliance project, we use information on whether the states in a dyad are allies (Gibler and Sarkees 2004).

Findings

- We find some evidence that there is less cooperation in dyads with higher water availability (in 5 out of 18 regressions). Because this finding is not robust, we are cautious to read too much into it. The direction of the finding is consistent with the idea that water scarcity often prompts states to cooperate more (e.g. Tir and Stinnett 2011).
- We also find some evidence that the more treaties a dyad has signed, the less cooperation happens within the dyad (in 10 out of 18 regressions). Similar to water availability, this finding is not robust. It is, however, consistent with our argument that dyads with more treaties (especially "shallow" treaties with little institutionalization) set themselves up for failure regarding water-related cooperation, and that the rate of cooperative actions declines subsequently.
- Many of the model specifications show democratic dyads to have a lower level of water-related cooperation. This finding does not necessarily indicate that democratic states are more conflict-prone than mixed or autocratic dyads. Here, we point out again that our outcome variable measures cooperation, with higher values indicating more cooperation, but the lowest value (0) indicating the absence of cooperation, but not necessarily conflict. With that, the finding could be an artifact of authoritarian states' attempting to over-compensate for their lack of credibility with frequent cooperative actions (e.g. Leeds 1999, Moon 2015, Arias et al. 2016).
- Economic development in the dyad exhibits no consistent relationship with water-related cooperation.
- Power discrepancies between riparian dyads exhibit no consistent relationship with water-related cooperation.
- Alliances between riparian dyads exhibit no consistent relationship with water-related cooperation.
- Dyads engaged in rivalries are no more or less likely to cooperate over water resources.
- Model 12 (Table A2) shows a a minuscular (negative) correlation between shared IGO memberships and water-related cooperation. Substantively, this relationship is too small to be meaningful, but it serves to isolate our estimate on treaty institutionalization and bureaucratic quality from other, possibly more general, influences of IGOs.
- We find no systematic difference in behavior between treaties with more or fewer members.

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