EXTENDED ABSTRACT

Title: Sustainability of transboundary Rivers in Asian regions

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Abstract:

Transboundary rivers are rivers that are divided by political borders and shared by two countries or more (De Stefano et al., 2012; Ganoulis and Fried, 2018a). In these environments, water conflicts might occur due to natural, political and socioeconomic causes, and this could impact on the water quality, quantity, and accompanying ecosystems (Ganoulis and Fried, 2018b). However, when countries that share transboundary water cooperate, they are able to obtain economic, social, environmental and geopolitical benefits (Ganoulis and Fried, 2018c). This may explain why the United Nations considers transboundary water cooperation critical as it is viewed to have a positive effect on all 17 sustainable development goals (United Nations, 2018).

This paper analyses the sustainability of 67 transboundary river basins that are located in Asian regions and compare them to basins found in Europe (72) and North America (45). Data are obtained from the TWAP Programme, a programme whose database covers 287 transboundary river basins in regions around the world. The aim would thus be to answer the following research question:

RQ1. What are the necessary and sufficient causal conditions related to sustainability that explain the absence of high hydropolitical tensions in transboundary basins?

To obtain the papers required for the ***literature review***, a search was carried out within the Web of Science database using the terms “transboundary” and “river”. Then, papers that were published in the years 2017, 2018, and 2019 were selected. Through analysing these works, we found that the literature on transboundary rivers can be divided into two important groups. The first covers works related to water conflicts, that is, the risk of hydropolitical tensions related to this shared resource (De Stefano et al., 2017). The second group refers to solutions for disputes, including management and cooperation (Ganoulis and Fried, 2018c).

Hydropolitical tensions are the consequence in the use of shared water and could affect other countries. The definition of transboundary rivers implies that their water will be used by different countries, increasing the risk of scarcity, and this could also intensify the risk of tensions (Wu et al., 2019). Prior literature has given specific reasons that often lead to an elevated risk of transnational tension. For example, De Stefano et al. (2017) consider water infrastructures (such as dams) and institutional capacity as factors which could increase the risk of hydropolitical tensions. These infrastructures, built in upstream regions of the basins, would affect downstream regions, especially when the parties that control the upstream supply apply certain decisions in drought environments (Ahmed et al., 2019; Bonnema and Hossain, 2019). Previous papers have also affirmed that dams impact upon water quantity (Bonnema and Hossain, 2019). Besides water availability, other factors can increase the risk of tensions, such as water variability and per capita income (De Stefano et al., 2017). Water variability can be also influenced by the increase in population, which reduces water availability (Yuan et al., 2019), or be affected by other factors, such as climate change (Yuan et al., 2019). Indeed, water quality is very important to assure the sustainability of the ecosystems of the countries sharing the basin (Ly et al., 2019). Pollution, on the contrary, endangers the ecosystems of these basins (Chakraborty et al., 2019). Campbell et al. (2019) explain, for example, how ecosystems are put in risk when the use of rivers endangers the habitat of fish.

Cooperation in transboundary rivers appears in the literature as an important point of Agenda 2030, particularly in sustainable development goal 6 (SDG 6). McCracken and Meyer (2018) analyse the use of the indicator SDG 6.5.2 that was used to measure water cooperation. They advised on the risk of over-simplification, as some indicators need to be met in full in order for it to be considered to have transboundary operational cooperation. As transboundary rivers flow through different countries, cooperation would need certain integrated management plans that will allow for a consideration of both the needs of the ecosystem and people (Domisch et al., 2019).

The next step in this paper was in explaining the ***methodology*** used to obtain the data and perform its analysis. The data used in the analysis were obtained from the Transboundary Waters Assessment Programme (TWAP; http://twap-rivers.org/indicators/). This database identified 286 transboundary river basins around the world. For this paper, data of basins in Asia (67), Europe (72) and North America (45) were selected.

