A MATTER OF TIME: REASSESSING THE OCCURRENCE OF CONFLICT AND THE ROLE OF INSTITUTIONS IN TRANSBOUNDARY FRESHWATER RESOURCES USING EVENT HISTORY ANALYSIS

by

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ABSTRACT

The study of international conflict and cooperation over shared freshwater has been advanced by the application of large *N* data sets and statistical methods. This thesis builds on this body of knowledge in three ways. First, because of the nature of the data, it adopts event history analysis methodologies (EHA) to refine previous research. Secondly, because EHA methodologies are employed, the concept of duration dependence is explored in further detail. Finally, it explores the role of international institutions in mitigating conflict between countries that share freshwater resources. The results of the statistical models generally support the need to adopt new methodologies and provide a more detailed understanding of duration dependence. In terms of the impact of international institutions, the models point to the pacifying effects of international institutions. Nevertheless, further research is necessary to clarify the relationship between shared freshwater resources, conflict and the role of international institutions.

Keywords:

Conflict; Cooperation; Shared Freshwater Resources; Duration Dependence; Event History Analysis

For Sima

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CHAPTER 1: INTRODUCTION

1.1 Introduction

Freshwater is one of the most important natural resources for human life. Water is not only necessary for the basic survival of the human body, but also plays a key role in economic development. As such, it should come as no surprise that individuals and their political communities prioritize access to water in order to maintain health and economic prosperity. Although enough freshwater exists in aggregate to meet the hygienic and economic needs of states and individuals, the fact that the world's freshwater resources are unequally distributed means that some regions are flush with an oversupply of freshwater, while other regions face tremendous shortages (Benvenisti 1996, 384; Gleick 1993, 79). This poor distribution means that maintaining as well as gaining access to freshwater is a real challenge to numerous states and individuals, a challenge that is further exacerbated by the reality that water does not respect international boundaries. There exist approximately 261 international watersheds, affecting 40% of the world's population, which means that access to this important resource is also an international problem (Wolf 1998, 252).

The fact that more than one state has access to a watershed has significant implications for the use of shared water resources as well as the political relations between states. This is because actions taken by one state to sustain economic development (such as building a dam to provide hydro electric power to one of its cities) can have repercussions for health and prosperity in a neighbouring state that also shares the same watershed. The neighbouring state may find that plans of the other state do not suit its needs or interests, for the reason that it may have historically used the river for irrigation purposes and continues to depend on the crops irrigated by the flow of the river for its survival. In this case, the action of one state to limit the flow of a river by building a dam could be extremely detrimental to the wellbeing of residents of another state.

In these situations, where separate states have different interests in and intentions for a shared watershed, inter-jurisdictional conflict can be an intractable reality. If disagreeing states can come to an agreement as to how to jointly manage the shared water resource, political conflict can be avoided. However, not all disputes over shared water resources play out so amicably in reality. States can act unilaterally. In the case that one state builds a dam without consulting another state using the shared watershed for irrigation, the dam-building state risks antagonizing the irrigation-state and receiving some sort of retaliation from the irrigation-state. This can escalate further into a situation of international conflict. In sum, the existence of international freshwater resources poses a challenge to states in securing access to and management over their freshwater resources at the same time as it creates the potential for political conflict as well as opportunities for inter-state cooperation.

The possibility of international conflict over scarce resources, even water, is by no means new to political science. Indeed, scholars have argued for some time that most international conflicts are over scarce resources, demonstrating in particular the prevalence of conflict over shared water resources (Vasquez 1993; Huth 1996; Homer-Dixon 1994; Gleick, 1993). In response to these early studies, a number of large *N* empirical studies have emerged more recently to systematically and empirically test the relationship between shared water resources and the possibility of conflict (Toset et al. 2000; Furlong et al. 2006; Gleditsch et al. 2006). Although these studies draw from different data sources, and develop slightly different hypotheses, they all find support for the proposition that states that share water resources in the form of a river or a basin will be more likely to experience conflict. As Gleditsch et al. have pointed out, their data "is not evidence for 'water wars', but shared waters resources can stimulate low-level interstate conflict" (Gleditsch et al. 2006, 22).

Although recent large *N* studies have found support for the possibility of international conflict over water, the actual paucity of examples of conflicts that specifically take place over water combined with the large number of bilateral and multilateral water related agreements have dampened the argument for water wars, and have led many scholars to study the role and impact of international institutions that focus on facilitating cooperation and joint-management of shared freshwater resources (Wolf 1999; Wolf and Hamner 2000). Indeed, numerous studies have been undertaken to study prominent agreements and institutions, such as the Mekong Commission (Makim 2002; Jacobs 2002); institutions relating the Nile River (Swain, 2002), and the Ganges River (Faisal and Tanzeema 2001; Faisal 2002). It is important to note, however, that these studies are case specific, and therefore make it difficult to draw larger conclusions about the impact of institutions on the possibilities of inter-state conflict over shared resources. Having identified this gap, Hensel et al. (2006) builds on previous literature by conducting a large *N* study to specifically analyze the role of institutions in the case of competing claims over shared water resources. They conclude that international institutions, both water specific, and general[1], positively impact the possibility of the peaceful settlement of disputes over shared water resources. Hensel et al.'s (2006) study therefore strengthens the notion that although conflict over shared water resources is possible, international institutions have played and can continue to play a significant role in reducing violent conflict between states.

The purpose of this study is threefold. First, it seeks to build on the empirical research of Toset et al. (2000), Furlong et al. (2006), and Gleditsch et al. (2006) regarding the relationship between shared water resources and conflict by extending their analysis to include the effects of institutions on the occurrence of conflict over shared water resources. Although this existing literature has focused on geographical variables to understand conflict over shared water resources, it has not explored the role of institutions. While Hensel et al.'s (2006) most recent work involves examination of the role of institutions, what this thesis will add is the first effort at understanding the role of institutions using the

[1] As specified by Hensel (Hensel et al. 2006) and adopted for the purposes of this research, water specific institutions are defined as "formal agreements that are designed to manage shared water resources" (Hensel et al. 2006, 388) and general institutions are defined "more broadly as formal regional or global organizations that promote peaceful dispute settlement in their charters" (Hensel et al. 2006, 388).

research approach pioneered by Toset et al. (2000), and then refined by Furlong et al. (2006) and Gleditsch et al. (2006)[2].

The second purpose of this thesis is to bring methodological refinement to the study of institutions in mediating conflict over shared water resources by moving away from logistic regression adopted by previous researchers, advancing the event history methodology in its place. This methodology is much better suited to the study of patterns and causes of change and in particular allows the researcher to understand how time spent in one social state will affects the probability of moving to another social state (Box-Steffensmeir 1997, 1414). By adopting a methodology better suited to the subject at hand, this study will strengthen the results of previous research[3]. It will also align this area of research with that of other researchers (Raknerud and Hegre 1997; Werner 2000; Ireland and Gartner 2001) who use event history methodologies in the study of international relations.

The third purpose of this thesis derives from the methodological refinement mentioned above. Because of the nature of the data there is a possibility to further explore the impact of time on the occurrence of conflict by using event history methodologies. As it will be seen, time could in fact be an important factor in the occurrence of conflict, and although previous studies have modelled time in a rudimentary fashion the use of event history methodologies

[2] See section three for a detailed explanation and justification of studying the role of institutions using the methodology pioneered by Toset (Toset et al. 2000), as opposed to Hensel (Hensel e. al. 2006)

[3] A number of researchers (Raknerud and Hegre 1997; Werner 2000; Ireland and Gartner 2001) argue that event history methodologies are more appropriate in the empirical study of international conflict than probit or logit analysis.

will allow the researcher to explore the phenomenon in even greater detail. Therefore, adopting a new methodology not only provides methodological refinement, but also a deeper insight into the role of time in the occurrence of conflict.

In order to explore the role of institutions in conflict over shared water resources and the benefits of moving to an event history methodology, both in terms of methodological refinement and the ability to explore the impact of time, this study will proceed in four sections. Section two will provide an extensive review of the literature on conflict over shared water resources, as well as the role played by institutions in the management of these resources in order to identify the major research gaps and present hypotheses to be tested in the data analysis section. Section three will then review the research design employed to conduct this research, underlining the benefits of moving to an event history methodology, explaining the selection of the data set, and describing the dependent, independent, and control variables. The fourth section of the thesis will present and analyze the results of the different models. The study will end with some conclusions and highlight areas for further research.

CHAPTER 2: THEORIZING CONFLICT AND COOPERATION OVER SHARED FRESHWATER RESOURCES

2.1 Introduction

Numerous authors have studied and analyzed the possibilities of conflict and cooperation over shared freshwater resources. This section will trace the evolution of these areas from their origins in political discourse and rhetoric, through theoretical discussions, and finally the large *N* statistical studies developed most recently. The development of large *N* statistical studies is especially critical here, as the purpose of this thesis is to build upon and bring methodological refinement to, the empirical study of conflict and cooperation over shared freshwater resources.

2.2 Shared Freshwater and Conflict

The impetus to study conflict over shared freshwater resources has been driven in large part by public statements and warnings headed by major political actors. Several scholars have justified and rationalized their interest in understanding why, when, and where conflict over shared freshwater resources occurs on the basis that many statements have been made by politicians linking water with war. Amery (2002, 314) quotes Madeleine Albright as saying that “unless properly addressed, water scarcity could become a major source of conflict”. Amery (2002) further mentions sentiments expressed by Egyptian politicians that Egypt's national security should not only be viewed in military terms, but also in terms of wars over water, and further the assertion by Israeli water officials that water scarcity could lead to war (Amery 2002, 314). In discussing potential conflict in the Nile River region, Gleick (1993, 86) points to statements made by Egyptian government officials that water issues could force Egypt into war, or that the next war in the Nile region will be over water, and not politics. Toset et al. (2000) among others draw on two statements from the Israeli Prime Minister Levi Eshkol, the first prior to the 1967 Six-Day War entailing that water was a matter of survival for Israel and the second made at the 1996 Habitat Conference claiming that water is replacing oil as a flashpoint for conflict between nations (Toset et al. 2000, 972).

The academic research spurred by the statements of politicians and government reports has grown from broad typologies to understand and explain the role of shared freshwater resources in conflict, to historical case studies, and finally large *N* statistical studies to understand the relationship between shared water and international conflict. Gleick (1993, 79) sets the stage for studying conflict over freshwater resources by describing "ways in which water resources have historically been the objectives of interstate conflict and how they have been used as instruments of war." Taking a historical approach, Gleick argues that water can become a source of conflict between states, and that the degree of scarcity, the number of states or regions that share water, the relative power of the basin states, and the ease of access to alternative freshwater sources indicate the possibility of conflict. He also argues that although access to freshwater resources may not be the primary driver for a conflict between states, water resource systems may be used as offensive and defensive weapons of war. Such scenarios could include the destruction of dams and irrigation systems, or in long protracted conflicts, the building of dams to restrict water resources to adversaries. By pointing out past experiences to give direction to future events and looking at the current strains on freshwater availability throughout the world, Gleick (1993, 96) concludes that freshwater resources are increasing in value in many regions of the world, and thus intensifying the likelihood for conflict.

Drawing on Gleick's initial description of the factors that lead to conflict over shared freshwater resources, Haftendorn (2000) creates a more complex typology of the causes of conflict using the historical-comparative approach. In total, Haftendorn discerns four different conflicts over shared freshwater. In the first instance conflict could occur through "use" such as the construction of a dam or the channelling of a river's flow (Haftendorn 2000, 53). That is, two or more riparian states could potentially disagree on the use of a river or a lake due to the different costs and benefits faced by each state if such a project where to be undertaken. A second type of conflict could occur due to pollution (Haftendorn 2000, 54). Haftendorn argues that rivers and other freshwater resources act as means of waste disposal, and that the problem of cleaning a river can take on an international dimension since many rivers and lakes either act as international borders, or flow across borders. For example, a river may be polluted by the industrial activity in once state, but the costs of pollution and its cleanup would not be born by the polluting state, but by the downstream states. To support her argument, Haftendorn points to the pollution of the Rhine by upstream states such as France, Switzerland, and Germany and the costs of cleanup being born by low lying states such as the Netherlands who use the Rhine primarily for drinking water. In such instances, frameworks and agreements are necessary to ensure costs are born by all parties, rather than one.

Conflict can occur because of distribution problems. According to Haftendorn, the third type of conflict is when there is a relative shortage of water, while the fourth type of conflict occurs when there is an absolute shortages of water. According to Haftendorn these two types of distributional conflicts are more complex than conflicts over use, since a solution is "only possible when the privileged state agrees to give up certain of its advantages" (Haftendorn 2000, 53). As the categorization implies, distributional conflicts with a relative shortage of water occur when the resource in upper levels of a river is plentiful, but is severely curtailed in the lower levels of the river because of its extensive use in the upper countries. Such relative shortages could occur with the construction of a dam, or irrigation projects in the upper states (Haftendorn 2000, 56). Situations with absolute shortages occur when there is simply not enough water to meet the needs of the riparians, regardless of its distribution. According to Haftendorn, such a problem can occur in the semi-arid regions of the world and "is intensified in cases where differing levels of development between states lead to varying utilization of the water resource" (Haftendorn 2000, 59).

