Water Treaties, Non linear effects and Politics

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Abstract

In this supplementary analysis of our article "When Climate Change Determines International Agreements. Evidence from Water Treaties" submitted to Environmental and Resource Economics, we conduct a series of robustness checks to ensure that the results obtained remain consistent when we consider the nonlinearity of weather variables and the introduction of political determinants. We find that the signing of Water Treaties is indeed influenced in a non-linear way by temperature and precipitation. In contrast, political variables (such as strong relationship between partners, economic asymetry, joint democracy, etc) have no impact of the likelihood to sign Water Treaties.

1 Introduction

Candau and Gbandi (2022) analyze the effect of weather variables such as temperature and precipitation on the likelihood to sign a water treaties by estimating the following equation:

$$WT_{ijt} = \alpha.Clim_{ijt} + \beta.Clim_{it} + \mu.Clim_{jt} + Z_{ijt} + f_{ij} + f_{y(i)t} + f_{y(j)t} + f_{ct} + f_t + \varepsilon_{ijt} \tag{1}$$

where WT_{ijt} is a binary variable taking one when countries that share a basin sign a WTs and zero otherwise. Variables $Clim_{it}$ and $Clim_{jt}$ refer to the per-capita level of renewable freshwater resources of country i and j, respectively. The term $Clim_{ijt}$ refers to the mean temperature and mean precipitation that affect the country-basins ij each year t. This study also introduce a long list of fixed effects, such income group-year effects ($f_{y(i)t}$ and $f_{y(j)t}$), continental time varying effects (f_{ct}, where c represents Africa, Americas, Asia or Europe), country-pair fixed effects (f_{ij}) and year specific effects (f_t) and finally country-pair fixed effects account (f_{ij}).

On this basis, we propose two extensions that take into account:

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1. Non linearities. Equation (1) presents a linear relationship between weather variables $Clim_{ijt}$, we propose to relax this assumption by using different thresholds of temperatures and a quadratic specification.

2. The introduction of fixed effects enable to control for various determinants of WTs whithout introducing several statistical bias (multicolinearity, omitted variables, etc.). However these fixed effects are 'black boxes' that we propose to open by introducing several economic and political variables.

On the one hand, we find that extreme temperature have a stronger effect on the likelihood of signing WTs. On the other hand, we find that joint democracy, elections, the economical, political or military hegemony of a country have effects which are hardly distinguishable from zero statistically in our sample.

In the first section we analyse non-linearities and in the second one the influence of economic and political variables.

2 Nonlinearity between weather variables and the likelihood to sign Water Treaties

While Equation (1) presents a linear causal link, it is possible that temperature (and/or precipitation) above (or below) a threshold can have a stronger effects on the likelihood of signing WTs. It is also likely that an increase in precipitation and/or in temperature have a different effect depending on the initial climate (e.g. in a hot or cold locations), we thus need to control for these differences.

- *Non linear effect of local warming*

The agronomic literature has shown that climate change first has a positive effect on agricultural yields, which however ends up to a dramatic catastrophic one after reaching a critical value of temperature. For instance for corn, soybeans, and cotton, yield growth increases gradually with temperature up to 29-32° Celsius, but then decreases sharply (Schlenker and Roberts, 2009). Such non-linearities are generally captured using the concept of the Growing Degree Units (GDU).

To compute the Growing Degree Units (GDU) indicator, we use the monthly distribution of temperatures to calculate the exposure to temperatures (for cropped areas along river basins of each country) between a lower and a upper bound, denoted T_l and T_h. Following the literature (e.g. Burke and Emerick, 2016), we set the lower bound at 8°C and the upper bound at 32°C. Then, the monthly temperature, denoted T_m is used to compute what the literature calls the monthly exposure, g_{imt}, as follows : $g_{imt} = 0$ if $T_m \leq T_l$, $g_{imt} = T_m - T_l$ if $T_l < T_m \leq T_h$ and $g_{imt} = T_h - T_l$ if $T_m > T_h$. Then the sum of these monthly exposures, denoted g_{imt}, is taken over a year:

$$GDU_{it} = \sum_{m=1}^{12} g_{imt}|_{T_m \in]T_l, T_h]} .$$

Obviously, this indicator is really based on the agricultural sector while the determinant of WTs are certainly broader. We thus use two additional indicators that have been proposed in urban economics to capture the demand of energy needed to cool or to warm housings (heating during cold weather and air conditioning during hot periods),[1] the so called Cooling Degree Units (CDU) and Heating Degree Units (HDU).

