Nature's Law and Water Treaties

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Does climate change lead governments to enforce international treaty to manage a common resource? This article answers this question by analyzing how weather conditions have affected the implementation of Water Treaties (WT) on common basins and rivers. We find that climatic conditions such as an increase in temperature and precipitations directly foster WTs in the short run, and even more in the long run. We conclude that WTs are climate policies representing an adaptation strategy of governments that cooperate more and more over time. We also find that few political and economic variables really matter (e.g., common democracy, asymmetrical power, the level of development). Only conflicts and economic dependency between countries significantly explain WTs.
JEL: F1, Q2

I. Introduction

The effect of climate change on water is a first order issue for the human kind since most of the agricultural production depends directly of this resource. The problem is even more acute for countries that share a basin or a river since the over-exploitation of the common resource may be exacerbated by climate change.

Consequently, a growing body of work analyses how common basins and rivers between countries are affected by climate shocks and how cooperation between governments, implemented by international Water Treaties, works. However many findings are based on cross-sectional analysis which is problematic since many determinants of WTs are unobserved or hard to measure. Furthermore the lack of a time dimension impedes to analyze the behavior of agents over time while the impact of climate change depends precisely on how individuals and governments are be able to develop adaptation strategies. It is thus crucial to determine whether agents respond differently in the short run and in the long run when climate change is perceived as a permanent changes and not as an unanticipated fluctuations in weather.

By using panel data and long run difference, the objective of this article is to determine whether climatic shocks have a causal effect on Water Treaties (WT) and how this effect evolves over time.

The history of international water treaties dates back to 2500 BC,[1] but despite this long history, the increase in the number of WTs in the world is a recent event

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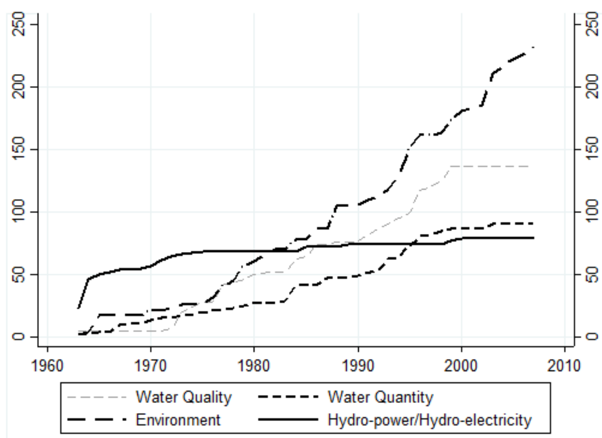
[1] see https://www.un.org/waterforlifedecade/transboundary_waters.shtml

that began in the 1960s. Figure (I) illustrates this by presenting the growing number of treaties according to four different topics: environment, water quality, water quantity and hydropower/electricity production. At least since the 1990s, an increasing number of environmental treaties have been signed while treaties related to dams have clearly reached a plateau. This graphic is however limited to understand whether WTs are enforced in reason of a growing awareness of climate change or whether they are linked to more traditional economic and political determinants.

Figure 1. Cumulative number of Water Treaties by contents



Source: Authors.

Our research question is therefore to analyze whether climate change is a causal factor of WTs both in the short run and in the long run. Such a question matter because adverse climatic conditions by reducing water resources lead to unsustainable livelihood and exacerbate inequality in the resource access. International treaties on water can be a way to regulate the competition over a scarce resource and to calm down the risk of conflict escalation.[2]

To convincingly answer this question we use panel data to exploit variation in climate across time within countries. Our value added is to focus on weather fluctuations such as temperature and precipitations variations. We find that all the fluctuation in weather have a significant effect which contrast with the estimates of economic and political variables since by analyzing several of these variables (alliance ties, the distribution of power between nations, the political regime, the level of development and past interstate dispute), we find that few of them explains WTs. Only economic and institutional interdependence matter, leading to the conclusion that WTs are mainly climate policies.

[2]See Gleditsch et al. (2006) for an interesting analysis on water conflicts, Koubi (2019) for a survey on this topic and Vesco et al. (2020) for a meta-analysis on the link between natural resources and conflict.

To analyses the time dimension, we exploit heterogeneity in weather conditions on two different period 1961-1970 and 1998-2007, then we take the average and compute the difference which are estimated in the similar way than for the year-to-year sample. Comparing the estimates between this "long differences" analysis and the short-run version, enables to study the degree to which WTs are an adaptation strategy. We find that longer-run adjustment to changes in climate has indeed exceeded shorter run adjustment regarding WT. More WTs are signed due to climate change on the long run.

Our work contributes to the rapidly growing literature on climate impacts. We apply the methodology used in the literature on climate change and conflicts (see Dell et al. 2014 for a survey) and the "long differences" approach proposed by Schlenker and Roberts (2009) and Burke and Emerick (2015). While it has been found that climate change fostered conflicts, we find that climate change also fosters cooperation via water treaties. These two results are maybe not so contradictory since we also observe that conflicts stimulate the implementation of WTs. Climate change seems to be at the source of conflicts that find a solution in the enforcement of WTs.

This contribution also belongs more directly to the literature analyzing the rationale behind the implementation of WTs. Tir and Ackerman (2009) analyze empirically how political institutions (preponderant power distribution, democratic governance), development and water scarcity increase the likelihood of international river cooperation between contiguous riparian states. Dinar et al. (2010) pursue this analysis and find that the water supply variability in international bilateral basins fosters international cooperation.[3] Dinar et al. (2011) consider that the relationship between scarcity and cooperation follows a bell-shaped curve with more WTs in situations where water scarcity is moderate rather than very low or high. Zawahri et al. (2016) analyze treaties according to their content in order to study the factors influencing treaty design.

We extend these works by introducing fixed effects both at the country level but also at the pair of countries that sign a WT, and then we control for unobserved reasons why countries may have signed a WT. We generalize some earlier findings such as the fact that the numbers of years without conflicts (being related to water or not) reduces the likelihood of cooperation (Brochmann, 2012) but we also show that the roles of allegedly important factors such as the level of development or the asymmetrical distribution of power have been exaggerated.

In Section 2 we briefly present how our contribution differs from the past literature based on a cross-sectional analysis of WTs and we present the different database used to lead our empirical strategy. In Section 3, we present the result concerning the determinants of WTs in the short run. Section 4 analyzes how WTs represent an adaptation policy to climate change on the long run. Section 5 concludes about the meaning of these results regarding climate change.