In a desk study of conflict and cooperation over shared freshwater resources, Mostert (2003) simplifies Haftendorn's typology while simultaneously extending its scope. Rather than separating conflict over freshwater into four categories, Mostert provides three ways to understand conflict. Similar to Haftendorn, Mostert argues that shared freshwater can be the *object* of a conflict between two or more countries where these countries disagree over distribution or pollution. Also like Haftendorn, Mostert points out that water can be an *instrument* of war. States can divert rivers, open/close dams or pollute water systems, all for the purpose of harming an opponent. Finally, Mostert diverges from Haftendorn, and argues that water can be a *catalyst* for conflict. For example, water scarcity in one state may lead to internal instability, which could in turn lead to international instability (Mostert 2003, 9). This category is further explored by Giordano (2002), who studies the relationship between water conflicts at the national level and their impact on conflicts at the international level. Using the quantitative analysis of three case studies, the authors argue that the results of their study indicate "that water-related events at the national level are related to both water and non-water events at the international scale" (Giordano et al. 2002, 306).

Given theoretical understandings of the possibilities of conflict over shared freshwater resources as described by Gleick, Haftendorn, Mostert, and Giordano, academics have focused on providing an empirical evidence of conflict over shared freshwater resources through small and large *N* studies. In terms of small *N* studies, the most comprehensive study to date was performed by Wolf and colleagues (2003). In order to gain a greater understanding of the relationship between water and conflict, the authors compiled a dataset of every event or interaction between two or more states that was driven by water between 1948 and 2000. The authors also defined a 15-point scale between -7 and 7, to measure the spectrum of conflict and cooperation. -7 was defined as a "formal declaration of war; extensive war acts causing deaths, dislocation or high strategic costs" and 7 was defined as "voluntary unification into one nation" (Wolf et al. 2003, 34). That is, on the one extreme, events driven by water could lead to war, while on the other they could lead to significant cooperation, such as political unification. According to the authors, not a single event ranks as a 7 or -7 between 1948 and 2000. In fact, of the 1,831 events identified, cooperative events where more than twice as common as conflictive events. Only 37 events where coded as acute conflict; of those, 30 where between Israel and one of its neighbours and only 5 acute conflict cases were between countries outside of the Middle East. (Wolf et al. 2003, 38-39). However, despite the lack of a large number of acute conflicts over water and the fact that the historical record shows that water can act as a unifier, the authors argue that water can still act as an irritant. In particular, water resources can make good relations bad and bad relations worse (Wolf et al. 2003, 40).

Toset et al.'s (2000) research represented the first true large *N* study that used statistical methods to explore the relationship between international rivers and conflict. Drawing from propositions developed in previous case studies on conflict over resources and especially shared water resources, Toset et al. formulated six hypotheses, as follows:

1. "Everything else being equal, countries that share a river have more dyadic conflict behavior." (Toset et al. 2000, 979)
2. "The more shared rivers between two countries, the higher the probability of conflict behavior between them." (Toset et al. 2000, 980)
3. "Among countries with shared rivers, upstream/downstream situations have more dyadic conflict behavior." (Toset et al. 2000, 981)
4. The relationship between shared river boundaries and conflict is accentuated over time. (Toset et al. 2000, 981)
5. Everything else being equal, two contiguous countries with water scarcity are more likely to have conflict behavior. (Toset et al. 2000, 981)
6. Water scarcity increases the extent to which river-sharing is associated with dyadic conflict behavior. (Toset et al, 2000, 981)

To test these hypotheses, the authors used Toset's (1998) database which relied heavily on a 1978 database developed by the United Nations known as the CRNET register that was then supplemented by further research from the authors to include shared rivers not mentioned in the register. Merging this information on shared rivers with the contiguity dataset of the Correlates of War (COW) project (Gochman 1991), Toset et al. created a dataset coded in dichotomous form containing a total of 1274 dyads with shared rivers between 1816 and 1992. (Toset et al. 2000, 982-983)

With the dataset in place, the dependent variable used to test the hypotheses was drawn from the Militarized Interstate Disputes (MIDs) dataset from the Correlates of War project and was set as the onset of a MID with at least one casualty in order to reduce attention bias (Toset et al. 2000, 984). That is, conflict behaviour was observed if an interstate dispute resulted in at least one casualty between dyads. In terms of dependent variables, Toset et al. chose to adopt a similar strategy to other multivariate studies on interstate war (i.e. Bremer 1992; Oneal & Russett 1999; Hegre 2000) and controlled for the standard variables of regime type, economic development, major power, peace history, and alliances[4] (Toset et al. 2000, 982). In order to test their river specific hypotheses however, they also included variables on the number of shared rivers between dyads, whether there was an upstream or downstream relationship between the dyads, and a measure of freshwater availability (Toset et al. 2000, 985)

The results drawn from the subsequent analysis, although expected, are extremely interesting. In terms of the first hypothesis, the relationship was found to be highly significant, therefore leading one to conclude that dyads that share a river are more likely to experience conflict than other contiguous dyads. More importantly, however, according to the authors, the effect of this variable (shared rivers) is greater than any of the other control variables in the analysis (Toset et al. 2000, 988). Testing for the second and third hypotheses, which explored the effect of the number of shared rivers between two dyads, and whether the dyads are faced with an upstream/downstream relationship, the results were in the predicted directions, although not statistically significant for hypothesis three. The results from the fourth hypothesis were not what was predicted, and it can therefore be concluded that time does not have an impact on the relationship between shared river boundaries and conflict. The fifth and sixth hypotheses,

[4] A detailed description of these different variables can be found in Toset (Toset et al. 2000, 984-985)

which test for different aspects of water scarcity were also found to have the predicted impact, and were statistically significant. (Toset et al. 2000, 989-990)

It can be concluded that the study does find some support for the argument that shared rivers can lead to interstate conflict (Toset et al. 2000, 990). However, along with the caveats that refining the measures used to determine the control variables and adding new control variables can improve the results of the study, one major problem stands out, mainly, that it is impossible to determine the actual issues that lead to a dispute in the dataset. That is, whenever a MID occurs in the dataset, it is impossible to know if the issue is over a shared river or some other contention between the dyads that is entirely unrelated to the challenges of shared water resources. Therefore, due to a lack of data that specifies more clearly the types of disputes occurring, the analysis presented by Toset et al. allows the reader to conclude that as an independent variable a shared river within a dyad does correlate with the possibility of militarized conflict. However, it does not tell us whether a shared river is an actual causal factor of conflict.

Two subsequent studies build on the analysis developed by Toset et al. (2000) by addressing some of these issues. In their study, Furlong et al. (2006) test Toset et al.'s concern that the relationship between shared rivers and conflict may be spurious since countries with long common boundaries are more likely to have shared rivers. That is, it might actually be the long common boundary that is related to the cause of conflict, and not the fact the countries share a river (Furlong et al. 2006, 87; Toset et al. 2000, 990-991). To test the caveat outlined by Toset et al. (2000) the authors restate the same six hypotheses, and add one of their own which they formulate as: "when controlling for the length of the boundary between two countries, sharing a river no longer increases the probability of dyadic conflict" (Furlong et al. 2006, 88).

In order to test this hypothesis, Furlong et al. use the same dataset, dependent variables, and control variables as Toset et al. (2000) but supplemented it with the Boundary dataset which provides data on the lengths of boundaries between all dyads. In terms of their last hypothesis, which is designed to test the suspected spurious relationship highlighted by Toset et al., the authors discover that the hypothesis is not supported since the variable measuring boundary length is not found to be statistically significant therefore leading the authors to conclude that the results originally found by Toset et al. (2000) are slightly strengthened (Furlong et al. 2006, 94).

The second study which builds on the work of Toset et al. and Furlong et al. is the work of Gleditsch et al. (2006). Gleditsch et al. not only build on previous work by asking new questions with old data, but also provide new data in order to enhance the results of the previous studies. In terms of the formulation of new hypotheses, Gleditsch et al. chose to test the "fuzzy boundary scenario" which is to say that "countries sharing large amounts of river boundary are not fighting over the direct control of the resource per se, but rather over the political boundary" (Gleditsch et al. 2006, 365). Such a scenario, therefore, challenges the argument put forth in previous studies that conflict between dyads that share rivers is actually about control of the water resource and not a boundary demarcated by a river.

In order to test this hypothesis, Gleditsch et al. (2006) developed a new dataset on shared water resources which aligns it with recent work on conflict and cooperation by looking at the water basin as a whole, rather than single rivers. They also addressed a number of the shortcomings of the Toset et al. database by recoding the shared river dyads so that the ratio between upstream/downstream and border demarcating rivers were clear in order to measure the fuzzy boundary scenario and include non-contiguous country dyads, which still shared a river basin (Gleditsch et al. 2006, 366). Furthermore, the database used by Toset et al. was somewhat incomplete, since it included little information on rivers in Africa or Asia, left out 51 basins, and a number of prominent rivers. The new database developed by Gleditsch et al. ensured to be much more complete by adding information where the Toset et al. database was found to be lacking. Like the studies before them, Gleditsch et al. also used the same dependent variable, control variables, and timelines.

The hypotheses developed by Gleditsch et al. are very similar to those previously posited:

1. Dyads sharing a river basin have more conflict.
2. Dyads sharing a river boundary have more conflict
3. Dyads with more river crossings have more conflict
4. Dyads that share greater amounts of water resources have more conflict.
5. Dyads with an unequal distribution of shared water resources have more conflict.
6. Dyads sharing a river basin have more conflict if one or both of the countries in the dyad have low rainfall.

7. Dyads sharing a river basin have more conflict if one or both of the countries in the dyad have recently experienced drought.
8. Dyads sharing a river basin have more conflict if one or both of the countries in the dyad are in the Middle East or North Africa.
9. Dyads sharing a river basin have more conflict if one or both of the countries in the dyad are in sub-Saharan Africa.
10. Among dyads that share a river basin, those with lower levels of development will have more conflict.
11. Among dyads that share a river basin, those with intermediate levels of development will have more conflict. (Gleditsch et al. 2006, 368-371)

Testing specifically for the fuzzy boundaries scenario, Gleditsch et al. control for the length of the river boundary and the number of river crossings. The results of this test are not statistically significant and therefore lead the authors to conclude that "the conflict proneness of shared basin must derive from something other than the presence of contentious river crossings or potentially fuzzy boundaries" therefore rejecting the fuzzy boundary hypothesis (Gleditsch et al. 2006, 373).

Despite shifting the unit of analysis to the river basin, and providing a much more complete dataset, Gleditsch et al. find that their results[5] are similar to those reported by Toset et al. (2000) and Furlong et al. (2006) therefore lending credence to the argument that "there is some relationship between shared river basins and conflict" (Gleditsch et al. 2006, 380).

2.3 Shared Freshwater Resources and Cooperation

As previous research has shown, there is a strong theoretical reason to argue that future conflicts over shared freshwater resources are possible (Gleick

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[5] See *Conflicts over Shared Rivers: Resource Wars or Fuzzy Boundaries?* (Gleditsch et al. 2006) for a complete discussion of the results of the analysis.

1993; Haftendorn 2000; Mostert 2003; Wolf et al. 2003). More importantly, large *N* statistical research has indicated that there is a strong correlation between shared freshwater and conflict (Toset et al. 2000; Furlong et al. 2006; Gleditsch et al., 2006). However, a significant caveat was raised by Wolf et al. (2003) that over the past 50 years, there have been very few acute conflicts over water, and that on the whole, there have been more cooperative than conflictive events. Given this, it is important to further explore the relationship between cooperation and shared freshwater resources.

Wolf is most likely the biggest sceptic of the shared freshwater and conflict thesis described above. While Wolf accepts that a lack of clean freshwater can lead to political instability, and in very rare circumstances, acute violent conflict he is much more impressed with the history of dispute resolution surrounding shared freshwater (Wolf 1998, 255; Wolf et al. 2003). Wolf points out that while there have only been seven minor skirmishes in modern history, more than 300 treaties that deal with the non-navigational use of water, such as dams, pollution, flood control have been signed since 1814 (Wolf 1998, 258).

Other than the existence of numerous treaties to illustrate the fact that cooperation over freshwater resources occurs more often that conflict, Wolf argues that international conflict over shared freshwater is irrational for several reasons. First, there is no apparent strategic argument for a state to launch a war over water. Wolf argues that for a war to be launched over water, the aggressor would have to be both the regional hegemon, (in order to win the war), as well as the downstream riparian, since an upstream riparian would have little reason to launch an attack on a downstream riparian. Moreover, according to Wolf, of the 268 international watersheds, only a handful would actually meet the basic scenario, therefore weakening the argument that there are often strategic reasons to go to war over water (Wolf 1998, 259). Second, Wolf argues that a case can be made for an economic argument against water wars. That is, water is neither a particularly costly commodity, nor a particularly scarce one since there are numerous technologies to store, divide and purify it; engaging in war, however, is a tremendously expensive endeavour (Wolf 1998, 261). Since a war would most likely be more expensive than finding alternative access to water, it would seem unlikely that states would choose war over the alternative (Wolf 1998, 261).

More interestingly, however, Wolf argues that institutions and inter-state cooperation make conflict over shared freshwater resources much less likely. Cooperation is more likely than conflict because of a strong argument for the existence of shared interests when it comes to transboundary freshwater resources. Shared interests may arise because all riparian states desire high water quality, or because no development along a river that acts as an international boundary could be done without cooperation. Historically, shared interests have regularly permeated water agreements, therefore facilitating relations between riparians (Wolf 1998, 259-260).