Concerning the HDU, the literature assumes that it is not necessary to heat a building when the temperature is above 18°C. After calculating an indicator for each month beyond that level, f_{imt}, With $f_{imt} = T_m - 18$ if $T_m > 18$ and $f_{imt} = 18 - T_m$ otherwise. We sum it by year:

$$HDU_{it} = \sum_{m=1}^{12} f_{imt}|_{T_m<18}$$

and similarly for the CDU:

$$CDU_{it} = \sum_{m=1}^{12} f_{imt}|_{T_m>18}$$

The non-linear effects accross the different measures presented above, are assessed by considering a modified version of Eq. (1) as follow:

$$WT_{ijt} = \alpha.Clim_{ijt} + \psi Clim_{ijt} * DU_{ijt} + \phi.DU_{ijt} + \beta.Clim_{it} + \mu.Clim_{jt} \quad (2)$$
$$+Z_{ijt} + f_{ij} + f_{y(i)t} + f_{y(j)t} + f_{ct} + f_t + \varepsilon_{ijt} \quad (3)$$

where DU_{ijt} designs HDU, CDU or CDU. We will observe the statistical significance and the sign on ψ, and the interpretation will depend on the climate variable considered. Having ψ statistically significant means that the effects of climate variables are different for the values of the DU considered. Thus, if ψ is positive, we can conclude that the effect of temperature on the probability of a couple of countries to enter a water agreement, increases more with the measure of degree unit measure (DU) considered; but an increase in this DU attenuated the negative effect of precipitations. But, if ψ is negative, this means that the effect of temperature on the probability of a couple of countries to enter a water agreement, decreases more with the measure of degree unit measure (DU) considered; But the effect is more negative with precipitation for an increase in this DU.

[1] See for instance Albouy et al. (2016) for the U.S.

Table 1: Temperature: Non linear effects and Interactions

	Growing	Cooling	Heating
Avg Temp (ij)	0.0096^b	0.0222^a	0.0274^a
	(0.005)	(0.0044)	(0.0049)
Avg Temp (ij)*Degree Unit (i&j)	0.0013^b	-0.0009	-0.0010^b
	(0.0005)	(0.0007)	(0.005)
Degree Unit (i&j)	-0.0191^c	0.0369^c	-0.0033
	(0.0116)	(0.0201)	(0.0116)
Common international organizations			
Constant	-0.1055	-0.3437^b	-0.4418^a
	(0.1754)	(0.1703)	(0.1661)
Observations	23736	23736	23736
% fitted values ϵ [0; 1]	69.08	59.72	76.25
R-squared	0.468	0.467	0.467

Notes: Standard errors adjusted for clustering at the country pair level. a: p<0.01, b: p<0.05, c: p<0.1. The dep variable is a dummy taking one when countries i and j have signed a river treaty at time t. All these estimations have done with data concerning "non renewable internal freshwater per capita" and "common organization" (as in the previous table), but not reported here to save space (coefficients were not significant). This dummy is built from the International Freshwater Treaty Database. Climate variables comes from WorldClim. We use a Linear Probability Model over the period 1961-2007. All the regressions include the following effects: year fixed effects, f_t, income-group time-varying effects $f_{y(i)t}$ and $f_{y(j)t}$, continental time-varying effects f_{ct} and bilateral fixed effects f_{ij}.

Column 1 of Table (1) shows that countries with a high Growing Degree Unit sign less WTs (negative coefficient however significant at only 10%) which seems quite logical since these countries benefit of a good weather to grow plants. However an increase in temperature in these countries leads to sign more agreements, indicating maybe a concern about a possible too high increase in the future. Interestingly while country with a high cooling degree unit sign more treaties (Column 2), an increase of temperature has no longer a significant effect there. Finally in countries with a high Heating Degree Unit (Column 3), an increase in temperature leads to sign less agreements. One may think to an increase in precipitation or snow melting in these countries to explain this result. A common result to these three columns is that the net effect of temperature is always positive and significant (even in the last column where we still find a positive coefficient by summing -0.001 to 0.0274) as in our baseline estimation. Finally, we led the same estimations with precipitation (see Table 2) and we found that this variable always has a negative effect on WTs whatever the non-linearity in temperature chosen.

