

A Game Theory Approach to Understanding the Nile River Basin Conflict

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Summary: Game theory can provide valuable insights into strategic water resources conflicts. In this chapter, non-cooperative game theory solution concepts are used to determine the possible outcomes of the Nile River Basin conflict. This conflict is the result of the desire of the main riparian countries, namely Egypt, Sudan, Ethiopia, and other upstream nations, to gain a higher share from the available water resources in the basin. The Graph Model for Conflict Resolution decision support system (GMCR II) is used to model the conflict, providing strategic insights, and identifying the stable outcomes of the game, given the players options and preferences. Results suggest that: 1) stability of the possible outcome is very sensitive to Egypt's preferences, and not very sensitive to Sudan's and Ethiopia's preferences; 2) the status-quo is not stable; and 3) any stable outcome includes retaliation by Egypt.

Introduction

During a seven year drought in Egypt from 1066–1072, the Egyptian Khalif entreated the Ethiopian king to allow the Nile's waters to flow again (Ayele 1986). While Ethiopia had no means to divert or otherwise control the Nile's waters, the discrepancy between the major origin of the Nile in Ethiopia and its primary use in Egypt continues, almost one thousand years later, to motivate one of the most challenging international hydro-political conflicts today. Though the conflict itself is well understood from a historical and contemporary hydro-politics perspective, political modeling

techniques can provide broader insights to how the conflict could change under different political conditions. All players in the region have some advantage or disadvantage under the status quo and all will either gain or lose if or when the status quo changes. In this chapter, we describe how game theory can be used to develop a new understanding of potential future outcomes of the Nile River conflict, given regional players' existing and new options and preferences.

To help understand the conflict, we first briefly review the hydro-political history of the Nile River Basin. Readers interested in a more detail are referred to Al-atawy (1996) or Waterbury (2002).

Hydro-political Conflict in the Nile River Basin

Since the Egyptian Khalif's futile entreaties in the late 11th century, the fate of the Nile River's waters, which currently serve over 300 million people in the Nile River basin (Kung 2003), has been a continual source of regional hydro-political concern—and even outright conflict. Despite the fact that 85 % of the river originates in Ethiopia, today Egypt controls 65 % of the flow and Sudan reaps a significant amount relative to Ethiopia (Waterbury 2002).

Though the conflict has historically been mostly between Egypt and Ethiopia, rapid regional development, especially over the past half century, has ensured that all the region's nations have at least some stake in the fate of the Nile's water. The dispute over the Nile River's waters expanded to the entire Nile Basin after Egypt envisioned a single, unified basin under the control of Egypt, beginning in earnest in the early 19th century (Tafesse 2002). Though this control was primarily targeted toward Ethiopia, with sixteen major battles between Egypt and Ethiopia from 1832–1876 (Arsano 1997), the goal of a unified basin to allow Egypt to continue its use of the Nile's water remained a central driver for hydro-political conflicts in the region. The Nile River basin today includes all or part of ten independent nations: Egypt, Sudan¹, Eritrea, Uganda, Tanzania, Kenya, Rwanda, Burundi, and the Democratic Republic of Congo. The region continues to be politically dominated by Egypt (Tafesse 2002), which is a downstream riparian (Figure 1), and has used the river's annual supply of rich salt deposits and water to support its extensive agricultural lands since ancient times.

¹ South Sudan, which gained independence from Sudan in July, 2011, is considered part of Sudan in this chapter.

In 1884, after Britain took control of Egypt to secure its interest in the Suez Canal, Britain and other colonial powers split up the Nile Basin region into spheres of influence (Al-atawy 1996). Britain gained control of much of the Nile, with a presence in Egypt, Sudan, and East Africa.