Further research on cooperation between India and Pakistan on matters of the Indus River by Alam (2002) strengthens Wolf's argument. Alam argues that because of the water scarcity in the region, and the fact that the two countries are enemies due to a wider conflict, it would be expected that conflict over the use of the river would erupt (Alam 2002, 341-342). However, Alam questions this rationale because Pakistan and India never went to war over water, and actually managed to create a cooperative regime through the signing of the Indus Water Treaty in 1960 (Alam 2002). Like Wolf, Alam argues that India and Pakistan never went to war over water because it was in fact in neither country's self-interest (Alam 2002, 347; Wolf 1998, 259). India and Pakistan realized that both had shared interests in the sharing of the waters of the Indus. According to Alam, cooperation occurred because "water is scarce, vital, expensive, a security issue, demand is outstripping supply and a war would not guarantee future resources" (Alam 2002, 347).

Wolf further argues that the institutions created because of shared interests tend to be extremely resilient over time, therefore adding to the stability of international watersheds. Institutions have survived and even thrived while conflict in other areas raged between riparians. Indeed, in their separate studies of the regimes of the Mekong River, both Makim (2002) and Jacobs (2002) argue that the different regimes have encountered success because of their remarkable resiliency in the face of conflict. Makim even argues that despite the relatively low technical output of the regime, (i.e. output in relation to water issues), the regime's resiliency has actually contributed a great deal to stability and order among the countries of the Mekong (Makim 2002, 41). Jacobs, on the other hand, argues that the Mekong regime served as a venue for cooperation and dialogue while tensions were high in other sectors and ultimately stands to play a role in furthering regional cooperation and security (Jacobs 2002, 363).

Given this seemingly logical anti-water wars argument, it is critical to gain a deeper understanding of the role played by institutions in mitigating conflict over shared freshwater resources. Most of the energy devoted to substantiating this theory with empirical evidence has focused on the use of individual case studies of different river basins and their regimes. Significantly less energy has been devoted to a broader, more general understanding of the role of institutions in this context.

Hensel et al.'s (2006) study represents the first large *N* statistical analysis to move away from a case study analysis of the role of institutions over shared freshwater. Unlike previous large *N* statistical studies that focus on the relationship between conflict and shared freshwater resources (Toset et al. 2000; Furlong et al. 2006; Gleditsch et al. 2006), Hensel et al.'s methodology also allows for the differentiation of issues of the different conflicts being observed.

As previously mentioned, the main problem with the earlier studies is that it was difficult to know the issues surrounding the conflicts being observed and therefore impossible to really establish if shared basins or shared rivers had a causal effect on conflict. Unlike previous studies which used a database that focused on all MIDs between contiguous and non-contiguous dyads over a specific period of time without differentiating conflict issues, Hensel et al. (2006) constructed a database entitled the Issues Correlates of War or ICOW that tries to avoid such a problem by only including claims over specific issues (Hensel et al. 2006). This dataset addresses only shared water issues, specifically issues of contention over shared rivers, and not shared basins. Hensel et al. (2006) argue that the COW project focuses only on contentious issues that are resolved through militarized force, and rather than peaceful settlement. Therefore contentious issues that resulted in the signing of an agreement between two states, or the creation of an institution are missing in the COW data. Accordingly, Hensel et al. argue that the project has attempted to overcome this problem

> by collecting data on contentious issues, which produces variation on the militarized side; some contentious issue claims lead to one or more militarized disputes, while others do not. Focusing on explicit verbal contention over a specific issue makes it possible to compare peaceful and militarized conflict management practices more effectively. (Hensel et al. 2006, 397)

With this new dataset in hand, Hensel et al. hypothesize that water scarcity increases the amount of claims over freshwater, increases the chance of militarized disputes over these claims, and makes it more difficult for conflict management institutions to be created or even be effective. Concerning the role of institutions, because their dataset allows them to look at the peaceful side of contentions over shared water resources, the authors argue that membership in general and river specific institutions should help to peacefully resolve shared river claims. (Hensel et. al. 2006, 388-390)

In order to test these hypotheses, the authors develop four distinct dependent variables: one, which codes militarized conflict over a given claim, a second dummy variable which indicates when a bilateral settlement between the two parties was attempted, a third dummy variable which indicates whether a multilateral settlement using a third party was attempted, and a fourth variable which measures the effectiveness of peaceful conflict management. In this case, peaceful conflict management was coded as successful when the attempt was determined to be able to end contention over the issue (Hensel et al. 2006, 398-402). Like the previous studies, Hensel et al. propose a number of independent and control variable for their analysis. These variables include water scarcity, river specific institutions, general conflict management institutions, joint democracy, issue salience on a scale of zero (low salience) to twelve (high salience), power asymmetry, recent military conflict over the river issue, and recent failed attempts at peaceful resolution. (Hensel et al., 2006, 402-403).

Using multivariate logistic regression, Hensel et al. (2006) find that their results generally support their argument. The data supports the conclusion that water scarcity will increase the likelihood of militarized conflict over a river. However, water scarcity and water demands do not have any effect on attempts to settle claims bilaterally. Water scarcity and demands do, however, increase the likelihood of third party management efforts. As for the pacifying effect that institutions have on specific river claims, the authors argue that the presence of institutions to manage disputes is important, since militarized disputes are much less likely when a river specific institution exists. Furthermore, they find that the existence of general institutions increases bilateral and multilateral agreements, but that river specific institutions do not. Overall, Hensel et al. argues that this supports their argument since general institutions help bring the parties to the table, while river specific institutions constrain member states from using military force to achieve their ends. (Hensel et al. 2006, 404-405)

2.4 Conflict and Cooperation over Freshwater Resources: Identifying the Gaps and Moving Ahead

2.4.1 The Role of Institutions

The previous discussion has illustrated how the body of knowledge that has developed to understand the relationship between conflict and cooperation over shared freshwater has grown significantly in the last twenty years. One of the first gap that becomes apparent after reviewing the literature is the lack of understanding of the role of institutions in studies that use COW data. This study will therefore continue to build on this area of study by exploring the role of institutions. More specifically, it will build on this area of study by focusing on the impact that general and water specific institutions have on the relationship between shared rivers and conflict using a dataset in which a MID is the dependent variable. So far, these studies have focused primarily on geographic/physical factors and their impact on the relationship between shared rivers and conflict. Indeed, Furlong et al. (2006) focused on the length of the boundary to see if the relationship uncovered by Toset et al. (2000) was spurious, while Gleditsch et al. (2006) focused primarily on the fuzzy boundary scenario to determine whether conflict was occurring over the use of the water resource or boundaries which were delimited by shared rivers.

By embarking on an initial exploration of the role of institutions in conflict over shared water resources, this project moves away from the geographic/physical aspect of the relationship of previous COW based research and begins to explore the more social aspects. This research explores, in a preliminary fashion, the impact that the existence of these institutions has on the possibility of militarized disputes over shared water resources and the role they play in mitigating conflict. Therefore, like Hensel et al., this study argues that institutions, both river specific and general play an important role in mitigating and decreasing the likelihood of conflict between two dyads that share freshwater resources. However, unlike Hensel et al., it falls in line with previous COW based research by observing all cases of MIDs between 1880 and 2001 and observing river basins rather than individual rivers.

2.4.2 Methodological Refinement: Event History Analysis

A second gap that can be observed in previous large *N* statistical research is the lack of methodological refinement. Researchers who have previously explored this topic (Toset et al. 2000; Furlong et al. 2006; Gleditsch et al. 2006) have employed regular logistic regression to conduct their analysis since such an approach permits the use of dichotomous dependent variables; in this case, the presence, or absence of conflict. However because the data being used is in time-series form, it is possible for the observations to be temporally dependent. If this were in fact true, one of the key assumptions of logistic regression mainly that all observations are independent, would be violated. According to Beck et al. (1998, 1261), this violation can lead to "overly optimistic inferences (underestimates of variability leading to inflated *t*-values)" that ultimately cast doubt on the validity of the findings. Realizing this risk, both Gleditsch et al.

(2006) and Toset et al. (2000) adopt a quick method developed by Beck to address this issue without having to learn a completely new methodology. According to Beck et al. (1998), the problem of temporal dependence can easily be corrected by adding a series of dummy variables to the logit specification, which will mark the number of periods since either the start of the sample period or the previous occurrence of an event (Beck et al. 1998, 1261). Accordingly[6]:

> A standard statistical test on whether these dummy variables belong in the specification is a test of whether the observations are temporally independent. The addition of these dummy variables to the specification, if the test indicates they are needed, corrects for temporally dependent observations (Beck et al. 1998, 1261).

Although such an approach may address the primary problem encountered when using regular logistic analysis in this type of research, acknowledging the strengths of event history analysis (Box-Steffensmeir 1997) many researchers (i.e. Rakenrud and Hegre 1997; Werner 2000; Ireland and Gartner 2001) prefer to abandon logistic regression altogether in favour the latter. This study will therefore provide methodological refinement to the study of conflict and cooperation over transboundary freshwater resources by adopting event history methodologies[7].

2.4.3 Time and the Occurrence of Conflict

As previously mentioned, the data being used for this study can best be characterized as time-series data, therefore providing the researcher with the

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[6] See Beck et al. (Beck et al. 1998) for a complete mathematical elaboration of their methodology and model, as well as an empirical evaluation using previous studies.

[7] See the Methodology section for a further explanation of the strengths of Event History Analysis over Multivariate Logistic Regression.

opportunity to study in greater detail the relationship between time and the occurrence of conflict. Previous research has shown that time can potentially be an important factor when studying the occurrence of international conflict (Rakenrud and Hegre 1997; Werner 2000; Ireland and Gartner 2001) and as such should be taken into consideration when the data allows it. Dyads that spend a significant amount of time in peace may perhaps be less likely to engage in conflict with one another since they have been able to build peaceful relations with each other, in other words, a culture of peace may have developed between them. On the other hand, studying the impact of time may show that the longer a dyad spends in a state of peace, the more likely it is to experience conflict.

While logistic regression can deal with time in a rudimentary fashion, event history analysis is ideal for this study because it allows researchers to study time as a distinct variable that can impact the occurrence of conflict in greater detail. The methodology proposed by Beck et al. does attempt to model the impact of time, however, as Chapter 3 will illustrate this methodology is not as sophisticated as event history methodologies. While Beck et al.'s method provides an overview of the impact of time on the occurrence of conflict, event history methodologies provide a much more sophisticated understanding of the impact of time, and do not limit the researcher to an understanding of time as described above. More specifically, event history methods can model patterns and causes of change (Box-Steffensmeir 1997, 1414), and understand "how the duration spent in one social state affects the probability some entity will make a transition to another social state" (Box-Steffensmeir 1997, 1414). In the case of this study, it analyzes the effect of river specific variables on the occurrence of conflict and the existence of institutions to manage these shared resources by taking into account the duration of peace prior to an observed conflict. Because of the properties of event history methodologies, this analysis will place a greater emphasis on the variable of time, something that has not been done in previous research, but because of the nature of the data is crucial.

This study will therefore contribute to the study of conflict over cooperation in three distinct ways. (1) The literature places an emphasis on the role of institutions in mitigating conflict over shared freshwater resources. By adding institution variables, albeit crude, this study will begin to explore the role of international institutions and conflict over shared freshwater resources in the context of COW data. (2) It will contribute by providing methodological refinement in the form of event history analysis. (3) In adopting event history analysis methods it is implicitly putting emphasis on the variable of time, that is, how time impacts on the occurrence of conflict.

CHAPTER 3: METHODOLOGY

3.1 Introduction

This section establishes the methodology, describes the dataset and the variables use to conduct the research, and lists the proposed hypotheses. It argues that event history methods are the most appropriate tools for analyzing the question at hand by contrasting it to multivariate logistic regression. Although the fundamentals of event history analysis have already been canvassed, it is important to go into greater detail in order to gain a firm understanding of the strengths of this methodology. The discussion will then move to a discussion of the dataset, and the justification for conducting research using the COW dataset despite the obvious benefits of the ICOW dataset. A description of the different variables will be provided with special attention to changes made to the replication dataset as well as a description of the new variables that will be used to test the three new hypotheses. Finally, this section will conclude with the proposed hypotheses and their expected results.

3.2 Event History Analysis

Event history methodologies are better suited to the study at hand than logit or probit analysis because they address the issues of temporal dependence, right censoring, and time-varying covariates (defined below)[8]. In terms of temporal dependence, unlike probit or logit analysis, event history analysis does not assume that each observation is temporally independent (Box-Steffensmeir and Jones 1997; Werner 2000). According to Werner, "this methodology can model any temporal dependence between observations within an event, like a spell of peace" (Werner 2000, 350). Such an approach is valuable for this study since the risk of conflict in a dyad may very well depend on the variable of time, that is, the period of peace within a dyad. Being able to model the full spell of peace is therefore important since it could very well have a great impact on the hazard of war in a dyad. The empirical research (Toset et al. 2000; Furlong et al. 2006; Gleditsch et al. 2006; Hensel et. al. 2006) conducted on the relationship between shared freshwater resources and international conflict has so far been unable to model this impact.

Some authors have adopted a simple methodology developed by Beck et al. (1998) to deal with temporal dependence without using event history methods, this method falls short of the more complex and sophisticated event history methods. Werner (2000) argues that event history modelling is preferable to the solution proposed by Beck to deal with temporal dependence for several reasons. Firstly, Werner argues that using a peace-years spline[9] to correct for temporal dependence means that information is lost since each year of peace is not accounted for (Werner 2000, 351). More obviously, if the peace-years spline

[8] See Janet Box-Steffensmeir and Bradford Jones (1997) and Paul Allison (2004) for a complete and detailed technical discussion of different event history methodologies and their application and how they specifically address the issues of temporal dependence, right-censoring and time-varying covariates.