Table 2: Precipitation: Non linear effects and Interactions

	Growing	Cooling	Heating
Avg Precip (ij)	-0.0084[c]	-0.0117[a]	-0.0065[a]
	(0.0046)	(0.0035)	(0.0019)
Avg Precip (ij)*Degree Unit (i&j)	0.0002	0.0014[b]	0.0003
	(0.0003)	(0.0005)	(0.0003)
Degree Unit (i&j)	0.0157[a]	0.0101	0.0097
	(0.0051)	(0.0094)	(0.0064)
Country renewable freshwater p.c (i)	-0.0036	-0.0012	-0.0022
	(0.0114)	(0.0115)	(0.0116)
Country renewable freshwater p.c (j)	-0.0036	-0.0012	-0.0022
	(0.0114)	(0.0115)	(0.0116)
Common international organizations	0.0001	0.0001	0.0001
	(0.0002)	(0.0002)	(0.0002)
Constant	-0.0092	0.0821	0.0928
	(0.1419)	(0.1390)	(0.1356)
Observations	23,736	23,736	23,736
% fitted values ϵ [0; 1]	66.58	78.42	77.22
R-squared	0.467	0.467	0.467

Notes: Standard errors adjusted for clustering at the country pair level. a: p<0.01, b: p<0.05, c: p<0.1. The dep variable is a dummy taking one when countries i and j have signed a river treaty at time t. All these estimations have done with data concerning "non renewable internal freshwater per capita" and "common organization" (as in the previous table), but not reported here to save space in reason of their unsignificant effects. The water treaty dummy is built from the International Freshwater Treaty Database. Climate variables comes from WorldClim. We use a Linear Probability Model over the period 1961-2007. All the regressions include the following effects: year fixed effects, f_t, income-group time-varying effects $f_{y(i)t}$ and $f_{y(j)t}$, continental time-varying effects f_{ct} and bilateral fixed effects f_{ij}.

To conclude, these results illustrate that the effects of precipitation and temperature are obviously heterogeneous, countries do not have the same incentive to sign a WTs in a wet area or in an hot one, but the significant effect of weather variables is robust. To analyze differently this point, we put in interaction temperature and precipitation with the total renewable internal freshwater resources of the two countries in Table (3). We verify that in areas where freshwater is abundant, the effects of temperature and precipitation are attenuated but are still significant and with the expected sign (temperature: 0.0356-0.0047>0, precipitation: -0.0192+0.0032<0).

Table 3: Temperature: Non linear effects and Interactions

	Growing
Avg Temp (ij)	0.0356^a
	(0.0074)
Avg Temp (ij)*Renewable internal freshwater resources (i&j)	-0.0047^b
	(0.0020)
Avg Precip (ij)	-0.0192^a
	(0.0045)
Avg Precip (ij)*Renewable internal freshwater resources (i&j)	0.0032^a
	(0.0009)
Common international organizations	
Constant	-0.2147^a
	(0.0743)
Observations	23736
% fitted values ϵ [0; 1]	
R-squared	0.467

Notes: Standard errors adjusted for clustering at the country pair level. a: p<0.01, b: p<0.05, c: p<0.1. The dep variable is a dummy taking one when countries i and j have signed a river treaty at time t. All these estimations have done with data concerning "common organization" (as in the previous table), but not reported here to save space in reason of their unsignificant effects. The water treaty dummy is built from the International Freshwater Treaty Database. Climate variables comes from WorldClim. We use a Linear Probability Model over the period 1961-2007. The regression includes the following effects: year fixed effects, f_t, income-group time-varying effects $f_{y(i)t}$ and $f_{y(j)t}$, continental time-varying effects f_{ct} and bilateral fixed effects f_{ij}.