[3] They also analyses the square of this variable and conclude of a U-shaped relationship between water supply variability and treaty cooperation.

II. Short run

A. About correlations

The most common empirical strategy to analyze WTs has been the cross-sectional approaches. The identification is based on the assumption that the populations sharing a basin in different countries are identical in all respects, except concerning the variable of interest once controls are introduced for observable economic, institutional and political correlates of treaties. The following specification has been used:

$$\Gamma_{ij} = \alpha X_{ij} + \beta Z_{ij} + \varepsilon_{ij}. \tag{1}$$

where Γ_{ij} represents the treaty signed between country i and j, X_{ij} the variable of interest and Z_{ij} a vector of different controls. This cross-section is often done by averaging data on long period of time e.g. between 1950-2000.

Among the different variable of interests, authors rarely analyze temperature or other classic variables of weather fluctuations (e.g. drought, floods), but built variables related to scarcity of water in the basin. Dinar et al. (2010) use an indicator of water supply variability that captures both annual runoff variability and precipitation variability. They find a significant positive coefficient and conclude that the water supply variability in international bilateral basins fosters international cooperation.[4] Zawahri et al. (2016) use the same specification to analyze treaties according to their content in order to study the factors influencing treaty design. Dinar et al. (2015) implement this empirical strategy to study water-related events/conflicts and find that country dyads governed by treaties with flexible and specific water allocation mechanisms have a more cooperative behavior. Dinard et al. (2019) investigate the trade-off between benefits and costs associated with basin-wide treaties (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).

The estimation of Equation (1) has also been the workhorse model of many studies concerned by the impact of climate change on various political variables. See for instance the analysis of Buhaug (2010) on climate change and civil wars.

This specification while providing interesting results concerning correlation between WTs and the right-hand-side variables, has at least two shortcoming impeding to conclude about a causal relationship. The first one is the classical bias of omitted variables and the second one concerns the long time period of these analysis. Indeed the assumption that all other correlates of WTs are independent from climate variation may be difficult to support over many decades. The timing of weather fluctuation at a given location is unlikely to be independent of the timing of changes in confounding variables over a long period of time. Even

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informal institutions have the time to adjust to climate variation in the time lapse of fifty years which is often the time span analyzed.

One possibility is to use panel data on a year to year basis assuming that these two problems are less acute (or easier to resolve). This empirical strategy has been adopted by Tir and Ackerman (2009) who estimate Equation (1) by adding the time dimension. They compute a polled regression, without fixed effects and without specific/separated controls for countries i and j. This paper provides many results such as the fact that WTs go hand in hand with asymmetrical power distribution, economic interdependence, democratic governance, and water scarcity.

Despite these interesting results, the full potential of panel data technique has however not yet been used, in particular the conditions needed for causal inference are not met, there are many ways in which country i and j differ that are not taken into account in Equation alike (1). Until now the literature has made great effort to built dyadic variable of control (such as the fact that the two countries have a democratic governance or water scarcity at the basin level), but the result are not conditioned to the fact that the two countries may have different characteristics that explain WTs. Moreover many determinants of WTs are unobserved or hard to measure, so to determine whether a climatic shock has a causal effect, we need to use all the apparatus of the panel analysis.

B. Causal analysis

We propose to analyze WTs by using the following specification :

$$(2)\quad WT_{ijt} = \alpha.Clim_{ijt} + \beta.Clim_{it} + \mu.Clim_{jt} + Z_{ijt} + f_{ij} + f_i + f_j + f_t + \varepsilon_{ijt}$$

This gravity-type equation differs from previous analysis in many respect. First regarding the variable of interest we focus on weather variations, the aim is to directly analyze climate change and these variables are the most commonly used to approximate it. Another interest is that the problem of reverse causality is not a concern here since climatic variables are exogeneously determined.

A second difference between Eq. (1) and Eq. (2) is the introduction of countries fixed effects (f_i, f_j), of country-pair fixed effects (f_{ij}) and year specific effects (f_t). Country-fixed effects take into account for instance institutions, political variables and/or the level of development that characterized countries throughout the period analyzed.[5] Without these fixed effects, the direct effect of climate change may be a naive interpretation of a relationship that fails to take into account local and political contexts (see Raleigh, 2014). This introduction follows

[5] To take just one example, cooperation can be boosted by the level of development or by the specialization of countries (at the source of lobbying activities). For instance analyzing the Paraguay-Parana Waterway, Schulz et al. (2017) shows that supporters of the project are often powerful stakeholder groups in the agribusiness. In that case, not controlling for the agricultural sector can biased the coefficient of interest such as the effect of drought on WTs.

the debate between political ecologists, geographers and economists on the neo-Malthusian point of view that less resources lead to more conflicts (see Hsiang and Meng, 2014; Acemoglu et al, 2020).

Country-pair fixed effects control for bilateral relationship and time effects for specific shock (for instance regional trade agreements). Time effects control for world-wide crisis that affect all the countries of our sample in a given year.

The term Z_{ijt} refers to a vector of bilateral variables that varies over time. These variable are economic, political and geographical variables that can have an influence on treaties according to different unformalized theory. We describe in the data section the computation and/or their source of these variables and in the result section the motivation to use them.

Limitations concerning the estimation of Eq. (2) are worth mentioning. First we still cannot control for all the variables that varies along countries and time. By introducing control variables Z_{ijt}, we fall here in the same critics that we have addressed to the literature (concerning variables Z_{ij}, Z_i or Z_j that are now replaced by fixed effects), namely we do not account for unobserved variables that varies across space and time and we can potentially introduce a multicolinearity problem. We will see that these bias are serious.

The second shortcoming is that this method is valid as long as the period before and after the climate shock is small enough. In that case, the assumption that all other correlates of WTs are independent from climate variation is realistic. This obviously implies that only high-frequency variation can be used because in the reverse case (e.g. gradual political or climate change), the idea that a population before and after a shock is directly comparable along the many unobservable dimensions that affect WTs is hard to support. Consequently this empirical strategy, that use fluctuations on an annual basis, focuses on the short-run effect of climate change. But while the advantage of using variation in weather might resolve the identification problem, the drawback is that if governments can adjust their policy in the long run in ways that are unavailable to them in the short run then our results may underestimate the long-run effect of climate change. For instance political tensions in a drought year, might be overcome in the long run by a common investment in the management of the resource. Indeed WTs, and maybe even more efficient WTs take time to be enforced.