As the most influential colonial power in the region, Britain signed several treaties with other regional actors to protect its interests, particularly in Egypt, its most important protectorate. Protecting its interests included ensuring that Egypt continued to receive a large and reliable water supply from the Nile River for agricultural production, including cotton (Al-atawy 1996; Waterbury 2002). However, there was also a growing interest in Sudan by the British administration there to develop a cotton industry as an economic base. After Egypt gained independence from Britain in 1922, Britain and Egypt signed the Nile Waters Agreement in 1929. This ensured that Egypt would maintain its historic appropriation of the Nile's water, but also allowed the development of water diversion works in the Sudan (Al-atawy 1996). The 1929 agreement allocated all water from the Nile to Egypt and Sudan, with no diversion allowed by upstream riparians, then also under British control.

As the 1929 agreement was unsatisfactory toward the development needs of Sudan, both Egypt and Sudan renegotiated their Nile sharing agreement. Though Egypt demanded its continued use of its historical "rights", Egypt and Sudan recognized that it was in each of their best interest to support the other's development (Al-atawy 1996). Egypt had also gained full independence from Britain in 1956 and was eager to settle its ongoing disputes with Sudan. Renegotiations of the 1929 agreement resulted in the Full Utilization of the Nile Treaty in 1959, also called the Nile Waters Treaty (hereafter called the "1959 treaty"). The 1959 treaty remains the most recent agreement in effect. It allocates 18.5 billion cubic meters annually to Sudan and an annual 55.5 BCM to Egypt, plus any other water Egypt needs to take from Sudan (Al-atawy 1996; Waterbury 2002; IWP&DC 2007). The 1959 treaty, which allocates more water to Sudan yet still recognizes Egypt's historical use, also has other important provisions that benefit Sudan: water shortages and excesses are shared equally between both nations. The provisions of the 1959 treaty have since been upheld by Egypt and Sudan. Importantly, the 1959 treaty does not include any of the remaining upstream riparian countries, yet it forbids them from using the water (consumptively) or constructing any obstructions. Ethiopia and other upstream nations do not recognize the 1959 treaty, yet have been reluctant to interfere. Despite Ethiopia's lack of significant development of projects that

would alter runoff from the Blue Nile, it's potential—and explicit desire—to do so has been a source of concern for Egypt. Divisions between Egypt and Ethiopia have remained for almost a millennia fueled by Egypt's concern that Ethiopia could reduce the flow of the Nile. This division has manifested itself in several ways, one example being Egypt's explicit support of Eritrea's rebels against Ethiopia (Al-atawy 1996; Tafesse 2002).

Since 1959, it has become clear that the bilateral decision of Egypt and Sudan to exclude the consumptive use of the Nile's waters by other riparian nations is unsustainable. In part, this is because Egypt, though feared, does not have the legal authority to completely prevent the development of upstream hydraulic development projects (Al-atawy 1996). In 1992, the seeds were sown for a basin-wide water development cooperative framework. The Nile Basin Initiative (NBI), an attempt to promote cooperative and equitable allocation of the Nile's waters, was officially formed in 2002 (NBI 2008). Though the NBI does not actually reallocate the Nile's water, its formation is an explicit recognition that the future of the basin depends on multilateral cooperative solutions, and that, specifically, the 1959 treaty will eventually be superseded by a more equitable agreement. Until such a new agreement forms, however, there is no official recognition of the rights of other riparian nations to reduce the inflow of water to Sudan and Egypt. In the interim, Egypt's primary interest remains unchanged from one thousand years ago: to maintain its historical use of the Nile's waters. The options and preferences of each riparian nation, in the context of this regional hydro-political history and future development, is explored further below as needed for the development of the game theoretic approach to understanding this hydro-political problem.

Game theory

The complexity of this resource conflict can be simplified and analyzed using game theory to explore the variety of potential outcomes resulting from the various strategies employed by the players of the game. A game involves a set of Decision Makers (DMs), or players, that each having a number of options (strategies) they can employ based on their preferences for particular outcomes or states. These preferences reflect political, social, and economic values. Game theory is a mathematical framework for analyzing the strategies of each DM, to maximize each player's chance of winning, and to predict possible outcomes of the game. A solution to the

game prescribes the decisions each DM might make and presents the resulting outcome (Madani, 2010; Madani and Lund, in press). In this study, non-cooperative game theory concepts are applied to determine possible outcomes in the Nile River strategic conflict.