- Non-linear effects across different levels of temperature and precipitations

We first analysed the non-linear effect across different levels of precipitation and temperature. We capture these non-linearities by including square terms of temperature and precipitations variables in the model (Eq. 1) as follow:

$$WT_{ijt} = \alpha_1.Clim_{ijt} + \alpha_2.Clim_{ijt} * Clim_{ijt} + \beta.Clim_{it} + \mu.Clim_{jt} \quad (4)$$
$$+Z_{ijt} + f_{ij} + f_{y(i)t} + f_{y(j)t} + f_{ct} + f_t + \varepsilon_{ijt} \quad (5)$$

where the marginal effect of weather variables on the probability to enter water treaties is given by $\alpha_1 + \alpha_2 Clim_{ijt}$. As such, this marginal effect depends on the level of temperature and precipitations. While statistically significant, the coeficient α_2 allows to capture the non linear effect. Results from the estimation of Eq. (4) are presented in Table (4). It shows evidence of a significant non-linear association between the probability to enter a water treaty and change in precipitations. On the contrary, there no evidence of a non-linear effect of temperature on the likelihood to sign a water treaty. Above a certain level of precipitations, increases in precipitations generate increases in the probability to enter a water treaty revealing . This result confirms our findings.

Table 4: Non linear effects across different levels of precipitation and temperature

	(1)
Avg Temp (ij)	0.0028
	(0.0062)
Avg Temp (ij) * Avg Temp (ij)	0.0006***
	(0.0002)
Avg Precip (ij)	-0.0135***
	(0.0037)
Avg Precip (ij) * Avg Precip (ij)	0.0003***
	(0.0001)
Country renewable freshwater p.c (i)	-0.0021
	(0.0116)
Country renewable freshwater p.c (j)	-0.0021
	(0.0116)
Common international organizations	0.0002
	(0.0002)
Constant	-0.0981
	(0.1645)
Observations	23,736
% fitted values ϵ [0; 1]	60.96
R-squared	0.467

Notes: Standard errors adjusted for clustering at the country pair level. a: $p<0.01$, b: $p<0.05$, c: $p<0.1$. The dep variable is a dummy taking one when countries i and j have signed a river treaty at time t. All these estimations have done with data concerning "common organization" (as in the previous table), but not reported here to save space in reason of their unsignificant effects. The water treaty dummy is built from the International Freshwater Treaty Database. Climate variables comes from WorldClim. We use a Linear Probability Model over the period 1961-2007. The regression includes the following effects: year fixed effects, f_t, income-group time-varying effects $f_{y(i)t}$ and $f_{y(j)t}$, continental time-varying effects f_{ct} and bilateral fixed effects f_{ij}.

3 Economical and political variables

In Candau and Gbandi (2022) we have focused our analysis on the "first nature" of water treaties,[2] namely on the weather conditions that may explain international agreement, and we have implicitly assume that all other variables of the economic, political and institutional sphere where controlled by fixed effects. This choice to focus on climate variables was made in order to develop a clean empirical strategy, indeed weather variables are exogenous while economic and

[2]The "first nature" in which people evolve, defined by Cronon (1991) as "the nonhuman world of ecological relations", are often compared with the "second nature" depending on economical, political and institutional factors. This vocabulary is often used to explain how location choices historically explained by geography (agglomeration of people in a coastal city) are now explained by economical factors. See Candau and Dienesch (2015) for a discussion. As noted by Cronon (1991) this terminology borrowed to the Helegian analysis (distinguishing the original nature to the "artificial nature that people erect atop first nature") is not exempt of ambiguity but nonetheless useful to categorize explanatory variables.

political variables are not, and furthermore their introduction opens the Pandora box of omitted variables. In addition, these data are not available for all years and all countries in our database (and are also less accurate than meteorological measurements), so the sample is small (or includes measurement errors), which may imply sample selection bias. There are however two reasons to take some risks by analyzing these variables. First, authors working on WTs have focused their debate on these variables, it is thus interesting to compare our result with what has been found until now. Second, even if climate variables are the main determinants of WTs, it is still rewarding to better understood in which economic and political context, climate change fosters international cooperation on water.

We then investigate if water treaties are influenced by:

- Presidential election a year before the signing of WTs. If WTs are negotiated before an election, political incumbents choose strategically their future commitment to signal their green position for the election. Battaglini and Harstad (2020) show that in the perspective of an election, incumbents tend to negotiate treaties that are simultaneously weak and overambitious.

- A common political regime between partners. Coordination may be easily implemented between similar democratic regimes (as analyzed by Tir and Ackerman, 2009, Dinar et al., 2010; Brochmann, 2012).