C. Data

Our final database covers the period 1961-2007 made up of 124 countries[6] around the world[7]. The dyad-years is the unit of our analysis. It is noteworthy that, our database is restricted to dyads that share rivers.[8]

- Dependant variable

[6]See Appendix A, Table 4for the list of countries

[7]Descriptive statistics are presented in Table (5)

[8]We also restrict the dyads to those on the same continent, since river basins do not involve countries that are separated by ocean (Brochmann and Gleditsch, 2012).

The WT_{odt} dummy is built from the International Freshwater Treaty Database[9] provided by the "Program in Water Conflict Management and Transformation" (College of Earth, Ocean, and Atmospheric Sciences[10]). This database gathered a full number of international, freshwater-related agreements between pair or groups of countries. These treaties concern "water as a scarce or consumable resource, a quantity to be managed, or an ecosystem to be improved or maintained [...] water rights, water allocations, water pollution, principles for equitably addressing water needs, hydropower/reservoir/flood control development, and environmental issues and the rights of riverine ecological systems". Agreements concerning fishing rights, navigation rights and tariffs, or delineation of rivers as borders are mentioned in some treaties.

To build our dummy of WTs, we extract from the International Freshwater Treaty Database, all the international water treaties since 1820 and countries that are involved in each of them. It is noteworthy that we restricted our final database to the years 1961 to 2007 according to the availability of independent variables. The groups that signed the treaties comprised two countries in case of bilateral agreements and more than two in case of multilateral agreements. We generate, for each treaty, a set of bilateral combinations of the signatory countries. Consequently, the number of bilateral combinations per treaty is given by $\frac{(n!)/((n-k)!)}{2}$, with $n \geqslant 2$ and $k = 2$; n designing the number of countries engage in a cooperation on water resources, and k is the number of countries in a dyad. Our final variable takes one in years when two countries signed a water agreement and zero otherwise. It still takes one even in years a dyad is involved in more than one agreement. Our final sample is limited to dyads that share at least one water basin.

- Climate's variables

Variables on temperature and precipitations are constructed by combining historical monthly weather data (available in rasters) provided by WorldClim[11] with river basin's shapefiles from McCracken and Wolf (2019)[12]. The historical monthly data provides average minimum temperature (°C), average maximum temperature (°C)[13] and total precipitation (mm) with a 2.5 minutes (˜21 km2) spatial resolution. McCracken and Wolf (2019) propose the spatial delineations of the international river basin around the world and also the basin country units. With the latter, we draw countries coverage in river basins, which indicates the surface of each country drain by international rivers and their tributaries. We use these data to draw monthly mean temperature and precipitations accross countries basin from 1961 to 2007. This implies that, in our dyadic database, each

[9] https://transboundarywaters.science.oregonstate.edu/content/international-freshwater-treaties-database

[10] Oregon State University

[11] https://www.worldclim.org/data/monthlywth.html

[12] https://transboundarywaters.science.oregonstate.edu/content/transboundary-freshwater-spatial-database

[13] A mean temperature variable is generated with these maximum and the minimum temperature.

country's weather variable has been built upon the land surface of the country that is the river basin.

With these variables at hand, we take into account the different facets of climatic effects in different ways. First, we build the yearly mean values of temperature and precipitations for every member of water agreements. Second, in each dyad, we consider an interaction between countries ($Precipitations_i \times Precipitations_j$, and $Temperature_i \times Temperature_j$) because we expect that a simultaneous chock is going to facilitate a WT.

We also use for every year, the number of months that a country experienced a temperature and precipitations above the country decade's mean level.

Finally, we account for potential nonlinearity between temperature and the likelihood of water agreements by relying on two different types of climates indicators that conceptually may describe two kinds of climate response. The first, intrinsically accounts for agriculture sector response to climate change in terms of productivity. Thus, we follow the climate-agriculture literature that usually accounts for climate effect by using the notions of Growing Degree Days (GDD) and Killing Degree Days (KDD). We adapt these indicators to our study since we only have monthly data, by computing what we call the Growing Degree Months (GDM) and Killing Degree Months (KDM). In our context, the GDM reflects heat accumulation that crops experienced between a lower (T_l) and upper bound (T_h), on which populations and therefore policy makers may base their appreciation of hotter years. Following the literature (Schlenker and Roberts, 2009; Burke and Emerick, 2016), we set the lower bound to 8°C and the upper bound to 32°C. In fact, this literature suggest that a mean temperature of 8°C contributes to 0 degree month, while a temperature equal or above 32°C is damaging to agriculture productivity and contributes to 24 degree months. These bounds, often used to analyze the agricultural sector in developing countries are set for particular crops and are thus subject to cautions when applied to our worldwide study, we thus lead a robustness check analysis with a different bounds.[14] Finally, we sum up the values obtained by year, yielding to our variable of yearly GDM. Actually, the monthly heat unit is obtained as follow:

$$g_{imt}(h) = \begin{cases} 0 & if \;\; T_m \leq T_l \\ T_d - T_l & if \;\; T_l < T_m \leq T_h \\ T_h - T_l & if \;\; T_m > T_h \end{cases}$$

where T_l is the lower bound while T_h is the upper bound. We obtain the annual

[14] In fact, for the sake of testing the robustness of our results, we also provide a supplemented analysis by using respectively 0°C as the lower bound and countries mean temperature in each decade as the upper bound. Thus, any monthly mean temperature is replaced by zero when it is equal or below the lower bound. But it is set to the month mean temperature minus the lower bound when the month temperature is comprised between 0°C and the countries mean temperature. Finaly, we set the values to the upper bound minus the lower bound when the month mean temperature is above countries' average temperature of the related per decade. These values are respectively summed by year to provide our measures of GDM and KDM.

GDD and KDD measures by summing these degree months over all years and according respectively to each intervals.