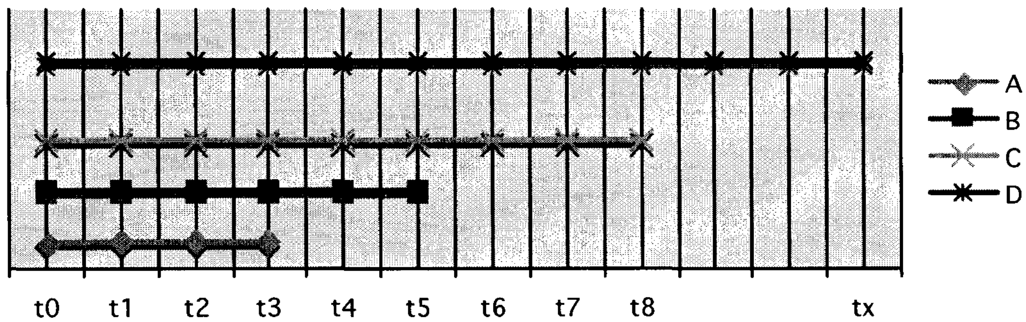
[9] See Beck (1998, 1270) for an explanation of cubic splines used in their analysis.

is used, the analyst will lose numerous degrees of freedom[10], due to the large amount of dummy variables included for each year of peace (Werner 2000, 351). Thirdly, the coefficients of the spline are challenging to interpret, therefore making analysis difficult for researchers interested in the nature of the temporal dependence. Using event history modelling allows the analyst to avoid these problems since hazard models allow duration dependence to be estimated without losing data or degrees of freedom and duration dependence can easily be interpreted (Werner 2000, 351).

The issue of right censoring also highlights the strengths of event history methodologies. Suppose for example the case of shifting from peace to conflict. Figure 3-1 illustrates four cases of conflict. In case A, the duration of peace is three time units, since at t_3, case A experiences the event (conflict). In case B, the duration of peace is five units of time (t_5), while case C experiences the event of conflict at the end of data collection, or, time eight (t_8). Case D is the problematic one, since it experiences the event at time t_x, or, sometime after the end of data collection (t_8). It is therefore impossible to know when D will experience conflict. It is considered to be right-censored.

[10] Degrees of freedom can be best defined as the constraint placed on a model by adding additional unnecessary or stochastic independent variables. The more variables included in a model (decrease in degrees of freedom) the more likely it is that the error term will affect inferences about the non-random aspect of the dependent variable (Studenmund 2001, 68).

Figure 3-1: Right-Censoring



According to Box-Steffensmeir, the problem with the regression model, including logistic regression, is that it fails to distinguish between cases C and D. Including right-censored cases (i.e. case D) in the model would implicitly treat them as having experienced the event (conflict) when in reality they have not. Because it is impossible to foresee the future, it is also impossible to know how long right-censored observations would go on for (Box-Steffensmeir and Jones 1997, 1416). One logical solution would be to eliminate all censored observations from the data set. This however would not truly solve the problem, and could actually make things worse. Box-Steffensmeir argues that:

> [I]f the factors producing censoring are completely unrelated to factors promoting an event's occurrence, then truncating the sample may be a solution; however, censored observations are often influenced by precisely the same factors uncensored observations are (Box-Steffensmeir and Jones 1997, 1416).

Including in the sample only uncensored observations would also be problematic because it would produce a biased sample since only those observations initially prone to experience an event would be included (Box-Steffensmeir and Jones 1997, 1417).

Box-Steffensmeir points out that another possible solution would be to include a dummy variable to indicate whether a dyad experienced the event of interest within the time frame being studied. This would avoid the censoring problem; however, "this 'solution' belies the logic of studying time-dependency in the first place" (Box-Steffensmeir and Jones 1997, 1417) since "a dummy indicator could not discriminate between varying times-to-adoption" (Box-Steffensmeir and Jones 1997, 1417) in the case of the study at hand, conflict. That is, such an approach would prevent the analyst from observing temporal dependence, which, as previously discussed, is critical to understanding the hazard of conflict in a dyad. Event history methods will allow for a more robust analysis of the hazard of conflict between states who share freshwater resources because it not only includes all cases censored at the end of the observation period but it is able to differentiate the different times to conflict (end of peace) experienced by the dyads.

Time-varying covariates are another important problem that event history methods can deal with. Because regular regression methods treat all covariates as fixed, such an approach would fail to take into account changing conditions such as changes in power distribution or membership in alliances that could very well have an impact on the occurrence of conflict (Box-Steffensmeir and Jones 1997, 1417). Indeed, Allison argues that this failure of regular regression models is more important than that of censoring (Allison 2004, 370). This is especially relevant to the study at hand, since a number of the control variables used shift from year to year in each dyad. While a number of the variables are relatively fixed in nature (river length, contiguity, distance) others may vary over time (system size, development, dyad size, or alliance). Since the control variables included in the analysis are believed to have an important impact on the hazard of conflict within dyads, it is important that the analytical method take into account changes in these variables since a change could very well have a significant impact on the hazard of conflict.

3.2.1 Model Selection

The different estimators used to model event history can be separated into four broad categories: (1) continuous-time models, (2) discrete-time models, (3) proportional hazard rate models, and (4) non-proportional hazard rate models (Box-Steffensmeir and Jones 1997; Box-Steffensmeir et al. 2003). In the case of this research, a continuous-time model with a log-logistic distribution will be used to estimate the hypotheses previously proposed.

There are a number of theoretical reasons that support the use of a continuous-time log-logistic model over any of the other models available. First, as implied by their name, discrete-time formulations presume that change, or events, only occur at discrete or pre-determined times (Box-Steffensmeir and Jones 1997, 1423) such as elections, or a speech from the throne. Many social events, however, are not as predictable and can plausibly occur anywhere in time. War, or conflict, is a perfect example of such a phenomenon, since it may not be appropriate to think of conflict as a discrete event, that is, to assume that wars only occur on particular days of the year, or even particular times of year.

Given the continuous nature of conflict, it may be more appropriate to adopt a methodology that takes this into account.

Within the family of continuous-time models, researchers have a choice of a number of different estimators, depending on the type of baseline hazard rate being observed, that is, how the hazard of an event occurring changes. To better illustrate a baseline hazard rate, Box-Steffensmeir and Jones provide an example of a changing hazard rate by looking at the hazard of death over the lifetime of an individual. Generally speaking the hazard of death is originally quite steep (birth); it then drops dramatically and flattens (childhood and adulthood) and finally begins to rise again in 'old age' (Box-Steffensmeir and Jones 1997, 1427). This bathtub shape can be seen as the baseline hazard of the event being observed and a proper estimator that reflects these parameters must be chosen. If the researcher believes that the hazard rate does not change over time, then the Exponential Model, which follows an exponential distribution, would be appropriate (Box-Steffensmeir and Jones 1997, 1427)

In the case of this research, however, the estimator selected to model the occurrence of conflict over shared freshwater resources is the log-logistic model. This model was selected, because unlike the exponential model it is appropriate in situations where the dependent variable shows signs of time dependence. Indeed as discussed earlier it is believed that the time spent in a peaceful state is critical to the occurrence of conflict within a dyad, more specifically that the longer time a dyad spends in peace; the less likely conflict is to occur, or on the other hand, the more likely it is to experience conflict. It is therefore imperative that the model selected allows for such dependence. The log-logistic model is ideal in this circumstance because it allows for nonmonotonic (Box-Steffensmeir and Jones 2004, 31), as well as monotonically decreasing, and unimodal hazard rates (Box-Steffensmeir and Jones 2004, 32). More specifically, the log-logistic model allows the researcher to observe the type of duration dependence by analyzing the shape parameter (p) reported in each analysis. When p is greater than one, the hazard rate first increases and then decreases, in other words it is not monotonic; however, when p is less than or equal to 1, the hazard rate is monotonically decreasing. This model was chosen over the very popular weibull model for two reasons. First, the researcher is not limited to a simple monotonically decreasing or increasing hazard rate,[11] but can also see if the duration dependence being observed is nonmonotonic in nature. Second, based on a comparison of the log-likelihood results in the weibull and log-logistic models, the log-logistic model was determined to be more appropriate for the data being analyzed.

It is also important to note that the log-logistic distribution was selected over the much more popular Cox model, which is also a proportional hazard rate, model for several reasons. The Cox model is appealing to social science research because unlike the log-logistic, weibull or exponential models previously discussed, it does not force the researcher to choose the shape, or parameter of the hazard rate being observed, *a priori*. Because the interpretation of the

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[11] The weibull model reports a parameter that is greater than, less than, or equal to 0, therefore suggestion positive, negative, or no duration dependence (Box-Steffensmeir and Jones 1997, 1429).

covariates in these models depend on the shape of the hazard function, it is important that the proper estimator is chosen; if not, the researcher risks drawing inaccurate or wrong inferences about the social process being observed (Box-Steffensmeir and Jones 1997, 1432). It is therefore not surprising that the Cox model is an extremely appealing methodology. However, the Cox model may not be ideal for the research at hand, since although this approach models the effects that different covariates have on the hazard rate, it cannot model time dependence (Box-Steffensmeir and Jones 1997, 1434), which is a critical and interesting aspect of the research being undertaken.

3.3 Dataset

With current data, the empirical study of conflict and cooperation over shared freshwater resources can be conducted in two distinct ways. The traditional approach has been to use the COW project data to study all militarized interstate disputes over a pre-determined period of time using river specific independent variables such as length, or shared boundary to understand the relationship between shared rivers and conflict. The second approach, as pioneered by Hensel et al., has focused uniquely on disputes over shared water resources, rather than looking at all militarized conflict. Such an approach strengthens the validity of their results since it avoids the problems encountered by Toset et al., Furlong et al., and Gleditsch et al., that although the incidence of conflict may be related to water or river related variables, the conflicts being observed in the data actually have nothing to do with water whatsoever. Interestingly enough, despite different data, the general conclusions drawn by these two approaches as they relate to conflict over shared water resources are very similar.

For practical as well as theoretical reasons, the proposed research adopts the former methodology to explore conflict and cooperation over shared water resources. In terms of practicality, using the former approach allows the researcher to have access to much richer data. While some ICOW data is available for research, the dataset is currently incomplete and only provides data on water issues in the Western Hemisphere from 1900 to 2001. The COW data set, on the other hand, provides data on all currently known river basins in the world from 1880 to 2001 (Gleditsch et al. 2006). Although research with ICOW data could reveal new and interesting relationships, while perhaps strengthening previous findings, the current lack of publicly available data to conduct further research makes ICOW an unattractive alternative.

More importantly, however, there are some theoretical reasons to prefer the COW approach as proposed by Toset et al., Furlong et al., and Gleditsch et al., to the ICOW approach undertaken by Hensel et al. The ICOW dataset analyzes the river, rather than the river basin. Hensel (2005) defends this choice by stating that studying rivers instead of river basins is more appropriate since:

> many river claims appear to involve a single river, rather than all rivers in a particular basin (e.g., when a dam or irrigation project is constructed on a specific river) in which case a river-based data set is appropriate. Similarly, a focus on individual rivers makes collection of salience indicators more straightforward (Hensel 2005, 1)

However, analyzing rivers, rather than river basins fails to take into account the importance of the river basin in contemporary dispute settlement attempts. Indeed, international law has acknowledged that international watercourses are to be treated as comprehensive hydrological units, or basins (International Law Association 1966; Dellapenna 2001). That is, dispute settlement must take into account the whole of a hydrological basin. Although a dispute might concern only one river in a basin, actions in other parts of the basin, whether in rivers, lakes or aquifers, will impact the river surrounding the dispute. Moreover, understanding the importance of the river basin as determined by international law, current researchers (Wolf 1999; Uitto and Duda 2002; Yoffe, Wolfe and Giordano 2003) have opted to analyze conflict and the possibilities of cooperation over shared water resources in terms of river basins over individual rivers. Given the importance placed on basins over individual rivers, it seems only logical that empirical studies follow the same pattern.

Finally, Gleditsch et al. point out that although approaches pioneered by Hensel et al. have a particular strength, - they exclude conflicts that are not related to the issue at hand, i.e. water - they are still imperfect since they "assume that the main (or only) issue can be reliably identified for each act or (sic) cooperation and conflict, which is not obviously true" (Gleditsch et al. 2006, 379). While it is relatively easy to identify MIDs with at least one battle death, Gleditsch et al. are correct in arguing that determining if a particular conflict is over shared water resources is much more difficult and therefore more prone to error. No approach to the study of conflict and cooperation over shared water resources is flawless. Given this particular caveat, as well as the lack of data, and the emphasis on rivers over basins a decision was made to adopt the proposed approach, rather than the one being left behind.

To answer hypotheses 1 through 6, the river basin dataset developed by Gleditsch et al. (2006) was used[12]. The *Correlates of War 2 International Governmental Organizations Data Set,* (Pevenhouse and Nordstrom 2003)[13] and the *Atlas of International Freshwater Agreements* (Wolf 2002) was used to supplement the Gleditsch et al. dataset in order to produce variables on general and river specific institutions that form hypotheses 7 and 8. The data is set up in a dyad-year format where each row of data is one dyad year. For example, row one could be a dyad consisting of country A and country B in the year 1880. The following rows could hypothetically be the same dyad but the following year (1881) and so on. It is important to note that a dyad enters the dataset when the younger state in the dyad becomes an independent state, and exits the dataset when one of the states in the dyad ceases to exist, or is right censored because data collection ends. Since the research seeks to explore the relationship between shared water resources, only dyads that are on the same continent are included in the dataset. Dyads constituting countries that do not share a continent, such as China and Mexico, are not included since it is physically impossible for these countries to share a freshwater basin. When including all dyads that coexist on the same continent, and all available years, there is a total

[12] Please see Gleditsch et al. (2006), and Owen et al. (2004) for a full description, as well as the structure, sources consulted and coding decisions made to create the dataset.
[13] Please see Pevenhouse & Nordstrom (2003) for a full description of version 2.1 of the dataset.

of 3,046 different dyads, and 124,271 dyad years, or rows of data. Attached to each dyad is a series of variables, both time-varying and time-invariant that relate to the political, economic, and water specific characteristics of each dyad year. Each of these variables has a specific value for every dyad year in the dataset. Because some of these variables are time-varying, such as membership in an international organization, the occurrence of drought, level of development, or political make-up, the values of these variables change from year to year.