Alternatively, water resource games can be studied using cooperative game theory. Cooperative game theory methods are used to find how cooperating parties shall fairly and efficiently share the incremental benefits of cooperation. Example applications of cooperative game theory in the water and environmental resources include Dinar and Howitt (1997), Madani (2011) and Madani and Dinar (2011), among others. Wu and Whittington (2006) used cooperative game theory to establish baseline conditions for incentive-compatible cooperation in the Nile River Basin, considering the economic benefits of cooperation. This study does not deal with allocation of benefits of cooperation and cardinal information. Instead, it focuses on studying the conflict using non-cooperative game theory, considering ordinal information about the game (ranking orders) to provide strategic insights into conflict.

The Graph Model for Conflict Resolution

Graph Model for Conflict Resolution (GMCR) (Kilgour et al. 1987; Fang et al. 1993), is a method suitable for representing water resources games with socio-political aspects (Madani and Hipel 2007) and is used here to model the Nile River conflict. A graph model for each DM has vertices representing its various states and arcs representing their different strategies. The conflict moves from state to state via these transitions based on DM preferences. This allows for systematic examination of permissible moves and countermoves by the DMs until a terminal point is reached at which equilibrium occurs. We use GMCR II (Hipel et al. 1997; Fang et al. 2003a; Fang et al. 2003b), a decision support system based on GMCR, for modeling the conflict as a game and finding its equilibria.

To find an equilibrium of the game, solution concepts are used. Solution concepts or stability definitions reflect human behavior in strategic decision making environments (Madani and Hipel, 2011). An outcome which is stable for all players under a given stability definition is an equilibrium, representing a likely outcome of the conflict. If a given outcome is stable for all players under a range of stability definitions, it is a strong equilibrium, representing the most likely outcome of the conflict (Madani and

Hipel, 2011; Madani and Lund, 2011). GMCR II facilitates finding the equilibria of the game under 6 non-cooperative game theory stability definitions, reviewed by Madani and Hipel (2011).

Elements of the Game

In the game theoretical approach to conflict resolution, three core components of the game are needed: players, their options, and their preferences for the possible outcomes of the game. The players and their options in the Nile River conflict are presented and described below, followed by a summary of their preferences and a description of alternative preferences for sensitivity analysis.

Players and options

The Nile River conflict has four players, as follows:

1 – The Upstream Nations: The upstream nations include Eritrea, Uganda, Tanzania, Kenya, Rwanda, Burundi, and the Democratic Republic of Congo. The upstream nations are located in the upper White Nile, centered on Lake Victoria (Figure 1). Although in reality not all upstream nations (UN) have the same hydro-political interests (Waterbury 2002), here they are represented as one player, with shared options and preferences. These nations have all been affected by water shortages due to the behaviors of Egypt and, to a lesser extent, Sudan, under the provisions of the 1959 treaty (El-Fadel et al. 2003). The upstream nations have generally three options. They can construct a separate artificial river from Lake Victoria, which would exclude the downstream countries (ICE 1997) and significantly improve the water-based development circumstances of these countries. Alternatively, the upstream nations could cooperate with the downstream states under the NBI, with an emphasis on the need to be active within the institution. As members of the NBI (with the exception of Eritrea), the upstream nations would cooperate under guaranteed equal representation, involvement of international actors, and equitable results (IWP&DC 2007). Finally, the upstream nations could maintain the status quo, implying adherence to the 1959 treaty, which does not recognize the rights of these countries (IWP&DC 2007). Water provision would continue to depend on Egypt, the most powerful country in the region.