In practice, we sum $g(h)$ corresponding to the cases where$T_l < T_m \leq T_h$:

$$GDM_{it,\,T_l<T_m\leq T_h} = \sum_{m=1}^{12} g_{imt}(h).$$

Likewise, we sum $g(h)$ for the cases where $T_m > T_h$:

$$KDM_{it,\,T_m>T_h} = \sum_{m=1}^{12} g_{imt}(h)$$

These two indicators are directly linked to the agricultural sector. While this sector is by far the main consumer of water, it possible that the choice of government to sign water agreements is unrelated to this sector but instead linked to the climate effect on population in their every day living. We thus use two additional indicators that have been widely use to explain for instance migration inside large countries (e.g. in the U.S., see Albouy et al. 2016), the so called Cooling Degree Days (CDD) and Heating Degree Days (HDD). These indicators are derived from the idea that people use more heating during cold weather and other technology during hot periods (e.g. air conditioning). These indicators enables to capture the demand of energy needed to cool or to warm a building. CDD and HDD designs are based on a literature assuming that it is not necessary to cool or heat a building when the temperature reaches 18°C. Since we only get monthly climate data, we propose similar indicators that we respectively call cooling degree months (CDM) and heating degree months (HDM). These indicators are calculated for every year-month and the monthly degree-months are cumulated for each year. CDM and HDM data can be resumed as follow:

$$f_{imt}(18) = \begin{cases} T_m - 18 & if \quad T_m > 18 \\ 18 - T_m & if \quad T_m < 18 \end{cases}$$

Thus, summing $f_{imt}(18)$ corresponding to $T_m > 18$ gives:

$$CDM_{it,\,T_m>18} = \sum_{m=1}^{12} f_{imt}(18)$$

Likewise, we have:

$$HDM_{it,\,T_m<18} = \sum_{m=1}^{12} f_{imt}(18)$$

With regard to precipitations, we consider the difference between monthly and the base precipitation when the former is greater than the latter; whereas we use the base precipitations minus the monthly precipitation. For each country, we set the base precipitations to the average precipitation over the decade.

- Bilateral political and and socioeconomic factors

Joint democracy: 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. Here, we follow Brochmann (2012) by considering a country as a democracy when it's polity-2 value is above 6.

Peace history: We rely on two different variables. First we consider 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[15]. 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). In addition to this variable, we consider a second measure that accounts for hostilities which are closely linked to water. We rely on the International Water Events Database which records the most complete and comprehensive list of international bilateral/multilateral reactions on water resources. It provides for each event, an intensity scale rating, ranging from -7 to 7 that allows distinguishing the conflict events (with a bar scale below 0) from the cooperative events (with a bar scale above 0). We use the conflict events to develop a new variable describing the number of peaceful years since the last hostilities over water resources between countries of each dyad.

Alliance between states: The alliance indicator between countries is a binary variable from COW Formal Interstate Alliance Dataset. It records all formal alliances among states, including mutual defense pacts, non-aggression treaties and ententes.

Intergovernmental Organization (IGOs): Countries that are members of the same intergovernmental organization may be more likely to cooperate because they have already a long-standing history of collaboration. We follow Broshman (2012) by using a variable indicating the log number of intergovernmental memberships shared by the two countries in a dyad. The new version of these database recorded 534 intergovernmental organizations from over the period 1815 to 2014.

Power distribution: We measure the asymmetrical distribution of power between partners by firstly 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[16] This indicator is built on six (6) different

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

variables that are respectively: (i) "total population", (ii) "urban population", (iii) "iron and steel production", (iv) "energy consumption", (v) "military personnel", and (vi) "military expenditure". Secondly, we consider two indicators of "economic asymmetry" which are the ratio of the most economically powerful state on the less powerful state of the dyad. For the first indicator we use Gross domestic Product (GDP) (Highest GDP on lowest GDP by dyad) and for the second we use GDP per capita (Highest GDP per-capita on the lowest GDP per-capita by dyad). Our data on GDP and population comes from the World development indicators (WDI).

Economic interdependency: The economic interdependence variable is based on trade flows (Dinar, 2010; Sigman, 2004) from the Direction of Trade Statistics (DOTS) Database. More precisely we take the yearly ratio of total trade (imports and exports) between the two countries in the dyad over their 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.

- Bilateral gravity data

We also introduce geographical and political variables that are considered as exogeneous by the literature such as the distance between countries, the fact to share a common border, and a dummy indicating whether countries in a dyad have had the same colonizer. These data come from the CEPII's Gravity database. Our variable that indicates whether countries in a dyad shared river is a dummy from Peace Research Institute Oslo (PRIO). Unlike the previous version of PRIO, this newest database accounts for dyads that share river basin without sharing a border.

III. Short run results

A. About the "second nature" of treaties

> "In the early twentieth century, those schooled in the conventional wisdom might have predicted that Argentina, with her fertile and vast pampas land, would grow faster than Japan, with her mountainous land and limited natural resources. To them, what happened to these two economies during the last 90 years may be puzzling." Matsuyama (1992, JET)

For many economists, the scarcity of the resource can be balanced with efficient markets and well functioning institutions. The above quotation of Matsuyama (1992) fully represents this point of view, natural resources such as water are not vital in an open world where manufacturing goods and services can be exchanged for agricultural products. Consequently, the "first nature" in which people evolve, defined by Cronon (1992) as "the nonhuman world of ecological relations", and determined by climatic and geographical variables, may have been relayed or contradicted by economic factors that are now the "second nature" of WTs.[17]

Many research explaining WTs have focused on these second sources of explanation and to make our results comparable with the literature we use these variables in Table 1, column 1, 2, 3 and 4. In the previous section we present the source of these data, in the current one we present the motivation to test their explanatory power. These variables (represented by a vector Z_{ijt} in Equation, 2) are:

Joint democracy. According to Tir and Ackerman (2009), democratic systems are more likely to cooperate between them because they share a similar culture favoring and ensuring a long term relationship that is required to manage a common resource. It is also asserted that democracies have a common "rule-making approach" that are crucial to enforce a well functioning treaty. Tir and Ackerman (2009) operates a brief review of the literature and find that joint democracy indeed positively influences WTs. Dinar et al. (2010) use different indicators and dummies to approximate democracy and also conclude in favor of a positive relationship.

Bilateral trade as a measure of economic interdependence. The idea that trade foster interdependence is an old one (Montesquieu, 1748) and has been revisited recently in the analysis of conflicts[18]. Concerning WTs, 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.