3.4 Variables

3.4.1 Dependent Variable: The Hazard of Peace

Because event history methods model how the duration in one social state affects the hazard of shifting to another social state, event and duration variables are critical. The event variable indicates a shift from one social state to another, in the case of this study, peace to war. The duration variable measures the time the subject spent in the first social state, prior to the shift to another state, in this case, the duration of peace in a dyad. In order to test the proposed hypotheses the event variable is the onset of militarized interstate disputes (MID), from the Correlates of War Project (COW). This is a slight shift from the methodology employed by Gleditsch et al. (2006), Furlong et al. (2006) and Toset et al. (2000) all of whom used a MID with at least one battle death in order to minimize "the potential attention bias inherent in data on low-level conflict" (Gleditsch et al. 2006). A decision was made to shift away from this, and use a MID which is defined as "a set of interactions between or among states involving threats to use military force, displays of military force, or actual uses of force. To be included, these acts must be explicit, overt, non-accidental, and government sanctioned" (Gochman and Maoz 1984, 586). This decision was taken for several reasons. First, the dataset does not include a duration variable that corresponds to the occurrence of MIDs with a least one battle-death. In fact, the duration variable used by Gleditsch et al. to construct their *peace-years* variable was based on the duration of peace between MIDs that did not necessarily experience at least one battle-death. The results regarding their *peace-years* variable are most likely inaccurate, as the duration times do not accurately reflect the recorded events. To achieve correct results on the *peace-years* variable reported in their article, they would have had to create a duration variable that accurately matched the event variable. Second, although Toset et al., Gleditsch et al. , and Furlong et al. raise the valid concern of potential attention bias by including MIDs that did not have at least one battle-death, this concern may not be completely warranted. As previous case studies have shown, very few of the conflicts regarding shared freshwater resources have actually involved the death of combatants. More often than not, these conflicts have consisted, rather fortunately, of military threats and political posturing. In order to correctly study the hazard of conflict over shared freshwater resources, it may be wise to broaden the definition of conflict to include events that did not result in casualties, therefore accurately reflecting the types of conflict over shared freshwater resources being witnessed today.

The duration variable is the spell of peace, or *peace-years*, for each dyad between MIDs[14]. The *peace-years* variable is set to 0 when the dyad enters the dataset[15], and increases until the dyad experiences a MID. When a dyad experiences a MID the *peace-years* variable is set back to 0 and begins to increase again until another MID occurs, or the dyad is right-censored. Because conflict is a reoccurring event in international relations, it is possible that a dyad may experience repeated MIDs over the observed period. Multiple events can have serious implications for event history analysis because they often do not occur for independent reasons. When this assumption of independence is violated, standard errors can be seriously biased downwards and test statistics biased upwards (Allison 2006). It is therefore important to adopt methods that take into account these occurrences. As suggested by Allison and Box-Steffensmeir and Jones (Allison 2006; Box-Steffensmeir and Jones 2004), a frailty model with a gamma distribution is implemented in order to deal with dependence between repeated events. This approach assumes that each spell of peace or interval between MIDs is dependent rather than independent because of unobserved heterogeneity. This approach therefore corrects for bias in both coefficient estimates and standard error estimates (Allison 2006; Box-Steffensmeir and Jones 2004).

[14] The data on years of peace is taken from the COW dataset and downloaded through EUGene (Bennet and Stam 2005).

[15] See Werner (2000), "The Effects of Political Similarity on the Onset of Militarized Disputes, 1816-1985" for a complete discussion of the *peace-years* variable and why dyads that existed during the first year of data collection (1816) may not have a *peace-years* variable coded as 0.

3.4.2 Independent Variables

The following water related independent variables are used to explore the relationship between shared water resources and answer the previously posited hypotheses. The first eight variables are drawn directly from the research of Gleditsch et al. (2006) and are used to replicate their research using event history analysis methods. The last two variables have been added to the Gleditsch et al. dataset in order to explore questions regarding the role of institutions in the relationship between shared freshwater resources and conflict.

Shared Basin. The shared basin variable is a dummy variable that indicates whether or not the two states in a dyad share a river basin. Because river basins can cover vast geographical distances and encompass more than one state it is possible that two countries that are not contiguous, still share a basin.

River Boundary. This variable is the logged length in kilometres of a river boundary between two contiguous states in a dyad (Gleditsch et al. 2006, 369).

River Crossings. This variable applies only to dyads in which the countries are contiguous. In order to create this variable, Gleditsch et al. (2006) counted the number of rivers that crossed the international boundary between states in a dyad. It is important to note that only main rivers, and not tributaries, that crossed international boundaries were counted. Only in a few instances were tributaries considered large, or significant enough to be counted as river crossings (Owen et al. 2004, 15).

Basin Size. This variable is simply the logged total area, in square kilometres of the river basin being shared by two states in a dyad (Gleditsch et al. 2006, 369; Owen et al. 2004).

Basin Upstream. This variable refers to the logged total size, in square kilometres of the river basin located in the upstream state in a dyad (Gleditsch, et al. 2006, 369; Owen et al. 2004).

Percent Upstream. Based on the variable *Basin Upstream*, this variable is the percentage of the total basin area that lies in the upstream state of the dyad (Gleditsch et al. 2006, 369; Owen et al. 2004).

Rainfall. The rainfall variable is calculated by taking the non-weighted average of rainfall for both states in the dyad between 1968 and 2001. This variable is the average rainfall over 30 years, and is therefore constant (Gleditsch et al. 2006, 369; Owen et al. 2004).

Drought. The data available for droughts spans the time period between 1975 and 2000. The drought variable is a dummy variable that indicates whether one or both of the countries in the dyad experienced at least one drought at any time during the past five years. (Gleditsch et al. 2006, 369; Owen et al. 2004)

Freshwater-Specific Institution. The *specific institution* variable is used to indicate whether two countries in a dyad are members of an institution that deals specifically with shared freshwater issues, such as water quality, distribution, or the dispute of conflicts related to the use of freshwater. Institutions are not limited to physical institutions consisting of a staff and a headquarters, but may also include treaties and agreements entered into by two or more parties for the purpose of joint management or regulation of shared freshwater resources. The data for this variable was collected from Wolf's *Atlas of International Freshwater Agreements* (Wolf 2002). This database covers 400 international water agreements between 1820 and 2002 and is the best and most complete comprehensive collection of bilateral and multilateral agreements currently available. The variable in question is a dichotomous variable that indicates the presence, or absence of a bilateral, or multilateral institution. Because institutions do not necessarily come into existence as soon as a dyad enters the dataset, and do not always endure for the lifespan of a dyad, this variable varies over time.

General International Institution. Like Hensel et al. (2006), this research is interested in the pacifying effects that international institutions have on conflict over shared freshwater resources. A variable that reflects a dyad's membership in a general international institution that has as its mandate the peaceful settlement of disputes between members was therefore created. Like the *specific institution* variable, this variable is dichotomous and indicates the presence or absence of an international institution of general nature that both states in a dyad are parties to. This variable was drawn from the data provided by Pevehouse and Nordstrom's (2003) *The Correlates of War 2 International Governmental Organizations Data Set.* Designed specifically for use with the COW dataset, the dataset provides membership information for 495 international governmental organizations between 1816 and 2000 (Pevehouse and Nordstrom

2003). In order to more accurately measure the pacifying effects of international institutions, all institutions that did not refer directly to the peaceful settlement of dispute among members were eliminated, and only those that dealt with peaceful dispute settlement (the UN, EU, OAS, NATO etc.) were included to create the variable.

3.4.3 Control Variables

In order to accurately replicate and build on Gleditsch et al.'s (2006) work, the same control variables used in their research were included. The inclusion of these variables is important because they highlight how water specific variables impact the probability of conflict independent of generally accepted explanations on the causes of conflict.

Political Make-Up. In order to test how the political make-up (two democracies, one democracy and one autocracy, and two autocracies) of a dyad impacts the risk of conflict, variables where constructed using the Polity IV scale of democracy and autocracy (Marshall and Jaggers 2003).

Development. This variable is a proxy measure of the level of development, which is achieved by measuring energy consumption per capita. This variable was taken from the National Material Capabilities data set from the COW project (Singer and Small 2005).

Dyad Size. Also taken from the National Material Capabilities data set from the COW project (Singer and Small 2005), this variable measures the dyad size by calculating the log of the combined population of the states that make up a dyad (Gleditsch et al. 2006, 372).

Major Power. This variable indicates the existence of one or more major powers within a dyad, and is taken from the EUGene software (Bennet and Stam 2005).

Alliances. This is a dichotomous variable indicating the existence of defence pacts and ententes between dyad members and is taken from the COW Formal Interstate Alliance Dataset (Gibler and Sarkees 2004).

System Size. This variable indicates the number of states in the international system at a given moment. This variable is included in the analysis "to control for the decrease in the risk of conflict in non-neighbouring countries resulting from the enormous increase in the number of non-neighbouring dyads in the international system (Gleditsch et al. 2006, 372-373).

Contiguity. This a dichotomous variable that indicates whether two states in a dyad are contiguous. (Owen et al. 2004)

Distance. This variable measures the distance between the capitals of two states in a dyad. It is downloaded through the EUGene software (Bennet and Stam 2005).

Boundary Length. This variable is taken from the *Shared River Basin Dataset* (Owen et al. 2004) and is defined as the log of the total length of the boundary between two contiguous states in a dyad.

Post Cold War[16]. This is a dummy variable that is included to take into account the decrease in interstate violence that followed the end of the cold war.

3.5 Proposed Hypotheses

In order to support the arguments discussed in chapter 2, a number of hypotheses will be tested. Firstly, because this research will be using Event History Analysis (EHA) rather than multivariate logistic regression to explore the relationship between shared rivers and conflict, a select number of hypotheses from Gleditsch et al. (2006) will be replicated to explore the possibly different results of this methodology. The results presented will include both the logistic and log-logistic results in order to provide a comparison of the results between both methodologies as well as a discussion of the impact of time and the presence of institutions on the occurrence of conflict.

Since Gleditsch et al.'s (2006) hypotheses were not designed for event history analysis methods, they made reference to the amount of conflict. The hypotheses have been reformulated to take this change into account by including the phrase "survival time". Survival time should therefore be understood in terms of the time spent by a dyad in peace before experiencing conflict. That is, how long the dyad survived before experiencing conflict.

H1. The survival time of a dyad decreases when dyads share a river basin.
H2. The survival time of a dyad decreases when dyads share a river boundary.
H3. The dyads with more river crossings experience a decreased survival time.

[16] In this instance, post cold war is defined as after 1990.

H4. The survival time of a dyad decreases when dyads share greater amounts of water resources.
H5. The survival time of a dyad decreases when dyads have an unequal distribution of shared water resources.
H6. Dyads sharing a river basin experience a decrease in survival time if one or both of the countries in the dyad have low rainfall
H7. Dyads sharing a river basin experience a decrease in survival time if one or both of the countries in the dyad have recently experienced drought

Using EHA, the following new hypotheses will also be tested.

H8. Membership in a general international organization will increase the survival time for dyads sharing a river basin.
H9. Membership in a water specific institution will increase the survival time for dyads sharing a river basin.

These two hypotheses build on the research of Hensel et al. (2006) by exploring the role of specific and general institutions in mitigating conflict over shared water resources within the context of a river basin, rather than a single river, and in terms of all MIDs rather than looking uniquely at conflict over water. Furthermore, they build on previous research (Toset et al. 2000; Furlong et al. 2006; Gleditsch et al. 2006), by looking at the institutional dimension that has yet to be studied. Despite the use of different data than Hensel et al., it is expected that results will be very similar.

It should of course be noted that the variables used to indicate the presence or absence of international institutions are rudimentary and provide a first glimpse at the relationship between conflict and institutions in the context of the COW dataset. Although they are accurate, they do not provide extensive insight into the role of institutions in the mitigation of conflict. As such, the hypotheses to be tested reflect this fact. It will be for future research to develop more sophisticated variables in order to test more sophisticated hypotheses that explore the relationship between institutions and the occurrence of conflict over shared freshwater resources.

H10. The survival time of a dyad increases the longer peace has endured within a dyad.

This hypothesis will illustrate the importance of modelling temporal dependence, or time, in the study of international conflict, including conflict over shared freshwater resources. Because the duration spent in one social state (peace) may possibly affect the hazard of moving to a different social state (war), it is important to model such an effect. Long spells of peace within a dyad may allow different mechanisms of peaceful resolution to develop, therefore institutionalizing peace within the dyad and making conflict less likely (Gelpi 1997; Werner 1999). It is therefore expected that the risk of conflict will decrease as the duration of peace increases.

CHAPTER 4: RESULTS

4.1 Introduction

The following chapter turns to an analysis of the results of the study. It focuses on the methodological refinement aspect of the study by establishing the models, and replicating the hypotheses established by Gleditsch et al. (2006) through a presentation of both the logistic and log-logistic models. It then turns to the second aspect of the study by exploring the relationship between the occurrence of conflict and the presence of international institutions using a log-logistic model. Finally, it discusses the third focus of this study by discussing in greater deal the relationship between time and the occurrence of conflict.