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Figure 1. A map of the Nile river basin (source: <http://siteresources.worldbank.org/>).

2 – *Ethiopia*: Ethiopia continues to be one of the poorest nations in the world, despite the fact that Lake Tana and 85 % of the Nile’s water originates in Ethiopia. Ethiopia has great potential for agriculture, yet only 0.2 percent of its arable land has been cultivated (El-Fadel et al. 2003; The Reporter 2006). Because Ethiopia currently relies on imported food from Egypt (Thompson 2005), Egypt is not supportive of any arrangement that would reduce that dependence. Independent water development would benefit Ethiopia by helping it avoid droughts and enhancing its resource security. However, in reality, Ethiopia has been unable to carry-out large-scale development due to lack of financial resources (The Reporter 2006). Alternatively, as a funder and participant of the NBI, Ethiopia could work with the remaining countries in this initiative, guaranteeing that its interests are represented in a transparent manner (NBI 2008). In this analysis, the cooperation option also includes a water development arrangement with Sudan, independent of Egypt’s actions and independent of the NBI (Waterbury 2002). Finally, Ethiopia can reluctantly allow the 1959 treaty to continue under the status quo. In this scenario, Ethiopia would remain marginalized from matters dealing with the Nile’s allocation. This would occur if Egypt continues to pressure the country to refrain from water development and to rely on imported food (El-Fadel et al. 2003).

3 – *Sudan*: Sudan is currently entitled to take about one-third the amount of water Egypt takes (Waterbury 2002; IWP&DC 2007). However, this guarantees Sudan’s good relations with its neighbor to the north, which often defends the country on regional and international fronts. Sudan’s first option is to maintain the status quo, to continue to receive its annual allocation of water under the 1959 treaty. This option is complicated because Sudan needs to maintain good bilateral relations with Egypt, but they also no longer completely disregard Ethiopia, as evidenced by joint water development projects undertaken by the two countries (IWP&DC 2007). Second, Sudan can cooperate under the NBI, which would supposedly ensure greater equity (NBI 2008). For Sudan, this is extremely important because if it does not cooperate with its neighboring countries, then the quantity and quality of its waters will not be sustainable (The Reporter 2006). Finally, Sudan can independently develop its water resources. It has already constructed several projects including the Sennar and Rossaries dams on the Blue Nile and Kashim el Ghirba dam on Atbara (The Reporter 2006; IWP&DC 2007), and continues to pursue additional projects with Ethiopia including the construction of a transmission line with support from a

Chinese company (IWP&DC 2007). Under this option, Sudan would develop its own resources more vigorously and with less regard for Egypt, which tolerates Sudan's water development projects as long as they do not interfere with its own water supplies.

4 – Egypt: Egypt is the most downstream of the players. The options for Egypt in this conflict are the most flexible since Egypt is the country with the most military and political power in the region. The Nile Waters Dispute has not been of major concern to the international community, with exception of the United Nations and World Bank providing guidance for the NBI. Egypt has constructed numerous large projects in the region, including the Aswan Dam, the Northern Sinai Agricultural Development Program, artificial lakes, and other massive projects (IWP&DC 2007). First, Egypt can maintain the status quo by following the provisions of the 1959 treaty. This is in Egypt's best interest since it ensures that it gets its annual quota and its rights to "borrow" water from Sudan during shortages (Biswas 1994). Egypt is likely to pursue this option as long as possible (Allan 1999; Waterbury 2002). Second, Egypt can invoke its military or economic retaliation in the event that another country pursues independent water development projects. Egypt is the strongest country in the region economically, militarily, and politically relative to the other nations (Waterbury 2002). Furthermore, it retains significant weight in the African Union as well as other regional agencies. Hence, despite the fact that aggression may jeopardize its image, Egypt would not refrain from using this option to protect the water it claims historic rights to (Sudan Tribune 2004). Finally, Egypt can cooperate within the framework of the NBI to develop more equitable and effective agreements. This option would be motivated mostly by the fact that Egypt wishes to maintain a good image in the international community as well as somewhat improve relations with the remaining basin countries. Egypt is integral to the NBI since the NBI was formed under the specific condition that Egypt participate (IWP&DC 2007).