Power distribution. According to the neo-realist school of thought (e.g. Mearsheimer, 2005), the distribution of powers between partners is a determinant of treaties. Strong states may have the capacity to use their power (or may have access to international institutions) in order to extract concession from a weaker state (Elhance, 1999; Tir and Ackerman, 2009).

Economic power distribution. 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; they are also better organized to put in place joint managements.[19] This pressure to find political responses to climate

[17]We build this argument on Cronon (1992) who 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 (1992) 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.

[18]Martin et al. (2008) shows that multilateral trade integration foster 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 dependant from each other. Candau et al. (2020) 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) foster civil conflicts.

[19]A similar argument is used to defend the environmental Kuznets-curve (see Dinda, 2004 for a survey).

change in developed countries may foster WTs with emerging countries. Many authors have rejected this thesis such as Dinar et al. (2010) by finding that asymmetrical economic power have a significant but negative coefficients.

Past conflicts. Security concerns and past conflicts are potential obstacles to cooperation. 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 (1993, 1995) and Amery and Wolf (2000) 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 the number of peaceful years by considering a) bilateral militarized interstate disputes, b) bilateral water disputes, and c) bilateral negative water events.

The main result of Table (1) is that many of these economic and political variables are no longer significant in our analysis with fixed effects. Regarding joint democracy, the distribution of power and alliance ties, we cannot reject the hypothesis that these variables have no effect on WTs. In particular the asymmetrical distribution in power, measured by three different indicators (GDP, GDP per capita, state capacity) is never significant. Previous research observing a negative effect of asymmetrical economic distribution or detecting a positive impact of diplomatic relationship may come from the lack of control regarding unvarying bilateral links.

On the contrary, we find that the economic interdependence, approximated by bilateral trade between countries, is always significant. This result is in line with the literature (e.g. Tir and Ackerman, 2009, or Dinar et al. 2010).

Finally, by using three different indicators of peace, we generalize the Brochmann (2012) result that the number of years without conflict seems detrimental to WTs, at least concerning military and water disputes (we find no effect for water negative events).

Table 1—Politics effects on international water agreements

	(1)	(2)	(3)	(3)
Joint democracy	-0.0004	0.0005	0.0007	0.0000
	(0.0114)	(0.0114)	(0.0112)	(0.0114)
Economic interdependence	0.0024[a]	0.0023[a]	0.0025[a]	0.0023[a]
(Indicator of Trade adjusted)	(0.0009)	(0.0009)	(0.0009)	(0.0009)
Economic Power	0.0100		0.0096	0.0102
(Highest GDP/lowest GDP by dyad)	(0.0078)		(0.0078)	(0.0078)
Welfare power		0.0098		
(Highest GDP p. capita/lowest GDP p. capita)		(0.0073)		
Power distribution	-0.0019	-0.0027	-0.0023	-0.0027
(Highest GDP on lowest GDP by dyad)	(0.0197)	(0.0193)	(0.0196)	(0.0198)
Alliance ties	-0.0034	-0.0051	-0.0064	-0.0054
	(0.0179)	(0.0177)	(0.0174)	(0.0174)
Number of peaceful years I	-0.0006[a]	-0.0006[a]		
(Bilateral militarised interstate disputes)	(0.0002)	(0.0002)		
Number of peacefull years II			-0.0024[b]	
(Bilateral water disputes)			(0.0011)	
Number of peacefull years III				-0.0006
(Bilateral negative events)				(0.0008)
Constant	0.0996[a]	0.1100[a]	0.0999[a]	0.0951[b]
	(0.0369)	(0.0346)	(0.0353)	(0.0359)
Observations	8,259	8,259	8,259	8,259
Pseudo R-squared	0.288	0.288	0.288	0.288

Note: Standard errors adjusted for clustering at the country pair level. a: p<0.01, b: p<0.05, c: p<0.1. All the regressions were done with year fixed effect, f_t, individual fixed effects f_i and f_j and bilateral fixed effects f_{ij}.

B. *About the "first nature" of treaties*

By testing how the bias of omitted variables was serious when considering different economic and political variables, we have found in the previous section that only two determinants, namely the economic interdependence of countries and their bilateral conflicts, remain significant once fixed effects are introduced. However, these two variables pose a great challenge concerning reverse causality. For instance, water conflicts are certainly a function of the past water treaties. Besides, trade, and in particular the agricultural trade, may be determined by WTs. Consequently, it is hard to conclude about a causal relationship regarding these factors.

Furthermore, the high number of missing values in the political and socioeconomic data, as presented in the section above, constitutes another significant limitations in the empirical literature on the political and socioeconomic drivers of water treaties. This issue may generate sampling bias which may bias the panel estimation coefficients, even if reverse causality and omitted variables problems are accounted for.

For that reason, and also because political variables presented above are generally determined by climatic factors, we decide to no longer use them here in order to avoid different econometric problems (e.g. the "over-controlling" or "bad control" problems, see Angrist and Pischke, 2008) and we focus on weather fluctuations (i.e. "first cause") for their exogenous characteristics. We hovewer control for these political variables by using various fixed effects as well as bilateral variables that are assumed exogeneous (dummies for past colonizer which explain past and current institutions, distance which explains economic interdependency and so on).

Table (2) presents the estimations of Equation (2) with the full set of fixed effects in each column (f_i, f_j, f_t and f_{ij}). It is worth noting that, by relying on fixed-effects estimator, we model the deviations from within-group averages as with the within estimator.

We can observe that the number of observations in Table (2) is more than three times the number of observations in Table (1). As a consequence, regressions with climate variables probably exhibit little or no sample selection bias problems because of the availability and the regularity of the weather data.

In Column 1, we test the effect of the average temperature and precipitations in country i and j. We find that an increase in dyads' temperature and precipitations, is positively associated with the likelihood of international water cooperation onset. In Column 2 we reproduce this estimation by considering interactions of climate variables between countries (e.g. $Temperature\, in\, i * Temperature\, in\, j$) in each dyad. Furthermore, since extreme variations may matter more, Column 3 uses the climate variable of the country which accounts for the highest variations. Whatever the variables used, the same conclusion holds: WTs are positively affected by climate change approximated by weather variations. The positive effect of precipitation is certainly related to floods and other extreme events. Indeed, it is possible that countries where successive extreme events occurs (e.g. heavy rain from tropical cyclones) are more likely to sign WTs to regulate rivers.