Qualitative Comparative Analysis (QCA) and network analysis were applied to examine the data. Data was then analysed through Qualitative Comparative Analysis (QCA) in order to answer the research question that was defined for this paper. Causal conditions used in the QCA analysis were obtained through a literature review, and the indicators were defined by the Transboundary Waters Assessment Programme (TWAP). This programme was selected as a base for organising the literature review as they considered more than the technical aspects that were related to sustainability. Indeed, the indicators were used to cover environmental indicators, along with governance, cooperation, and socio-economic factors. Some transformations were made to adapt values for the analysis. The database TWAP assigns values from 1 to 5, and these values are indicative of very low tensions to very high tensions. For our analysis, we

transformed these values to 1 (very high and high tension) and 0 (moderate, low and very low tension). Table 1 includes the variables used and values used for the analysis. The software fsQCA (Ragin and Davey, 2016) was also used in the analysis and the types of analysis selected were crisp sets.

Table 1. Variables used and values defined for the analysis

Variables from the TWAP database		Variable name	Values used in the analysis
Variable group	*Indicator*		
Output			
Governance tension	*H*ydropolitical tension	Hydropolitical	High or very high tension → 1 Otherwise → 0
Causal conditions			
Water Quantity tension	*E*nvironmental water stress *H*uman water stress *A*gricultural water stress	WQuantity	Two or three indicators with high or very high tension → 1 Otherwise → 0
Water Quality tension	*N*utrient pollution *W*astewater pollution	WQuantity	One or two indicators with high or very high tension → 1 Otherwise → 0
Ecosystems tension	*W*etland disconnectivity *E*cosystem impacts from dams *T*hreat to fish *E*xtinction risk	Ecosystem	Two or more indicators with high or very high tension → 1 Otherwise → 0
Governance tension	*L*egal framework *E*nabling environment	Governance	One or two indicators with high or very high tension → 1 Otherwise → 0
Socioeconomics tension	*E*conomic dependence on water resources *S*ocietal well-being *E*xposure to floods and droughts	Socioeconomics	Two or three indicators with high or very high tension → 1 Otherwise → 0

One general model was defined for the analysis and the output considered was the absence of Hydropolitical tension. This model was:

General Model: ~Hydropolitical = f (WQuality, WQuantity, Ecosystem, Governance, Socioeconomics)

However, some variants that were included for the three regions were analysed due to low variance in certain variables. For example, in the model for Asia, the condition WQuality had a value of 1 for every basin, while Socioeconomics had a value of 0 in all the basins except for three. Therefore, these two conditions were excluded from the model. In the model for Europe, two conditions were excluded: WQuantity (value 1 in every basin) and Socioeconomic (value 0 in all the basins). Finally, in the model for North America, three conditions were excluded due to similar reasons. These conditions are WQuality (value 1 in every basin), WQuantity (only three basins out of 45 with value 1) and Socioeconomics (value 0 in all the basins). If these conditions were not excluded, then the analysis of necessary conditions would give contradictions. Therefore, the models used in each region are as follows:

Model for Asia: ~Hydropolitical = f(WQuantity, Ecosystem, Governance)

Model for Europe: ~Hydropolitical = f (WQuality, Ecosystem, Governance)

Model for North America: ~Hydropolitical = f (Ecosystem, Governance)

After the QCA analysis, which was focused on variable groups in Table 1, the network analysis was used to obtain the most important indicator that was used by the TWAP database. The analysis is individualized for the three regions analysed (Asia, Europe, and North America).

After explaining the methodology, we obtained the results for the QCA analysis and network analysis. In the selection of the causal conditions for the QCA analysis, certain ***results*** were found that indicated no high or very high tensions that were related to socioeconomic indicators within the three regions analysed. However, an important difference was obtained for these regions, showing that high and very high tensions related to water quality appear in every basin in Asia and North America, while in Europe, all the basins presented high and very high tensions that were linked to water quantity.

Table 2 includes the results for the analysis of the necessary conditions, and is indicative of the fact that there are no necessary conditions when the output considered is the absence of high and very high hydropolitical tensions. All the option in the analysis of necessary conditions were included in order to check for contradictions.