The options of each player as used in GMCR II are summarized in Table 1.

Preferences

The player's preferences of the game's outcome vary according to their position in the power/economic hierarchy of the region, the options available to the other players, their water resources potential versus current development

Table 1. *Players and their options.*

Player	Options
Upstream Nations	<ul style="list-style-type: none"> – Adherence to the 1959 treaty – Cooperation – Independent water development
Ethiopia	<ul style="list-style-type: none"> – Adherence to the 1959 treaty – Cooperation – Independent water development
Sudan	<ul style="list-style-type: none"> – Adherence to the 1959 treaty – Cooperation – Independent water development
Egypt	<ul style="list-style-type: none"> – Adherence to the 1959 treaty – Cooperation – Military economic relations

level, and their physical location in the Nile River basin. The preferences for each state were used as input to the GMCR II model to determine the stable states under those preferences. These preferences are discussed below and summarized in Table 2. The rankings indicate each player's preferences over the possible states. For example, the upstream nations prioritize avoiding retaliation from Egypt over independent water development.

1 – Upstream Nations: The preferences of the upstream nations are defined by their desire to change the current circumstances, which have ignored their water development needs since 1959. They do not want to jeopardize their security, but are losing patience with their downstream counterparts, specifically Egypt. The upstream countries first do not want Egypt to resort to military or economic retaliation. Egypt has previously taken a hostile tone towards Kenya when the latter suggested that water allocation be adjusted; prompting Egypt to state that such comments are almost equivalent to a “declaration of war” (The Nation (Nairobi) 2004). If Egypt refrains from retaliating, the upstream nations would develop their own water projects, such as a completely separate artificial river that would branch out from Lake Victoria (ICE 1997). The upstream nations would then prefer to cooperate within the NBI, since this will permit them to operate within a forum that promotes open dialogue, attempts to establish more equitable arrangements, and sustainable development (NBI 2008). Finally, the upstream countries want Egypt to give up the Treaty of 1959 entirely.

Table 2. *Players preferences.*

Upstream Nations (UN)	Ethiopia	Sudan	Egypt
No relation	No relation	No relation	1959 agreement
WD if no relation	No 1959	1959 agreement	No WD by Sudan
Coop	WD if no relation	Coop if Egypt coop	No WD by Ethiopia
No 1959	Coop	Coop if Ethiopia coop	Relation if Ethiopia WD
	Sudan coop	No WD by Ethiopia	Relation if Sudan WD
		No WD by UN	Coop if Sudan and Ethiopia coop

WD: War Declaration

2 – *Ethiopia*: Ethiopia’s first priority is to maintain its security, thus preferring Egypt not to take retaliatory measures against it, and second, to try to gain a portion of the vast amount of the water that originates in its territory. At the same time, Ethiopia would prefer that Egypt not maintain the status quo. The status quo means a continuation of the dire situation for Ethiopia where droughts continue to occur (Thompson 2005). Ethiopia’s next preference is to pursue water development projects, followed by cooperation within the NBI framework. Ethiopia would also want Sudan to cooperate in the NBI.