In Columns 4-6, we follow the literature by accounting for the non-linear relationship in climate effects as exposed in the data section. We expect that above a particular threshold of temperatures, more WTs are going to be enforced. The results concerning the indicator of GDM (based on temperatures between 8°C and 32°C) and of the indicator of KDM ((based on temperatures above 32°C) does not allow to verify this hypothesis. Indeed, these two variables give the same answer, better conditions to grow plants and conditions that kills plants, favor WTs. The result concerning the HDM and CDM are more interesting since they clearly indicates that the number of WTs is driven by hot temperatures. Indeed an increase in the cooling degree-month (above 18°C) is significant while the indicator of cold weather (the heating degree-months) has a non-significant effect.

Table 2—Climate reasons of water agreements

	(1)	(2)	(3)	(4)	(5)	(6)
	Likelihood of water agreements					
Avg Temp in i and j	0.0160[a]					
	(0.0035)					
Avg Precip in i and j	0.0304[a]					
	(0.0101)					
Interaction: Temp i and j		0.0010[a]				
		(0.0001)				
Interaction: Precip i and j		0.0054[a]				
		(0.0014)				
Temp: member highest CV			0.0106[a]			
			(0.0029)			
Precip: member highest CV			0.0109			
			(0.0079)			
Avg number of warmer months (ij)				0.1384[a]		
				(0.0193)		
Avg number of rainier months (ij)				-0.0035		
				(0.0148)		
Avg GDM in i and j					0.0324[a]	
					(0.0052)	
Avg KDM in i and j					0.0233[a]	
					(0.0072)	
Avg HDM in i and j						0.0012
						(0.0037)
Avg CDM in i and j						0.0628[a]
						(0.0064)
Avg sum of additional Precip in i and j					0.0006[a]	0.0007[a]
(Below the threshold)					(0.0002)	(0.0002)
Avg sum of Precip gap in i and j					0.0004	0.0005
(ie. Above the threshold)					(0.0003)	(0.0003)
Constant	-0.3491[a]	-0.3896[a]	-0.1599[b]	-0.0143	-0.3216[a]	-0.2168[a]
	(0.0869)	(0.0572)	(0.0669)	(0.0127)	(0.0586)	(0.0304)
Observations	24,252	24,252	24,252	24,252	24,252	24,252
R-squared	0.318	0.319	0.317	0.318	0.318	0.320

Source: Authors. Standard errors adjusted for clustering at the country pair level. a: p<0.01, b: p<0.05, c: p<0.1.

All the regressions include year fixed effect, f_t, countries fixed effects f_i and f_j and bilateral fixed effects f_{ij}.

IV. Long differences

To partially address the problems presented previously we implement the long differences methodology proposed by Burke and Emerick (2015). We thus estimate the effect of climate change on WTs by relying on the following equation:

$$\overline{WT_{ijt_2}} - \overline{WT_{ijt_1}} = \alpha(\overline{Clim_{ijt_2}} - \overline{Clim_{ijt_1}}) + \beta(\overline{Clim_{it_2}} - \overline{Clim_{it_1}}) + \beta(\overline{Clim_{jt_2}} - \overline{Clim_{jt_1}}) + \Delta\varepsilon_{ij} \tag{3}$$

where $\overline{WT_{ijt_2}}$ and $\overline{WT_{ijt_1}}$represent the average number of water treaties signed during two periods which are respectively $t_2 = 1961 - 1970$ and $t_1 = 1998 - 2007$.

We chose these most extreme periods of our database for two reasons. First during the period 1998-2007, a growing interest and knowledge of climate change have been acknowledged (the Stern report on the "Economics of Climate Change" was for instance published in 2006), while on the opposite the period 1961-1970 was a period of relative indifference about climate change (the Meadow report on "The Limit to Growth" is published almost a decade later, in 1972).

Results presented in Table (3) show that for many climate variables, coefficients are stronger than in the short run. This is the case concerning average temperature and precipitations, temperature and precipitations in interactions, the average number of warmer months, the average growing and killing degree months, the average cooling degree months, and the yearly sum of average precipitations above the country mean. To make easierthe comparison of coefficients, we report in the Appendix D, Figure IX, both thelong and the short run (presented in the previous section) results. We also report in Appendix E, Figure 4, the short run and long-difference effect of GDM and KDM while using 0°C and the countries' average temperature of the related per decade, respectivelly as the lower bound and the upper bound. This robustness check analysis delivers the same results as earlier: in addition of being positive, the long-difference effects still stronger than the short run effect.

From these finding we can conclude that the change in climatic conditions observed between 1961-70 and 1998-2007 have been a significant determinants of WTs. The international cooperation on common basins seems to be a function, not solely of weather fluctuations, but of more fundamental change in temperatures and precipitations observed during this long period of time.

Different explanations can be proposed to discuss this result. The most natural is that the environmental consequences of climate change have grown over time, leading governments to sign more WTs treaties with environmental purposes (as discussed in the introduction). A second explanation is that governments and individuals have failed to resolve problems linked to climate change and water in the short run, leading to more WTs in the long run. This result echoes to the finding of Burke and Emrick (2015) who show that the adaptation of farmers to climate change has been negligible on a similar period of time. It is thus possible that governments react to this individual lack of adaptation, by signing more agreements on the long run.

TABLE 3—CLIMATE REASONS OF WATER AGREEMENTS

	(1)	(2)	(3)	(4)	(5)	(6)
	Likelihood of water agreements					
Avg Temp in i and j	0.0390^{a}					
	(0.0103)					
Avg Precip in i and j	0.0964^{c}					
	(0.0560)					
Interaction: Temp i and j		0.0024^{a}				
		(0.0004)				
Interaction: Precip i and j		0.0299^{a}				
		(0.0079)				
Temp: member highest CV			0.0247^{a}			
			(0.0093)			
Precip: member highest CV			0.1207^{a}			
			(0.0463)			
Avg number of warmer months (ij)				0.1800^{b}		
				(0.0723)		
Avg number of rainier months (ij)				0.5778^{a}		
				(0.1963)		
Avg GDM in i and j					0.1959^{a}	
					(0.0217)	
Avg KDM in i and j					0.1615^{a}	
					(0.0226)	
Avg HDM in i and j						-0.0483^{a}
						(0.0112)
Avg CDM in i and j						0.1531^{a}
						(0.0204)
Avg Precip in i and j					0.0082^{a}	0.0086^{a}
(Below the threshold)					(0.0027)	(0.0029)
Avg Precip in i and j					-0.0047	-0.0023
(Above the threshold)					(0.0029)	(0.0032)
Constant	0.0082	-0.0175^{c}	0.0191^{b}	0.0268^{a}	-0.0721^{a}	-0.0476^{a}
	(0.0093)	(0.0090)	(0.0088)	(0.0045)	(0.0136)	(0.0119)
Observations	516	516	516	516	516	516
R-squared	0.022	0.091	0.023	0.021 1	0.20	0.099

Source: Authors. Standard errors adjusted for clustering at the country pair level. a: p<0.01, b: p<0.05, c: p<0.1.