- Past conflicts between countries. Conflicts and the lack of trust that follows these conflicts may be important determinants preventing the enforcement of river cooperation. In contrast, past conflicts may be a motive to sign a treaty to avoid another disputes (these different arguments are developed in Lowi, 1995; Amery and Wolf, 2010, Brochmann, 2012). A problem of reverse causality is likely with this variable since conflicts may be driven by climate-driven water variability (see Dinar et al., 2015).

- Economic asymmetry between members (Dinar et al., 2010). Countries with a high GDP may have a higher bargaining power than small countries (because they represent significant outlet for exporters or because many goods are imported from these countries).

- Military/State asymmetry between members. Countries with a high level of military spending (even if not an economic hegemon) may have the overexercise force to impose a treaty (see Hensel et al., 2008). We use here an indicator that takes into account the military spending and other variables of the government capacity to impose its power.

- Economic interdependence measured by international trade (adjusted, namely total trade on GDP) between partners. It is often assumed that trade fosters interdependence between nations (Montesquieu, 1748),[3] and then, when economic affairs are interconnected the benefit of cooperation (or the

[3]MARTIN et al. (2008) shows that multilateral trade integration fosters conflicts while regional trade integration has the opposite effect. This result is explained by the fact that

opportunity cost of conflicts) is higher. We also add a dummy of alliance ties to approximate political relationships between partners.

A full description of the data used are presented below.

3.1 Literature and description of data used in Table

- *Institutions*

  - *How about election cycle and the likelihood of cooperation?*

  The literature has mentioned that election can influence the likelihood of signing agreements (Buisseret and Bernhardt, 2018; Battaglini and Harstad, 2020). Battaglini and Harstad (2020) argue that, political incumbents can strategically signal their green (or brown) position for the election by negotiating agreements. We thus include a binary variable that is equal to one in the years of presidential elections in country i or in country j. The election years data are from the National Elections Across Democracy and Autocracy (NELDA)[4]. As a robustness check, we also consider a binary variable that is equal to one in the year of presidential elections, but also in the year before the elections in country i or in country j.

  - *Does joint democracy always foster cooperation?*

  Tir and Ackerman (2009) find that joint democracy positively influences the signing of international water treaties. Dinar et al. (2010) use different indicators and dummies to approximate democracy and also conclude in favor of a positive relationship. We wonder whether our results concerning weather conditions is robust to this introduction. Our variable of joint democracy is based on the Polity 2 score of democracy from the PolityV database, the joint democracy variable is a binary dyad-year varying variable that is coded one when both countries in a pair are declared democratic in a given year. We follow Brochmann (2012) by considering a country as a democracy when it's polity-2 value is above 6

- *Peace history: an ambiguous effect on cooperation*

  Security concerns and past conflicts are potential obstacles to cooperation. However, ambiguous results have been found.

regional openness foster economics ties between neighbors countries while multilateral trade integration on the opposite makes closed partners less dependent from each other. Candau et al. (2021) in contrast try to go beyond the income effect of trade considering that trade has many other consequences on institutions, culture, and on the environment that can play on conflicts. Markets are places of socialization and then trade by fostering exchanges may have a role in building trust between communities. They find that domestic and international trade integration have peaceful effects while regional trade integration (between neighboring countries where ethnic groups have been separated by a border) fosters civil conflicts.

[4] https://nelda.co/

Countries with shared interests and no security concerns, are likely to enhance stability which can be a motive to sign an international treaty on water. By the same token, governments that are already in conflicts or in competition for the resource are certainly less prone to engage their countries into a discussion on transboundary water flows. Lowi (1995) and Amery and Wolf (2010) are seminal papers showing that conflicts and the lack of trust that follows these conflicts are important determinants preventing the enforcement of river cooperation in the Middle East.

On the opposite, some authors have argued that cooperation happens in the aftermath of conflict. Brochmann (2012) in particular finds that the longer time two countries have lived in peace, the lower the chance of water cooperation. To contribute to this debate we use in the text the number of peaceful years by considering bilateral militarized interstate disputes.[5] More precisely, we use the number of years since the last militarized interstate wars (MID) arose between the countries in a dyad (Dinar et al. (2011); Brochmann (2012)). This variable is built using data from the Correlate of War (COW) project[6]. We consider as a MID the cases where the dispute event in COW's original database takes the values 3, 4 and 5, which correspond respectively to situations where there are a display of force (e.g. a decision of mobilization or a border violation), a use of force (e.g. an attack or an occupation of territory) and an interstate war (more than 1000 military deaths).