3 – *Sudan*: Sudan currently has good relations with Egypt, although they are strained at times. In addition, the country wants to maintain good relations with Ethiopia and the remaining countries for both water quality and economic development purposes (Waterbury 2002; Africa News 2004; The Reporter 2006). Sudan currently balances its relationship with Egypt by permitting Egypt to take as much water as it wants in exchange for support from Egypt (CBS News 2007). Like the other nations upstream from Egypt, Sudan’s first preference is for Egypt not to use aggression. Sudan’s second preference is to continue with the 1959 treaty to help maintain good relations with Egypt and to be guaranteed at least some of the Nile’s waters for development. This preference would be somewhat problematic since the country also needs to maintain good relations with the remaining countries. If Egypt cooperates under the NBI, Sudan would follow suit. If Ethiopia chose to cooperate, Sudan would cooperate in turn to maintain sustainable development (The Reporter 2006). Sudan would prefer for Ethiopia not to independently carry out water development projects, which could threaten its own supply. Similarly, it would not want the upstream nations to develop their own projects. If either Ethiopia or the upstream countries pursue their own course of action, Sudan would be in a precari-

ous position where it either criticizes them, allying with Egypt, or sides with them, which would damage its relations with Egypt (Waterbury 2002).

4 – Egypt: Egypt's preferences depend on the extent to which Egypt wishes to maintain its influence in the region. Its first preference is to maintain the status quo (Waterbury 2002). This allows it to take as much water as it wants without a direct threat from the remaining countries (Allan 1999). Egypt prefers that Sudan and Ethiopia do not independently divert water (El-Fadel et al. 2003), but is prepared to retaliate if need be. This is consistent with its pattern of threatening other nations in the basin when they suggest an alteration to the current water allocation regime (Thompson 2005). It is reluctantly willing to cooperate under the NBI only in the event that it is pressured by Sudan and Ethiopia.

Model Results

GMCR II uses eight different solution concepts to determine the equilibria. Only the states that were recognized as equilibrium by all solution concepts are included here, assuming that a state is more likely to be an outcome of the game when it is stable under different solution concepts which reflect different behaviors, risk attitude, and level of foresight of players. The model found six outcomes to be stable under all eight solution concepts (Table 4). The equilibria of the game can be described as follows:

1. Upstream nations, Ethiopia and Sudan develop water independently and Egypt retaliates.
2. Upstream nations and Ethiopia develop water independently and Egypt retaliates. Sudan and Egypt maintain the 1959 treaty.
3. Ethiopia develops independently and Egypt responds with retaliation. Egypt and the other nations maintain the 1959 treaty.
4. Upstream nations develop independently and Egypt responds with retaliation. Egypt and others maintain the 1959 treaty.
5. Upstream nations develop independently and all others cooperate with each other. No retaliation occurs.
6. Upstream nations develop independently and Egypt retaliates. Egypt and others cooperate.

Table 3. *Nile Rivers conflict game most likely outcomes.*

Players	Options	Equilibria					
		1	2	3	4	5	6
Upstream Nations	- 1959 treaty			Y			
	- Cooperation						
	- Water development	Y	Y		Y	Y	Y
Ethiopia	- 1959 treaty				Y		
	- Cooperation					Y	Y
	- Water development	Y	Y	Y			
Sudan	- 1959 treaty			Y	Y		
	- Cooperation					Y	Y
	- Water development	Y					
Egypt	- 1959 treaty		Y	Y	Y		
	- Cooperation					Y	Y
	- Relation	Y	Y	Y	Y		Y

Sensitivity Analysis

In order to test the sensitivity of the model, five alternative preference scenarios were developed, as described below, and the results compared to the main model results.

1. Egypt prefers not to retaliate, but still prefers the status quo to cooperation.
2. The upstream nations' actions are considered insignificant in Nile sharing between the three lower nations and are removed from the model.
3. Ethiopia prefers to aggressively pursue independent water development, without worrying about Egypt's possible retaliatory actions, followed by cooperation with Egypt and Sudan.
4. Sudan prefers no retaliation, followed by independent water development, cooperation, and finally no independent development by Ethiopia and Upstream Nations.
5. Sudan no longer prefers the 1959 treaty and prioritizes cooperation with Ethiopia.

Under the more peaceful Egypt preference scenario modeled during the sensitivity analysis, GMCR II found the following two equilibria:

1. Egypt retaliates to water diversion by all other nations.
2. Upstream nations develop independently. Ethiopia, Sudan, and Egypt cooperate.