V. Conclusion

While the neo-malthusian literature concludes that climate change leads to more conflict, our analysis shows that these variables also have a positive effect on cooperation concerning water issues. Conflict and climate change may be complementary to explain WTs. After significant conflicts, WTs may be a solution to resolve water problems linked to climate change. We also find that few political or economic variables matter concerning WTs. The level of development, the asymmetrical distribution of power, or the political system (joint-democracy) fail to explain WTs in a robust way. One of the sole variable that is always positive for international treaties is the interdependence of countries (measured by bilateral trade). But the real contribution of the current paper lies in the analysis of climate variables to explain the enforcement of WTs. We find that many climatic variables such as temperature, precipitations, and related variables (growing degree or killing degree temperature) strongly explain WTs. We also test the idea that WTs are adaptation policies in a sense that long run difference in climate variables fosters the enforcement of WTs. Obviously the effectiveness of these international agreements remain unknown, and the increasing number of these treaties might reflect the fact that solutions to preserve common basins are hard to find. However, it is comforting to observe that governments look for these solutions by cooperating more between them regarding the forthcoming stress of common water ressources due to climate change.

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Table 4—List of countries

Afghanistan; Albania; Algeria; Angola; Argentina; Armenia; Austria; Azerbaijan; Bangladesh; Belgium; Belize; Benin; Bhutan; Bosnia and Herzegovina; Botswana; Brazil; Bulgaria; Burkina Faso; Burundi; Cambodia; Cameroon; Canada; Central African Republic; Chad; Chile; China; Colombia; Congo; Costa Rica; Croatia; Denmark; Djibouti; Dominican Republic; Ecuador; Egypt; El Salvador; Equatorial Guinea; Eritrea; Estonia; Ethiopia; Finland; France; Gabon; Gambia; Georgia; Germany; Ghana; Greece; Guatemala; Guinea; Guinea-Bissau; Guyana; Haiti; Honduras; Hungary; India; Indonesia; Iran (Islamic Republic of); Iraq; Israel; Italy; Jordan; Kazakhstan; Kenya; Kyrgyzstan; People's Democratic Republic; Latvia; Lebanon; Lesotho; Liberia; Libya; Lithuania; Luxembourg; Malawi; Malaysia; Mali; Mauritania; Mexico; Mongolia; Morocco; Mozambique; Myanmar; Namibia; Nepal; Netherlands; Nicaragua; Niger; Nigeria; Norway; Pakistan; Panama; Paraguay; Peru; Poland; Portugal; Republic of Korea; Republic of Moldova; Rwanda; Senegal; Sierra Leone; Slovakia; Slovenia; Somalia; South Africa; Spain; Sudan; Suriname; Sweden; Switzerland; Syrian Arab Republic; Tajikistan; Thailand; Togo; Tunisia; Turkey; Turkmenistan; Uganda; Ukraine; United Republic of Tanzania; United States of America; Uruguay; Uzbekistan; Zambia; Zimbabwe.

VI. Appendix A: list of countries

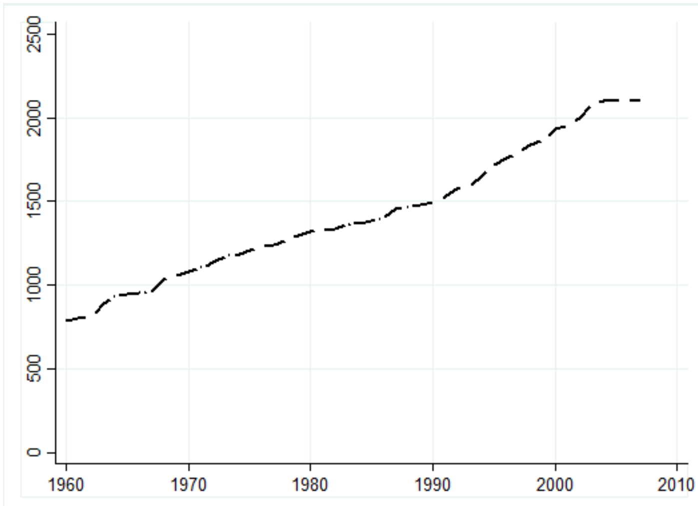
VII. Appendix B: Descriptive statistics

Table 5—Descriptive statistics

Variables	Obs	Mean	Std. Dev.	Min	Max
Bilateral water agreements	24,252	.0571499	.2321337	0	1
Climate variables					
Temperature	24,252	17.67191	8.135788	-4.125309	30.39625
Precipitations	24,252	78.99774	53.402	.591507	376.1403
Number of warmer months	24,252	.5270827	.1052048	0	1
Number of rainier months	24,252	.4339089	.1132334	0	.9166667
Growing degree month (GDM)	24,252	129.0508	73.00652	.4920588	248.5835
Killing degree month (KDM)	24,252	3.236022	13.07411	0	144
Heating degree months (HDM)	24,252	50.28388	61.62184	0	265.5037
Cooling degree month (CDM)	24,252	46.34675	41.32003	0	148.755
Sum Additional Precipitations	24,252	280.5506	219.0661	0	1486.287
Sum Precip gap	24,252	280.7039	205.3317	1.913925	1237.182
Politics' variables					
Joint democracies	17,531	.1888084	.3913675	0	1
Economic interdepedance (Trade) -log-	8,324	-19.10356	3.78844	-32.09417	3.623303
Highest GDP/lowest GDP -log-	14,827	1.69394	1.439966	-1.46703	7.249705
Highest GDP p. cap/lowest GDP p. cap) -log-	14,827	.7065186	.8135756	-3.619766	4.156245
Power distribution	17,804	1.51738	1.23756	.0001009	6.586875
Alliance ties	18,432	.2004123	.4003198	0	1
Peacefull years (Bil Militarised interstate disputes)	18,432	9.057346	20.84449	0	174
Peacefull years (Bilateral Water disputes)	18,432	.8507487	4.168201	0	54
Peacefull years (Bilateral negative Water events)	18,432	2.492188	6.670862	0	49