We also used an alliance indicator between countries which is a binary variable from COW Formal Interstate Alliance Dataset. This variable is called "Alliance ties" in Table (5). It records all formal alliances among states, including mutual defense pacts, non-aggression treaties and ententes.

- *Military power distribution: does asymmetry between partners matter?*

  We measure the asymmetrical distribution of power between partners by taking the "strongest state" proportion of the dyad-year total capabilities (Hensel et al., 2008). The state capability is measured by the Composite Index of National Capability (CINC) extracted from the COW National Material Capabilities database[7] State's CINC is an aggregation of six (6) different variables into a single value for every year. These variables are respectively: (i) "total population", (ii) "urban population", (iii) "iron and steel production", (iv) "energy consumption", (v) "military personnel", and (vi) "military expenditure". It ranges from 0 to 1 with the highest level power at 1. We approximate here the unequal distribution of power

[5] In a different but related topics, Dinar et al. (2015) study water-related conflicts and find that country dyads governed by treaties with flexible and specific water allocation mechanisms have a more cooperative behavior. Dinar et al. (2019) investigate the trade-off between benefits and costs associated with basin-wide treaties, they find that the larger the number of participants, the higher the transaction costs of the negotiation but the lower the cost of the joint operation of treaties.

[6] https://correlatesofwar.org/data-sets

[7] https://correlatesofwar.org/data-sets/national-material-capabilities

by considering the ratio of the highest CINC on the smallest CINC of the pair of countries that sign a treaty. This variable is called “Military/State Capacity Asymmetry” in Table (5).

- *Unequal economic power distribution: bane or boon to cooperate?*

  Finally the level of development of countries may be an important determinant of cooperation. Countries with high level of development may have a demand from environmental protection coming from environmental lobbies and/or citizens.[8] This pressure to find political responses to climate change in developed countries may foster transboundary waters cooperation with emerging countries. The economic hegemony also facilitates financial transfers, that may be considered as development aids to satellite countries. Many authors have however rejected these positive effects, and instead have argued that an unequal economic power distribution between partners is not a pre-requisite of cooperation. Dinar et al. (2010) even find that the asymmetrical economic power has a negative effect treaty likelihood.

  We follow the literature by using an indicator of “economic asymmetry” based on the ratio of the most economically powerful state on the less powerful state of the dyad, namely the highest GDP per-capita on the lowest GDP per-capita for each pair. Our data on GDP and population comes from the World development indicators (WDI). In Table (5), this variable is called “Economic Asymmetry”.

- *International trade and economic interdependence*

  International trade has often been used in the literature to explain water treaties.[9] The main explanation is that trade fosters interdependence between nations (Montesquieu, 1748, MARTIN et al., 2008),[10] and then, when economic affairs are interconnected the benefit of cooperation (or the opportunity cost of conflicts) is higher.

  Our variable of international trade comes from the Direction of Trade Statistics (DOTS) Database.[11] We take the yearly ratio of total trade (imports and exports) between the two countries in the dyad over their

[8] A similar argument is used to defend the environmental Kuznets-curve.

[9] For instance Dinar et al. (2011) find that an increase of 1% in the trade exports increase the number of water treaties by 1 to 14 treaties. See also Sigman (2004).

[10] Martin et al. (2008) shows that multilateral trade integration fosters conflicts while regional trade integration has the opposite effect. This result is explained by the fact that regional openness foster economics ties between neighbors countries while multilateral trade integration on the opposite makes closed partners less dependent from each other. Candau, Guepie and Gbandi (2021) in contrast try to go beyond the income effect of trade considering that trade has many other consequences on institutions, culture, and on the environment that can play on conflicts. Markets are places of socialization and then trade by fostering exchanges may have a role in building trust between communities. They find that domestic and international trade integration have peaceful effects while regional trade integration (between neighboring countries where ethnic groups have been separated by a border) fosters civil conflicts.

[11] The IMF’s DOTS database has various advantage in comparison with other databases

total GDP. Since the trade data are expressed in currents US$, we converted countries import and export values into constant 2010 US$ (for IMFDOT) to merge these data with GDP. This variable is called "Economic interdependence" in Table (5).