4.2 A Bivariate Model for Conflict over Shared Freshwater Resources

Table 4-1 provides the results of the bivariate relationship between conflict and the independent variables (water specific variables). In a first instance, it should be noted that the logistic regression results differ significantly from Gleditsch et al.'s (2006, 370) results for two reasons. First, as discussed in chapter 3, the dependent variable (conflict) is different. Second, because they used a logit model, it became obvious during the current study that Gleditsch et al. (2006) had to include the dyad year 2002 in their analysis. This could perhaps lead to differing results because the dyad year of 2002 was coded as experiencing a conflict for every single dyad in the dataset. This is a clear illustration of the problems encountered when dealing with right censored data sets. Moreover, because an EHA methodology was implemented, this problem of right censoring was effectively dealt with.

Table 4-1: Bivariate analysis of conflict and the independent variables 1880-2001

	Model A (Logistic*)			Model B (Log-Logistic**)				
Variable	Parameter Estimate	Standard Error	p	Parameter Estimate	Standard Error	p	Gamma***	Theta
Shared Basin (yes/no)	2.411	0.124	0.000	-2.012	0.108	0.000	0.827	3.164
River boundary (ln of km)	0.388	0.0252	0.000	-0.314	0.025	0.000	0.850	4.74
River Crossings (number)	0.0178	0.016	0.254	-0.134	0.169	0.000	0.855	5.613
Basin Size (ln of km2)	0.168	0.009	0.000	-0.150	0.008	0.000	0.829	3.344
Upstream Basin (ln of km2)	0.191	0.011	0.000	-0.170	0.010	0.000	0.831	3.924
Percent Upstream (%)	3.734	0.365	0.000	-4.098	0.413	0.000	0.852	5.606
Dry (yes/no)	0.060	0.146	0.677	0.083	0.123	0.497	0.872	7.269
Drought (yes/no during past 5 years)	-0.372	0.145	0.010	0.028	0.127	0.824	0.846	13.308
General Institution (yes/no)	-.0789	0.112	0.000	0.532	0.080	0.000	0.850	6.987
Water Institution (yes/no)	1.700	0.141	0.000	-0.659	0.115	0.000	0.878	6.340

* Logistic results reported are calculated using the same methodology as Gleditsch et al., 2006.
**Log-Logistic results are reported in accelerated failure-time form
*** Gamma significant at p>0.05

In terms of the parameter estimates, the results reported are in the same, and expected directions. Unlike Gleditsch et al., however, not all results are significant. Of note, where Gleditsch et al. reported the *River Crossings* variable to be significant at $p<0.05$ (Gleditsch et al. 2006, 370), it can be seen that in this context, the *River Crossings* variable is no longer significant. The significance of the two drought variables also changes, since the dichotomous drought variable is no longer significant, and the 5 year drought variable is now significant.

Other than a change in significance, the most substantial changes between the results reported by Gleditsch et al. and those reported in Table 4-1 are the magnitudes of the different parameter estimates. As illustrated in Table 4-2, a comparison of the odds ratio reported in Table 4-1 and those reported by Gleditsch et al. the reported odds ratio of the *Shared basin*, *River boundary*, *River crossings*, *Basin size*, *Upstream basin* and *Percent Upstream* all have a much more significant correlation on the occurrence of conflict in this new analysis. Of particular interest are the dramatic changes that occur on the *Shared basin* variable and the *Percent upstream* variable. On the other hand, by changing the dependent variable, and restricting the analysis to 1880-2001, the impact that the two drought variables have decreased on the odds of the occurrence of conflict.

Table 4-2: Comparison of Odds Ratios

Variable	Odds Ratio*	Odds Ratio**
Shared Basin (yes/no)	11.14	2.3
River Boundary (ln of Km)	1.47	1.113
River Crossing (number)	1.01	1.0095
Basin Size (ln of km2)	1.18	1.0059
Upstream Basin (ln of km2)	1.21	1.072
Percent Upstream (%)	41.84	4.85
Dry (yes/no)	1.06	1.48
Drought (yes/no in past 5 years)	0.68	0.73

* Based on the parameter estimates reported in Table 1
** As reported by Gleditsch et al. (2006, 370)

In terms of the differences between using logistic regression and the log-logistic model a quick glance at Table 4-1 shows that all the variables, except *Dry*, are in the same direction. Although the results for this variable are not statistically significant when using either methodology, it is important to point out that when using logistic regression, the occurrence of drought increases the odds of conflict. However, when using the log-logistic model, the occurrence of drought actually increases the survival time of a spell of peace, therefore decreasing the likelihood that a spell of peace will end with a conflict.

When considering the hypotheses to be tested, the results, both in logistic regression and log-logistic form are in the expected direction except for the two drought variables, which are not statistically significant. Surprisingly, the *Water institution* variable is also in the unexpected direction since it actually decreases the survival time of a spell of peace.

In terms of the impact of time, one of the key variables in the model, the results of table 4-1 provides initial insight into the relationship between time and the occurrence of conflict. The results of gamma[17] in table 4-1, for all independent variables, indicates that the duration dependence is statistically significant and that the hazard first rises rapidly and then drops over time. This implies that a dyad is more likely to experience conflict soon after it has entered a spell of peace. However as the duration of that spell of peace increases, the hazard that a spell of peace ends in conflict actually diminishes. This process makes intuitive sense as a dyad that has just experienced conflict may relapse into conflict in the first few years since that conflict ended as tensions could potentially still be high, issues unresolved or memories still vivid. However, as time progresses, tensions may abate, issues may get resolved, and a culture of peace may develop within a dyad, therefore decreasing the likelihood of conflict. Moreover, this reflects the results obtained by Gleditsch et al.'s peace history variable (Gleditsch et al. 2006) and is similar to Werner's results (Werner 2000).

Theta is the result that is produced when specifying a frailty model that addresses the issue of repeated events and the possibility that the repeated events are not independent because of unobserved heterogeneity. The fact that *Theta* is greater than 1 for all variables indicates that there is unobserved heterogeneity and that there is therefore high dependence between repeated events within a dyad.

4.3 Multivariate Analysis of Conflict and Control Variables

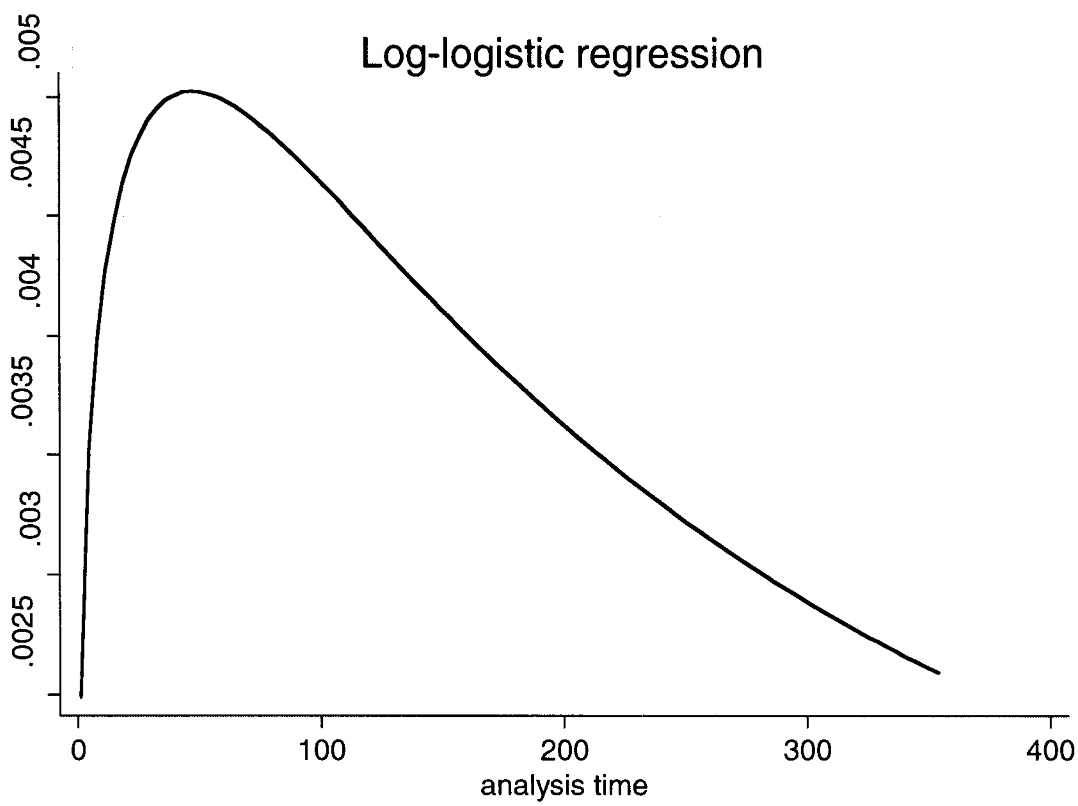
Tables 4-3 and 4-4 represent a multivariate analysis of conflict and the control variables in logistic and log-logistic form respectively. Not surprisingly,

[17] Gamma is reported as 1/p.

and as reported by Gleditsch et al., the greatest predictor of conflict in the logistic model is *Peace history*, therefore re-enforcing the argument that the risk of conflict decreases with the length of time a dyad spends in peace. It also points to the importance of clearly understanding duration dependence in the context of interstate conflict. This finding is further strengthened by the results of the log-logistic model, where Gamma is statistically significant and has a value of 0.808[18]. Similar to the results of the bivariate analyses in Table 4-1, and as illustrated graphically in Figure 4-1, Gamma points to a hazard rate that first dramatically increases the likelihood of a spell of peace ending in conflict, but then as time lengthens, the likelihood of a dyad experiencing conflict slowly decreases.

[18] All results reported are based on the control models of Tables 4-3 and 4-4.

Figure 4-1: Hazard Rate based on Table 4-1



Previous research has shown that the political makeup of dyads has an impact on the occurrence of conflict (Russett and O'Neal 2001). Democratic Peace theorists argue in particular that interstate dyads that consist of two democracies are less likely to go to war with one another than dyads made up of states with a different political makeup (Raknerud and Hegre 1997; Gleditsch and Hegre 1997) and that in fact dyads that are politically mixed are the most dangerous (i.e. most likely to experience conflict) (Gleditsch and Hegre 1997; Mansfield and Snyder 2002). In this study, the variables relating to the political makeup of the dyad as referenced to a dyad of two democracies are statistically significant in both the logistic and log-logistic models and all contribute to increasing the risk of conflict. In both the logistic and log-logistic models, dyads made up of inconsistent regimes[19] are most likely to experience conflict. In the logistic model, dyads made of up a single democracy are the second most dangerous type of dyad, and those made up of two autocracies are the third most dangerous. In the log-logistic model, the coefficients for dyads with a single democracy and dyads made up of two autocracies are almost identical, meaning that both variables have very similar impacts on the survival time of dyads and are more likely to experience conflict than dyads that consist of two democracies. Since the results in both the logistic and log-logistic indicate that dyads that are not made up of two democracies (regardless of whether they consist of no democracies, or only one democracy) are more likely to experience conflict then the reference dyads, the findings fall in line, and correspond to the hypotheses of the democratic peace theory.

[19] Gleditsch defines an inconsistent regimes as "a case in which both states have a combined score that is either missing or in the inconsistent range (falls between -5 and +5), or the combination of an autocracy (with a score of -6 or less) and a state with either a missing or inconsistent coding". (Gleditsch et al. 2006, 371)

Table 4-3: Multivariate analysis of conflict and control variables, all dyads, 1880-2001 – Logistic Model

	Full Model (A)*			Control Model (B)*		
Variable	Parameter Estimate	Standard Error	p	Parameter Estimate	Standard Error	p
Peace history	-2.076	0.082	0.000	-2.075	0.076	0.000
Inconsistent regimes (yes/no)	1.525	0.244	0.000	1.508	0.230	0.000
Single democracy (yes/no)	1.454	0.218	0.000	1.427	0.222	0.000
Two autocracies (yes/no)	1.275	0.272	0.000	1.229	0.259	0.000
Development (ln energy per cap)	0.009	0.026	**0.721**	---	---	---
Dyad size (ln population)	0.339	0.048	0.000	0.331	0.051	0.000
Major power (yes/no)	0.533	0.136	0.000	0.548	0.136	0.000
Alliance (yes/no)	0.064	0.123	**0.602**	---	---	---
Distance (ln km)	-0.694	0.103	0.000	-0.683	0.096	0.000
Contiguity	-1.409	0.789	**0.073**	---	---	---
Boundary length (ln km)	0.241	0.096	0.012	0.154	0.061	0.012
Post-cold war (yes/no)	0.390	0.100	0.000	0.313	0.096	0.001
System Size	0.371	0.119	0.002	0.128	0.121	**0.291**
Constant	-4.124	0.778	0.000	-4.896	0.665	0.000
Pseudo-R^2	0.2492	---	---	0.2465	---	---

* Logistic results reported are calculated using the same methodology as Gleditsch et al. (2006).