With the upstream nations removed from the game (and no other changes), the stable states became:

1. All countries maintain the 1959 treaty.
2. Ethiopia and Sudan independently develop water and Egypt retaliates.
3. All countries cooperate.

When Ethiopia's preferences were changed from the main scenario, the outcomes were identical to the initial results, except that outcome (4) was eliminated. With a significant change in Sudan's preferences, equilibria were the same as in the main scenario. This means that under the main scenario, all else being equal, changes in Sudan's preferences do not change the most likely outcomes.

Discussion

One of the first things to note about the outcome is the number of stable states that include retaliation by Egypt. This indicates that Egypt's use of retaliation in the region is more likely, with five out of the six equilibria including retaliation for some reason or another.

In state (1) Egypt retaliates because all nations independently develop their water resources. In states (2) and (3) they retaliate against Ethiopia's independent development of its water resources. This is evident from the fact that in state (3) both Sudan and the upstream nations accept the current 1959 treaty conditions, yet Egypt still retaliates. All of these results are consistent with the preferences, in which Egypt favors retaliation against Ethiopia and/or Sudan if they independently develop. Ethiopia's and Sudan's strong aversion to retaliation is not enough to keep the region free from Egypt's retaliation, at least under equilibrium conditions.

More interesting, however, is the difference in Egypt's retaliatory decision among stable states (4) through (6). That states (4), (5) and (6) are all stable indicates that in this analysis Egypt would retaliate against the upstream nations if the lower three nations are working under the 1959 treaty, yet is ambivalent toward retaliation against the upstream nations if the lower three are cooperating under the NBI.

An important question to ask is: if these states are found to be in equilibria in this analysis, why do none of these states represent the status quo (all adhering to the 1959 treaty stipulations)? The status quo is not stable because it includes increasing pressures to change the current water re-

sources development situation with the upstream nations, Ethiopia and Sudan increasingly desiring to tap into their water resources potential.

Also significant is the fact that cooperation among all Nile Basin nations is not a likely outcome. While this outcome might be desirable and ideal to some, it is not necessarily what would happen when the countries work within the framework of their own internal and external geopolitical situations. The specific reasons have to do with either a) the preferences as set up in the model or b) political realities (assuming the preferences reasonably reflect those realities). Egypt, for example, does not favor cooperation. Or rather, it favors cooperation in the region so long as it still gets the Nile water it needs (Waterbury 2002).

The results of the sensitivity analysis also reveal some interesting insights. In contrast to the consistent use of retaliation in the main modeling results, with a more peaceful Egypt, the only equilibrium in which it retaliates is if all the other players develop independently. Otherwise, it cooperates with its immediate neighbors and does not retaliate against independent upstream nations.

The fact that the equilibria are relatively insensitive to changes to either of Ethiopia's or Sudan's preferences seems to indicate that Egypt's preferences generally override those of all other nations. We predict stable outcomes identified here are likely to be more sensitive to changes in countries' preferences in the case of a more peaceful Egypt. This is because with less fear of retaliation from Egypt, Sudan, Ethiopia and the upstream nations will have more impact on the hydro-politics of the region. Further analysis would be needed to verify this.

Conclusion

The GMCR was applied to the politically volatile conflict over the use of the Nile River for water resources development. The results indicate that there are 6 equilibria states, 5 of which include retaliation on the part of Egypt due to independent development of water resources by the other nations. The results were highly sensitive to the preferences of Egypt. While the model suggests the future use of force by Egypt, Egypt and others in the Nile Basin are in fact working within the context of an international community that is applying both political and economic pressure to the Nile Basin nations. With this reality, the basin is very likely to work out differences in water resources without the use of aggression. This study

suggests that the Nile Basin nations' preferences—especially those of Egypt—will have to change to resolve their conflict peacefully.

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Caveat

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