3.2 Results

In Table (5) we thus estimate Equation (1) by including in Z_{ijt} all these economical and political factors. The main result is that our variable of weather are almost unaffected. Temperature and precipitation are still significant, with the same sign and coefficients are only sightly higher, indicating that the bias of omitted variable in this specification is perhaps no so high in that case.

Another result, is that many of the economic and political variables introduced are not significant. We find that joint democracy, elections, the economical, political or military hegemony of a country have effects which are hardly distinguishable from zero statistically in our sample. The negative effect of peaceful years confirms the result obtained so far (Dinar et al., 2010, Brochmann, 2012) that conflicts increase the likelihood to sign a river treaty. However, this last variable may suffer of various biases, if drought periods cause tensions between countries, the peace/conflicts variable may be biased due to omitted variables and multicollinearity issues.

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of trade flows (e.g. COMTRADE). Trade flows are for instance corrected for non-reporting or slow reporting countries (which are numerous in developed countries) and cover a larger period of time (in comparison for instance with the CEPII's BACI database). See Candau, Guepie and Kouakou (2021) for a discussion of these databases.

Table 5: Which Political and Economic Variables Really Matter for Water Cooperation?

	(1)	(2)	(3)	(4)
	Likelihood of water agreements			
Avg Temperature	0.0269^{a}	0.0198^{b}	0.0199^{a}	0.0139^{b}
	(0.0058)	(0.0094)	(0.0050)	(0.0070)
Avg Precipitation	-0.0063^{a}	-0.0080^{b}	-0.0075^{a}	-0.0075^{a}
	0.0020	0.0034	0.0021	0.0029
Country renewable freshwater p.c	-0.0273^{b}	-0.0303	-0.0161	-0.0395^{c}
	(0.0136)	(0.0251)	(0.0155)	(0.0210)
Common international organizations	0.0011^{a}	0.0008	-0.0011^{a}	-0.0001
	(0.0002)	(0.0008)	(0.0003)	(0.0006)
Presidential election in i or j	-0.0040	-0.0014		
		(0.0049)		
Joint democracies			-0.0140	0.0162
			(0.0096)	(0.0115)
Economic Asymmetry		-0.0008		-0.0009
(Highest GDP/lowest GDP by dyad)		(0.0053)		(0.0051)
Military/State capacity asymetry		0.0059		-0.0221^{a}
(Highest CINC on lowest CINC by dyad)		(0.0103)		(0.0099)
Economic interdependence		-0.0014		-0.0017
(Indicator of Trade adjusted)		(0.0018)		(0.0017)
Alliance ties		0.0207^{c}		0.0214^{c}
		(0.0115)		(0.0113)
Number of peaceful years since the latest MID		-0.0007^{a}		-0.0005^{b}
		(0.0002)		(0.0002)
Constant	-0.2208	-0.0693	0.0655	0.3208
	(0.2024)	(0.3990)	(0.2180)	(0.3054)
Observations	17,537	9,823	18,748	12,245
Pseudo R-squared	0.486	0.530	0.468	0.504

Notes: Standard errors adjusted for clustering at the country pair level. a: p<0.01, b: p<0.05. The dep variable is a dummy taking one when countries i and j have signed a river treaty at time t. This dummy is built from the International Freshwater Treaty Database. We use a Linear Probability Model over the period 1961-2007. All the regressions include the following effects: year fixed effects, f_t, income-group time-varying effects $f_{y(i)t}$ and $f_{y(j)t}$, continental time-varying effects f_{ct} and bilateral fixed effects f_{ij}. MID = Bilateral militarized interstate disputes.

3.3 Robustness checks with other measures of peace history and international trade

In section, we study the effect of water events and disputes as a robustness checks. We also use a different indicator of trade dependence by distinguishing multilateral trade and regional trade. We motivate these variables hereafter.

- Water disputes

In addition to peace related variable related to the occurrence of militarized conflicts presented in the text, we test two additional variables that also account for peace history between countries, but are more related to water events. We first rely on the International Water Events Database[12] which records the most complete and comprehensive list of international bilateral/multilateral events over water resources. Actually, it provides for each event, an intensity scale rating, ranging from -7 to 7 that allows distinguishing conflict events (bar scale below 0) from the cooperative events (bar scale above 0). Then, we first rely on conflictual events to develop a variable describing the number of peaceful years since the last hostilities over water resources took place between countries of each dyad. Second, we consider positive events and build a bilateral variable indicating the number of years since the last cooperation event over water resources took place between each pair of countries. It is worth mentioning that, as specified in the text, all the explanatory variables are lagged one year.