Table 2. Analysis of Necessary Conditions

Sub-model 1. Asia					
Outcome variable: Hydropolitical tension					
Conditions tested	*Consistency*	*Coverage*	*Conditions tested*	*Consistency*	*Coverage*
WQuantity	0.100000	0.050000	~WQuantity	0.900000	0.191489
Ecosystem	0.300000	0.214286	~Ecosystem	0.700000	0.132075
Governance	0.900000	0.191489	~Governance	0.100000	0.050000
Outcome variable: ~Hydropolitical tension					
WQuantity	0.333333	0.950000	~WQuantity	0.666667	0.808511
Ecosystem	0.192982	0.785714	~Ecosystem	0.807018	0.867925
Governance	0.666667	0.808511	~Governance	0.333333	0.950000
Sub-model 2. Europe					
Outcome variable: Hydropolitical tension					
WQuality	0.888889	0.137931	~WQuality	0.111111	0.071429
Ecosystem	0.222222	0.125000	~Ecosystem	0.777778	0.125000
Governance	0.888889	0.285714	~Governance	0.111111	0.022727
Outcome variable: ~Hydropolitical tension					
WQuality	0.793651	0.862069	~WQuality	0.206349	0.928571
Ecosystem	0.222222	0.875000	~Ecosystem	0.777778	0.875000
Governance	0.317460	0.714286	~Governance	0.682540	0.977273
Sub-model 3. North America					
Outcome variable: Hydropolitical tension					
Ecosystem	0.250000	0.090909	~Ecosystem	0.750000	0.088235
Governance	1.000000	0.125000	~Governance	0.000000	0.000000
Outcome variable: ~Hydropolitical tension					
Ecosystem	0.243902	0.909091	~Ecosystem	0.756098	0.911765
Governance	0.682927	0.875000	~Governance	0.317073	1.000000

The analysis for sufficient conditions is presented in Table 3. Results show the solutions found for each region analysed. These solutions indicate two sufficient conditions in regions with the absence of high and very high hydropolitical tensions, and these are in governance and ecosystem. Absence of governance tensions is a sufficient condition in the basins of the three regions analysed, while the absence of tensions in ecosystem appears in Asia and North America. Table 1 indicates that the ecosystem includes indicators such as the impact of dams and the protection of fish habitat. Previous works have linked dams to the impacts of upstream regions decisions on water availability in downstream regions, which increases the risk of tensions (Bonnema and Hossain, 2019). Fish habitat can also increase tensions when it harms the livelihoods of inhabitants in other regions (Campbell et al., 2019).

Table 3. Analysis of sufficient conditions

Conditions	Output: ~**Hydropolitical tension**				
	Solutions Asia		*Solutions Europe*	*Solutions North America*	
	S1	S2	S3	S4	S5
WQuality					
WQuantity					
Ecosystem		⊗			⊗
Governance	⊗		⊗	⊗	
Cases	(See Annexe)				
Consistency	0.95	0.867925	0.977273	1	0.911765
Raw coverage	0.333333	0.807018	0.68254	0.317073	0.756098
Unique coverage	0.122807	0.596491	0.68254	0.219512	0.658537
Frequency cut-off	2		4	2	
Consistency cut-off	0.8125		0.954545	0.9	
Solution coverage	0.929825		0.68254	0.97561	
Solution consistency	0.883333		0.977273	0.930233	
	● = Core causal condition present		⊗ = Core causal condition absent		
	• = Complementary causal condition present		⊗ = Complementary causal condition absent		

Network analysis allowed for the inclusion of 15 indicators in the analysis. The software used to calculate the centrality was Gephi (Bastian et al., 2009). The measure of centrality selected was the eigenvector centrality, which for our case would mean those indicators that are central and are connected to others that are also central. Table 4 presents the results obtained for each region and the highest value from the eigenvector, which is value 1. In Asia, eight out of fifteen indicators had the highest centrality value, while in North America, this value was shared by thirteen out of fifteen indicators, and the fifteen indicators had a value of 1 in centrality for Europe. The results also indicate that the risk of tensions connect many problems, so results show that the risk of tension can be viewed to be associated with many issues. Finding solutions that cover all issues will be complicated, especially when such solutions need to be coordinated between different countries or between regions within the same country.