VIII. Appendix C: World evolution of international water agreements onset, 1960-2007

Figure 2. Cumulative number of Water Treaties onset in the word

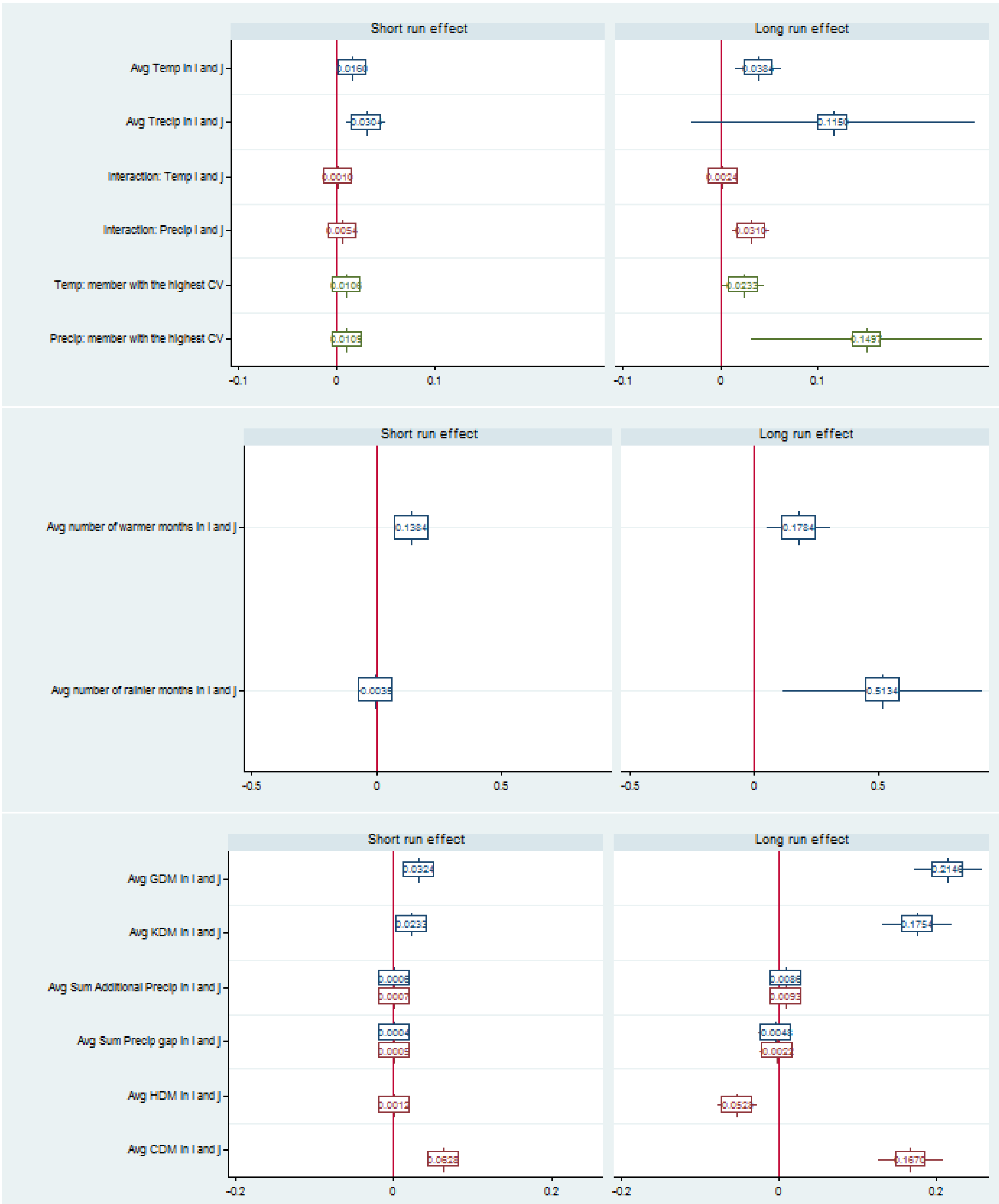


Source: Authors.

IX. Appendix D: Visualisation of the short-run and the long-difference results

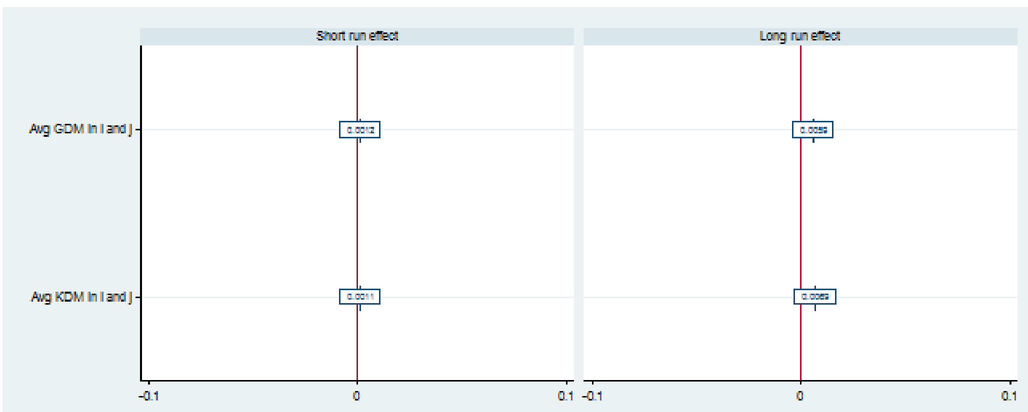
X. Appendix E: Visualisation of the short-run and the long-difference results with new measures of GDM and KDM

Figure 3. Short-run vs long-difference coefficients



Source: Authors.

FIGURE 4. SHORT-RUN VS LONG-DIFFERENCE COEFFICIENTS: ROBUSTNESS CHECK



Source: Authors.