Table (6) columns (1) and (2) present the results with these variables, respectively, and they appear to have statistically weak effect on WTs while weather variables remains significant.

- Trade and economic dependency

  While there are many theories on the causality between trade and cooperation, the one presented previously relies on the opportunity cost effect; when international trade increases income, the cost of dispute follows suit. By testing the validity of the opportunity cost theory, MARTIN et al. (2008) find that not all trade flows lead to economic interdependence with peaceful effect. Distinguishing regional trade integration and multilateral trade opening, these authors argue that only the former fosters peace. Multilateral trade liberalization by decreasing the *bilateral dependency* weakens the opportunity cost of conflicts between these partners. We follow these authors and we estimate Equation (1) by using their definition of regional and multilateral trade.

  Bilateral trade is approximated by the arithmetic average of bilateral import flows over GDP:

$$Adjusted\,bilateral\,trade_{ijt} = \frac{m_{ijt}}{GDP_{it}} + \frac{m_{jit}}{GDP_{jt}},$$

  and multilateral trade is measured as the arithmetic average of total imports of the two countries excluding their bilateral imports divided by their GDPs:

$$Adjusted\,multilateral\,trade_{ijt} = \sum_{h \neq d,o} \frac{m_{iht}}{GDP_{ot}} + \frac{m_{dht}}{GDP_{dt}}.$$

[12] https://transboundarywaters.science.oregonstate.edu/content/international-water-event-database#:~:text=The%20International%20Water%20Events%20Database,a%20quantity%20to%20be%20managed.

Column 3 in Table (6) introduces these indicator of bilateral and multilateral trade, none of them are significant to explain WTs. In comparison precipitations and temperatures are always significant.

Table 6: Supplementary estimations

	(1)	(2)	(3)
Presidential election year in i or j	-0.0018	-0.0019	-0.0019
	(0.0054)	(0.0054)	(0.0054)
Economic power (Highest GDP on lowest GDP by dyad)	0.0049	0.0052	0.0042
	(0.0058)	(0.0057)	(0.0057)
Power distribution	0.0087	0.0083	0.0086
	(0.0129)	(0.0129)	(0.0129)
Economic interdepedance (Trade)	0.0012	0.0013	
	(0.0017)	(0.0018)	
Alliance ties	0.0222*	0.0236*	0.0230*
	(0.0129)	(0.0128)	(0.0128)
Number of peacefull years since the latest WD	-0.0012		
	(0.0011)		
Number of years since the latest PWE		-0.0005	
		(0.0005)	
Number of peacefull years since the latest MID			-0.0006**
			(0.0003)
Avg Temp (ij)	0.0362***	0.0362***	0.0360***
	(0.0105)	(0.0105)	(0.0105)
Avg Prec (ij)	-0.0068*	-0.0068*	-0.0066*
	(0.0039)	(0.0039)	(0.0039)
Country renewable freshwater p.c (i&j)	-0.1000**	-0.0997**	-0.0897*
	(0.0493)	(0.0497)	(0.0520)
Common international organizations	0.0003	0.0003	0.0005
	(0.0009)	(0.0009)	(0.0010)
Bilateral trade			0.0014
			(0.0017)
Multilateral trade			-0.0029
			(0.0115)
Constant	0.1877	0.1871	0.0831
	(0.4757)	(0.4778)	(0.5732)
Observations	8,372	8,372	8,372
Pseudo R-squared	0.545	0.545	0.545

Notes: Standard errors adjusted for clustering at the country pair level. a: $p<0.01$, b: $p<0.05$, c: $p<0.1$. The dep variable is a dummy taking one when countries i and j have signed a river treaty at time t. This dummy is built from the International Freshwater Treaty Database. All the regressions include the following effects: year fixed effects, f_t, income-group time-varying effects $f_{y(i)t}$ and $f_{y(j)t}$, continental time-varying effects f_{ct} and bilateral fixed effects f_{ij}. WD = Bilateral Water Disputes, PWE = Bilateral positive Water Events. MID = Bilateral Militarised Interstate Disputes.

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