Table 4. Eigenvector centrality

Variable group	Indicator	River basins		
		Asia	*Europe*	*North America*
Water Quantity tension	Environmental water stress	X	X	X
	Human water stress		X	X
	Agricultural water stress	X	X	X
Water Quality tension	Nutrient pollution		X	X
	Wastewater pollution		X	X
Ecosystems tension	Wetland disconnectivity	X	X	X
	Ecosystem impacts from dams		X	
	Threat to fish		X	X
	Extinction risk		X	X
Governance tension	Hydropolitical tension	X	X	X
	Legal framework		X	
	Enabling environment	X	X	X
Socioeconomics tension	Economic dependence on water resources	X	X	X
	Societal well-being	X	X	X
	Exposure to floods and droughts	X	X	X
TOTAL		8	15	13

In this paper, we have analysed the sustainability of 184 transboundary river basins found within Asia, Europe, and North America. QCA and network analysis were used for the analysed. Data from the TWAP database were also obtained for the analysis.

From the analysis, two ***conclusions*** can be inferred. The first is that the sustainability of the transboundary river basins depends on the capability of countries to reduce the hydropolitical tensions. Moreover, regions where river basins present an absence of high and very high hydropolitical tensions also present an absence of tensions in governance and the ecosystems. The second conclusion is that the positive occurrence of multiple indicators represents the risk of tensions; so considering all of them together would be necessary for a reduction of tensions between countries sharing the water of transboundary rivers and between regions in the same country that share rivers. The fact that indicators that are likely to generate tensions are interconnected will complicate the process of cooperation and in the designing of any integrated plans that preserve ecosystems, water quality, and water availability.

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Annexe

Solutions from analysis of sufficient conditions (Table 3)

Solutions Asia	
S1 (~Governance)	*S2 (~Ecosystem)*
Amur (1,1), An Nahr Al Kabir (1,1), Aral Sea (1,1), Asi Orontes (1,1), Atrak (1,1), Ganges Brahmaputra Meghna (1,1), Ili Kunes He (1,1), Indus (1,1), Jenisej Yenisey (1,1), Jordan (1,1), Mekong (1,1), Ob (1,0), Oral Ural (1,1), Pu Lun T'o (1,1), Samur (1,1), Shu Chu (1,1), Sulak (1,1), Talas (1,1), Terek (1,1), Tigris Euphrates Shattal Arab (1,1)	Amur (1,1), Aral Sea (1,1), Asi Orontes (1,1), Astara Chay (1,1), Atrak (1,1), Bahu Kalat Rudkhanehye (1,1), Bangau (1,1), Beilun (1,1), Ca Song Koi (1,0), Coruh (1,1), Dasht (1,1), Fenney (1,1), Fly (1,1), Golok (1,1), Hamuni Mashkel Rakshan (1,1), Han (1,1), Har Us Nur (1,1), Hari Harirud (1,1), Helmand (1,1), Ili Kunes He (1,1)
Solutions Europe	
S3 (~Governance)	
Bidasoa (1,1), Danube (1,1), Daugava (1,1), Dnieper (1,1), Dniester (1,1), Don (1,1), DouroDuero (1,1), Ebro (1,1), Elancik (1,1), Elbe (1,1), Garonne (1,1), Glama (1,1), Guadiana (1,1), Kemi (1,1), Klaralven (1,1), Kogilnik (1,1), LavaPregel (1,1), Lielupe (1,1), Lima (1,1), Maritsa (1,0)	
Solutions North America	
S4 (~Governance)	*S5 (~Ecosystem)*
Colorado (1,1), Columbia (1,1), Fraser (1,1), Mississippi (1,1), Nelson Saskatchewan (1,1), Pedernales (1,1), Rio Grande North America (1,1), Skagit (1,1), St. Croix (1,1), St. John North America (1,1), St. Lawrence (1,1), Tijuana (1,1), Yaqui (1,1)	Alsek (1,1), Artibonite (1,0), Belize (1,1), Chamelecon (1,1), Changuinola (1,1), Chilkat (1,1), Chiriqui (1,0), Choluteca (1,1), Coatan Achute (1,1), Coco Segovia (1,1), Conventillos (1,1), Corredores Colorado (1,1), Firth (1,1), Fraser (1,1), Goascoran (1,1), Hondo (1,1), Lempa (1,1), Massacre (1,1), Moho (1,1), Motaqua (1,1)