The level of development in a dyad does not have a substantial impact on the occurrence of conflict in the logistic or the log-logistic models. Development is therefore not included in the control models that will be used in subsequent analysis. The size of the dyad is positively correlated to conflict and is highly significant in both the logistic and log-logistic models. In the log-logistic model, an increase in *Dyad Size* decreases the survival time of a dyad, that is to say the time to the occurrence of conflict, by 30%. These results also do not differ from those reported by Gleditsch et al. (2006, 372). Moreover, they are in line with the research of Hegre (2005) and Boulding (1962) who argue that large countries are not only more likely to go to war because their large populations lead to larger markets and can therefore afford to do so (Hegre, 2005), but because large countries also have a greater opportunity to fight each other since distance between themselves and an opponent is less of an obstacle than it is to smaller states (Boulding, 1962). Indeed, it is much easier for the United States of America today, or the USSR in the middle of the 20th century to project their power around the globe than their smaller satellite states. The presence of one or two major powers in a dyad is also positively related to conflict and is significant in both models. The direction of the relationship is the same as reported by Gleditsch; however, Gleditsch reports *Major Power* as not being statistically significant in the model (Gleditsch et al. 2006, 372). In the log-logistic model, the presence of a major power in a dyad decreases the survival time by 54%.

Like *Dyad Size*, the impact of major powers on conflict can be interpreted in very similar ways since it is major powers that have the greatest ability and capability to engage in conflict. Moreover, major powers often have more international interests, therefore are more likely to engage in conflict and war to pursue and defend their interests. Great powers may also be more conflict prone, since declining powers often revert to violent behaviour to maintain their great power status (Gilpin 1981).

Table 4-4: Multivariate analysis of conflict and control variables, all dyads, 1880-2001 – Log-Logistic

	Full Model (A)**			Control Model (B)**		
Variable	Parameter Estimate	Standard Error	p	Parameter Estimate	Standard Error	p
Peace History	---	---	---	---	---	---
Inconsistent regimes (yes/no)	-1.521	0.174	0.000	-1.471	0.169	0.000
Single democracy (yes/no)	-1.261	0.168	0.000	-1.254	0.166	0.000
Two autocracies (yes/no)	-1.281	0.186	0.000	-1.232	0.185	0.000
Development (ln energy per cap)	-0.018	0.023	**0.421**	---	---	---
Dyad size (ln population)	-0.383	0.044	0.000	-0.365	0.042	0.000
Major power (yes/no)	-0.732	0.132	0.000	-0.784	0.131	0.000
Alliance (yes/no)	0.088	0.105	**0.403**	---	---	---
Distance (ln km)	1.028	0.066	0.000	1.030	0.064	0.000
Contiguity	2.785	0.654	0.000	2.568	0.637	0.000
Boundary length (ln km)	-0.331	0.078	0.000	-0.309	0.077	0.000
Post-cold war (yes/no)	-0.469	0.101	0.000	-0.425	0.098	0.000
System Size	-0.542	0.127	0.000	-0.521	0.122	0.000
Constant	-0.224	0.666	0.088	1.023	0.626	0.102
Gamma	0.798	0.021	---	0.808	0.021	---
Theta	1.202	0.076	---	1.176	0.171	---

**Log-Logistic results reported in accelerated failure-time form

The results for the *Alliance* variable differ, depending on the methodology used. When using logistic regression, the presence of an alliance increases the risk of conflict; however it is not statistically significant[20]. When using the log-logistic model, the result is not statistically significant and the sign changes direction. That is, the existence of an alliance within a dyad increases the survival time of a dyad, although very slightly, only 9%. This is particularly interesting, since Werner (2000, 359), who used a weibull model to explore the hazard of conflict obtained the opposite result. This discrepancy may be

[20] It should be noted that Gleditsch reported the *Alliance* variable as also not being statistically significant, but of having a negative impact on the occurrence of conflict. (Gleditsch, 2006, 372)

accounted for by the different independent variables used, and the different time frame of each study. Because *Alliance* is not statistically significant in both the logistic and log-logistic models, it is not included in the control models.

Not surprisingly, the greater the distance between two dyads, the less likely the hazard of conflict. This conclusion is supported by both the results of the log-logistic, logistic models, and previous research (i.e. Buhaug and Gleditsch 2006; Gleditsch et al. 2006; Vasquez 1995; Gleditsch 1995; Boulding, 1962) since it is understandably more difficult for dyads that are separated by a great distance to wage war on one another. In the log-logistic model, a one-unit increase in distance between countries in a dyad increases the survival time of a dyad by 180%.

The effect of the *Contiguity* variable on the hazard of conflict is not as predicted, given previous research (Vasquez, 1995) as well as the results of the *Distance* variable discussed above. While contiguity has been a robust predictor of conflict (see Gleditsch et al. 2006, 372; Vasquez 1995) the *Contiguity* variable in the instance of the log-logistic model and logistic model has a strong negative impact on the occurrence of conflict. Although it is not statistically significant in the logistic model, the results of the log-logistic model indicate that the likelihood that a spell of peace will end in conflict decreases significantly if the countries in a dyad are contiguous. Indeed, in the log-logistic model, contiguous dyads have survival times that are 13.03 times the survival times of non-contiguous dyads. This discrepancy, however, seems to have more to do with the nature of the dataset being used to conduct the analysis. It is very possible that this result was obtained because the dataset only considers same continent dyads, and not all dyads in the world therefore having a large number of contiguous states and very few non-contiguous states. Indeed when including all dyads in the analysis, contiguous dyads are much more likely to experience conflict than non-contiguous dyads. This result is further strengthened when the *Boundary* and *Distance* variables are removed from the equation. It makes intuitive sense to do so, as Gleditsch argues that since "distance always is low for contiguous countries, and boundary length is zero for non-contiguous countries, there is not much additional information in the contiguity variable" (Gleditsch et al. 2006, 372).

As expected, and reported by Furlong (2006) boundary length does increase the hazard that a spell of peace will end in conflict. This result is consistent in both the log-logistic and logistic models, and is also statistically significant in both. Moreover, it is in line with Hegre (2005) and Boulding's (1962) argument that states with long borders are more likely to fight since they will have more conflicting interests. In the log-logistic model, a one-unit increase in the length of a boundary decreases the survival time of a dyad by 26%.

The *Post-cold war* and *System size* variables both have a positive impact on the risk that conflict will occur in a dyad and are statistically significant in both the logistic and log-logistic models, unlike the results reported by Gleditsch et al. (2006, 372). It should be noted that Gleditsch attributes the lack of statistical significance of the system size variable to the fact that a "higher fraction of same-continent dyads are neighbours, and the statistical problems resulting from an increase in the size of the international system are less serious" (Gleditsch et al., 2006, 373). This analysis may not be entirely accurate given that the results reported above used the same dataset, but as previously mentioned used a different dependent variable. The fact that the *System size* was not statistically significant in Gleditsch's analysis may have less to do with a restriction of the analysis to same continent dyads, but to the use of a more restricted dependent variable.

In order to conduct the multivariate analysis including the variables related to shared freshwater resources and replicate Gleditsch's study as closely as possible, control models were created. Like Gleditsch, the control model consists of all variables except for those that where not significant in Tables 4-3 and 4-4. Because not all the variables where found to be significant in the log-logistic model, the 'control' model for the log-logistic analysis includes all variables except for the *Development* and *Alliance* variables (See Table 4-4, model B). For the logistic model, the *Development*, *Alliance*, and *Contiguity* variables where dropped (See Table 4-3, model B). Without these variables, *System size* becomes no longer statistically significant, but the impact of the estimates for all other variables does not change by much.

4.4 The Impact of a New Methodology

To explore the impacts of a new methodology, Tables 4-5 through 4-10 show the results of the logistic and log-logistic models that explore hypotheses 1 through 7. Each table reports the results of the water specific variable but not the control variables as the results for these variables are similar throughout. The results of the logistic model will be based on the control model reported in table 4-3, while the results of the log-logistic model will be based on the control model reported in table 4-4. Whenever significant differences arise between the results of the control variables in the control models and the results of the control variables in tables 4-5 through 4-10, they will be reported.

4.4.1 Conflict over Basins or Borders

Table 4-5 explores the relationship between conflicts and shared freshwater resources. As expected, both the logistic and log-logistic models support the hypothesis that dyads that share a basin are more likely to experience conflict. The risk of a conflict in a dyad is significantly increased when said dyad shares a freshwater basin. In the logistic model, the estimated probability for a typical dyad[21] to experience conflict without a shared basin is 0.54% while the presence of shared basin increases this probability to 1.33%[22], more than double the risk. In the log-logistic model, the parameter estimate indicates that the presence of a shared basin decreases the survival time of a dyad, therefore implying that a dyad sharing a basin of freshwater will more likely experience conflict than a dyad that does not share a freshwater basin. More specifically, the survival time of dyads that share a freshwater basin is 0.34 times the survival time of dyads that do not share freshwater basins. When comparing the results of the other covariates in both models, and the impact that these have on the occurrence of conflict, it becomes apparent that the selection of a different

[21] In the case of the logistic models, the typical dyad was defined as a dyad with one democracy, no unconsolidated regimes, no major powers and the mean value for the remaining variables.

[22] The estimated probabilities reported for the logistic models were obtained using the statistical program Clarify (King, Tomz, and Wittenberg 2000).

model (logistic vs. log-logistic) is not that critical. Indeed the impact of the shared basin variable in comparison to the other covariates is similar in both models. In both models, the shared basin variable has a greater impact on the occurrence of conflict (either positive or negative) than the size of the dyad, the presence of a major power, the distance between dyads, the length of the boundary, and the post-cold war variable.

Table 4-5: Shared Basins – all dyads, 1880-2001

	Model – Logistic*			Model – Log-Logistic**		
Variables	Parameter Estimate	Standard Error	p	Parameter Estimate	Standard Error	p
Shared Basin	0.864	0.176	0.000	-1.075	0.128	0.000
Peace History	-2.048	0.078	0.000	---	---	---
Pseudo – R^2	0.2526	---	---	---	---	---
Gamma	---	---	---	0.782	0.021	---
Theta	---	---	---	1.15	0.166	---

* Logistic results reported are calculated using the same methodology as Gleditsch et al. (2006).
**Log-logistic results reported in accelerated-time form

Tables 4-6 and 4-7 test Gleditsch's (2006, 373) fuzzy boundary scenario to see if the risk of conflict over shared basins is due to resource scarcity, or the fact that dyads with shared basins also share river crossings and potentially fuzzy river boundaries. It does so by testing the length of the river boundary and the number of river crossings in a dyad. In the case of the length of the river boundary, this variable is significant and increases the risk of conflict in both the logistic and log-logistic models. However, the impact of the length of the river boundary is less than the impact of the overall length of the boundary in the logistic model but is slightly more in the log-logistic model[23]. The results in this case differ significantly from the results reported by Gleditsch et al. (2006, 374), since they found the length of the river boundary to not be statistically significant, leading them to believe that it was not the existence of shared river boundaries that led to conflict in dyads that shared freshwater basins.

Table 4-6: Log River Boundary Length - all dyads, 1880-2001

	Model – Logistic*			Model – Log-Logistic**		
Variables	Parameter Estimate	Standard Error	p	Parameter Estimate	Standard Error	p
River boundary (ln of km)	0.113	0.028	0.000	-0.152	0.024	0.000
Peace History	-2.078	0.077	0.000	---	---	---
Pseudo – R^2	0.2508	---	---	---	---	---
Gamma	---	---	---	0.793	0.021	---
Theta	---	---	---	1.165	0.167	---

* Logistic results reported are calculated using the same methodology as Gleditsch et al. (2006).
**Log-logistic results reported in accelerated-time form

This discrepancy is most likely due to the use of a different conflict variable, and the analysis of the time period between 1880 and 2001. It should be noted however, that these results do not necessarily completely contradict Gleditsch et al.'s findings. The results reported above do not point clearly to the conclusion that it is the existence of shared river boundaries that lead to conflict in dyads that share freshwater resources. The results of the log-logistic model do point in that direction, but the difference is so minute that it is almost negligible.

[23] In the Log-Logistic model a one unit increase the length of the river boundary decreases the survival time of a dyad by 14%, while a one unit increase in the length of the boundary between two countries in a dyad decreases the survival time of a dyad by 15%, an extremely minute difference.

The number of river crossings, as reported in table 4-7 also has a minute positive impact on conflict in both models. Indeed when comparing the river crossing variable to the other covariates in the model, its impact is the least important. Moreover the impact of the variable is not statistically significant. This finding leads one to conclude that dyads that share river basins are conflict prone for reasons other than contentious river crossings.

Table 4-7: River Crossings – all dyads, 1880-2001

	Model – Logistic*			Model – Log-Logistic**		
Variables	Parameter Estimate	Standard Error	p	Parameter Estimate	Standard Error	p
River crossing	0.004	0.003	0.223	-0.030	0.016	0.065
Peace History	-2.072	0.077	0.000	---	---	---
Pseudo – R^2	0.2468	---	---	---	---	---
Gamma	---	---	---	0.802	0.021	---
Theta	---	---	---	1.199	0.172	---

* Logistic results reported are calculated using the same methodology as Gleditsch et al. (2006).
**Log-logistic results reported in accelerated-time form

The results of hypothesis 4 and 5 are found in tables 4-8 to 4-10. These tables examine the resource conflict scenario by analyzing the impact that the size of the basin and the distribution of freshwater resources in a basin have on the occurrence of conflict. As reported in table 4-8, the size of the basin does have a significant impact on the occurrence of conflict in a dyad. In the logistic model, when the size of the basin increases by one unit, the odds that a dyad will experience a conflict increased by a factor of 1.06. In the log-logistic model, a one-unit increase in the size of a shared freshwater basin decreases the survival time of a dyad by 7.5%. It is important to note however, that although this variable is significant in both models it has the least impact on the occurrence of conflict in both models.

Table 4-8: Basin Size- all dyads, 1880-2001

	Model – Logistic*			Model – Log-Logistic**		
Variables	Parameter Estimate	Standard Error	p	Parameter Estimate	Standard Error	p
Basin Size (ln km^2)	0.061	0.012	0.000	-0.079	0.009	0.000
Peace History	-2.054	0.078	0.000	---	---	---
Pseudo – R^2	0.2523	---	---	---	---	---
Gamma	---	---	---	0.784	0.021	---
Theta	---	---	---	0.167	0.167	---

* Logistic results reported are calculated using the same methodology as Gleditsch et al. (2006).
**Log-logistic results reported in accelerated-time form

Although the size of the basin has an impact on the occurrence of conflict, it is interesting to determine if the distribution of resources within a dyad also impacts the occurrence of conflict. Tables 4-9 explores this possibility by examining the total size of the basin found in the upstream state, while table 4-10 explores this possibility by examining the percentage of the basin found in the upstream state. As table 4-9 illustrates, the absolute size of the basin located in the upstream state of the dyad has an impact on the occurrence of conflict. In the logistic model a one unit increase in the size of the basin that is located in the upstream state increases the odds that conflict will occur by a factor of 1.07. In the log-logistic model, the size of the basin found in the upstream state also increases the hazard that a spell of peace will end in conflict. In this model the survival time of a dyad is decreased by 8.14%, a slightly greater impact than the variable indicating the overall size of the basin. These results indicate that the distribution of freshwater resources within a dyad have an impact, although a minute one, on the occurrence of conflict.

Table 4-9: Upstream Basin - all dyads, 1880-2001

	Model – Logistic*			Model – Log-Logistic**		
Variables	Parameter Estimate	Standard Error	p	Parameter Estimate	Standard Error	p
Upstream Basin (ln km^2)	0.065	0.014	0.000	-0.085	0.010	0.000
Peace History	-2.050	0.079	0.000	---	---	---
Pseudo – R^2	0.2520	---	---	---	---	---
Gamma	---	---	---	0.785	0.027	---
Theta	---	---	---	0.158	0.168	---

* Logistic results reported are calculated using the same methodology as Gleditsch et al. (2006).
**Log-logistic results reported in accelerated-time form

This finding is further strengthened by the results in table 4-10. In the logistic model, a comparison of the size of the parameter estimates shows that the impact of the *Percent Upstream* variable is approximately 15 times more than the *Upstream Basin* and *Basin Size* variables. In the log-logistic model, a comparison of the size of the parameter estimates shows that the impact of the *Percent Upstream* is significantly greater than the impact of the *Upstream Basin* and *Basin Size* variables. Indeed, in the log-logistic model, a one percent increase in the percent of a freshwater basin located in the upstream state will decrease the survival of a dyad by 79%. These results point to the conclusion that what matters is the distribution of resources within a dyad, and not the absolute size of the shared resource itself when analyzing the relationship between shared freshwater resources and conflict.

Table 4-10: Percent Upstream - all dyads, 1880-2001

	Model – Logistic*			Model – Log-Logistic**		
Variables	Parameter Estimate	Standard Error	p	Parameter Estimate	Standard Error	p
% Upstream	0.936	0.279	0.001	-1.575	0.345	0.000
Peace History	-2.067	0.078	0.000	---	---	---
Pseudo – R^2	0.2490	---	---	---	---	---
Gamma	---	---	---	0.796	0.027	---
Theta	---	---	---	1.194	0.173	---

* Logistic results reported are calculated using the same methodology as Gleditsch et al. (2006).
**Log-logistic results reported in accelerated-time form

Before moving on to other results in the study, one caveat that must be addressed is the possibility of a spurious relationship between shared freshwater resources and the occurrence of conflict. As previously mentioned, researchers such as Vasquez (1995), have found that countries in close proximity to one another are more likely to engage in violent conflict with one another. Therefore it is possible that what is being observed is not the propensity of dyads to go to war with one another because of shared freshwater resources but because they are in close proximity to one another since dyads that share freshwater basins are by definition close to one another. The possibility of such a spurious relationship was partially controlled by the use of a *Contiguity* and *Distance* variables that are both measure of geographic proximity. The results indicate that even when controlling for contiguity and distance between dyads, dyads that shared freshwater resources are more likely to experience conflict.

4.4.2 Water Scarcity and Conflict

Hypotheses 6 and 7 seek to explore the relationship between water scarcity and the occurrence of conflict for dyads that also share a freshwater basin. Tables 4-11 and 4-12 report the results of these hypotheses. When measuring water scarcity in a dyad in terms of the average amount of rainfall, drier dyads are more likely to experience conflict in both the logistic and log-logistic models. The results are extremely similar in terms of the magnitude of the impact of the independent variables and their statistical significance in both models. In the log-logistic model, a one-unit increase in the average rainfall of a dyad increases the survival time of a dyad by 0.03%.

Table 4-11: Average Rainfall – all dyads, 1880-2001

	Model – Logistic*			Model – Log-Logistic**		
Variables	Parameter Estimate	Standard Error	p	Parameter Estimate	Standard Error	p
Shared Basin	1.008	0.188	0.000	-1.292	0.132	0.000
Average Rainfall	-0.0001	0.0001	0.190	0.0003	0.00008	0.000
Peace History	-3.141	0.086	0.000	---	---	---
Pseudo – R^2	0.3637	---	---	---	---	---
Gamma	---	---	---	0.768	0.028	---
Theta	---	---	---	1.124	0.165	---

* Logistic results reported are calculated using the same methodology as Gleditsch et al. (2006).
**Log-logistic results reported in accelerated-time form

The impact of drought also has similar results in both models. In the logistic model, the occurrence of drought in the past five years decreases the likelihood of conflict, but is not statistically significant. In the log-logistic the occurrence of drought increases the survival time, however, the result is not statistically significant.

Table 4-12: Drought – all dyads, 1880-2001

	Model – Logistic*			Model – Log-Logistic**		
Variables	Parameter Estimate	Standard Error	p	Parameter Estimate	Standard Error	p
Shared Basin	1.159	0.223	0.000	-1.293	0.175	0.000
Drought	-0.175	0.143	0.222	0.136	0.119	0.253
Peace History	-3.369	0.140	0.000	---	---	---
Pseudo – R^2		---	---	---	---	---
Gamma	---	---	---	0.744	0.037	---
Theta	---	---	---	2.245	0.460	---

* Logistic results reported are calculated using the same methodology as Gleditsch et al. (2006).
**Log-logistic results reported in accelerated-time form

The different models developed to test the impact of water scarcity on the occurrence of conflict have provided differing and contradictory results when implementing the log-logistic model. On the one hand, an increase in rainfall in a dyad increases the survival time of that dyad. However, when using the drought variable, a different way of measuring scarcity, the result is in the opposing direction. That is, the occurrence of drought actually increases the survival time of a dyad. The fact that the impact of the average rainfall variable is minuscule and that the drought variable is not statistically significant does mitigate this seeming discrepancy. Although beyond the scope of this research, it would be beneficial to explore the impact of water scarcity on the occurrence of conflict in further detail.

4.5 Shared Basins, International Institutions, and Conflict

Having discussed the impact of a new methodology by comparing the results of the logistic and log-logistic models in the replicated hypotheses, this study now turns to explore the results of another focus of this study, the relationship between conflict and the presence international institutions. Tables

4-13 and 4-14 report the results of hypotheses 8 and 9 using the log-logistic model. Because both hypotheses are concerned with the impact of international institutions in mitigating conflict where dyads share freshwater resources, the results reported in both tables are restricted to those dyads that share freshwater basins. As expected, the presence of a general international institution increases the survival time of a dyad. When restricting the analysis to include only those dyads that share freshwater basins, the presence of a general institution is statistically significant, and increases the survival time of a dyad by 53.4%. Of note, when including all same continent[24] dyads in the analysis, the survival time of a dyad is increased to 70%. This difference in the strength of the parameter estimates indicates that although general institutions do play a positive role in decreasing the occurrence of conflict, they appear to be less effective in mitigating conflicts between countries that share freshwater resources. Because the available data is not limited to water specific conflict, it is likely that what is being observed is the ability of international institutions to mitigate conflict between dyads that share freshwater resources. Whether this conflict is over shared freshwater resources cannot be determined from the data currently available. It will be the task of future research to explore this relationship in further detail.

[24] Instead of only including dyads who share freshwater basins in the analysis.

Table 4-13: General Institutions – Dyads sharing freshwater resources – 1880-2001

	Model – Log-Logistic**		
Variables	Parameter Estimate	Standard Error	p
General Institution	0.428	0.106	0.000
Gamma	0.680	0.026	---
Theta	0.590	0.133	---
**Log-Logistic results are reported in accelerated failure-time form			

The impact that water specific institutions have on the occurrence of conflict is less clear-cut. As reported in table 4-14, when limiting the analysis to dyads that share freshwater resources, the presence of a water specific institution increases the survival time of a dyad by 14.22%. However, this result is not statistically significant. It is also the independent variable in the model with the smallest coefficient, and the least impact, either positively or negatively on the survival time of a dyad. Based on the current data available, it is therefore difficult to draw strong conclusions on the impact of water specific institutions.

Table 4-14: Water Specific Institutions – Dyads sharing freshwater resources – 1880-2001

	Model – Log-Logistic**		
Variables	Parameter Estimate	Standard Error	p
Water Specific Institution	0.133	0.110	0.225
Gamma	0.691	0.039	---
Theta	0.605	0.136	---
**Log-Logistic results are reported in accelerated failure-time form			

The results presented in tables 4-13 and 4-14 are further reinforced when both the *General Institution* and *Water Specific Institution* variables are included in the same model. As illustrated in table 15, when both variables are included in a log-logistic model which restricts the analysis to only those dyads that share freshwater resources, the *General Institution* variable is statistically significant, and increases the survival time of a dyad by 49%. The *Water Specific Institution* variable also increases the survival time of a dyad, but only by 7%, moreover it is not statistically significant.

Table 4-15: General and Water Specific Institutions – Dyads sharing freshwater resources – 1880-2001

	Model – Log-Logistic**		
Variables	Parameter Estimate	Standard Error	p
General Institution	0.403	0.108	0.000
Water Specific Institution	0.073	0.108	0.498
Gamma	0.680	0.026	---
Theta	0.582	0.131	---

**Log-Logistic results are reported in accelerated failure-time form

4.6 Shared Freshwater Resources and Conflict: A General Model

Table 4-16 reports the results of a comparison of the logistic and log-logistic model that incorporates all the water specific independent variables; thus presenting a general model of freshwater resources and conflict. The results of this analysis are similar to the models that included each independent variable separately and should be interpreted while taking into account the possibility of a spurious relationship as previously mentioned. Except for the *Basin Size* and *Water Institution* variables, the parameter estimates of the water specific independent variables are in the same direction as when they where included in separate models. Of note is the fact that most of the water specific independent variables are not statistically significant. This is likely due to the fact that including all the independent variables into one model dramatically decreased the sample size. In table 4-5, the number of observations is 104,277, while table 4-16 only has 45,102 observations.

In terms of the different hypothesis tested, when including all the variables in a single model, the variables are in the expected direction except for the *Basin Size* variable which relates to hypothesis 4, the *Drought* variable which relates to hypothesis 7, and the *Water Specific Institution* variable, which relates to hypothesis 9. Based on the results of table 4-16, when controlling for the different independent variables, dyads with larger river basins have longer survival times, a result that differs significantly from the results obtained in table 4-8 when the model did not include any other water related variables. This result is somewhat surprising since one would assume that the larger the size of the shared water resources, the more areas there are for potential conflict. However, when coupled with the results of the *Percent Upstream* variable and the *Drought* variable it appears that what matters is not the amount of water shared by a dyad, but rather the overall distribution of the resource. Indeed, the *Drought* variable in table 4-16 is positively signed, and therefore not in line with the expected result according to hypothesis 7. The results of this parameter estimate indicates that dyads that have experienced a drought have longer survival times than those who have not experienced a drought. Finally the results of the *Water Specific Institution* variable in this model do not support hypothesis 9. According to the parameter estimate, when controlling for the different water specific independent variables, the presence of a *Water Specific* institution actually decreases the survival time of a dyad by 22%. This is a surprising result given that the models reported in tables 4-14 and 4-15 were in line with hypothesis 9.

Table 4-16: Multivariate analysis of water specific variables, all dyads, 1880-2001

	Logistic Model*			Log-Logistic Model**		
Variable	Parameter Estimate	Standard Error	p	Parameter Estimate	Standard Error	p
Shared Basin (yes/no)	2.817	1.133	0.013	-1.488	1.010	0.141
River boundary (ln of km)	0.052	0.055	0.343	-0.111	0.043	0.011
River Crossings (number)	-0.004	0.006	0.465	-0.028	0.026	0.280
Basin size (ln of km^2)	-0.117	0.078	0.137	0.064	0.075	0.391
Percent Upstream (%)	0.359	0.612	0.556	-0.469	0.643	0.466
Average Rainfall	-0.0004	0.0002	0.035	0.0005	0.0001	0.000
Drought (yes/no, during past 5 years)	-0.412	0.164	0.012	0.059	0.119	0.618
General Institution (yes/no)	-1.414	0.342	0.000	1.044	0.219	0.000
Water Institution (yes/no)	0.046	0.245	0.851	-0.252	0.199	0.206
Pseudo-R^2	0.2376	---	---	---	---	---
Gamma	---	---	---	0.718	0.035	---
Theta	---	---	---	1.974	0.402	---

* Logistic results reported are calculated using the same methodology as Gleditsch et al. (2006).
**Log-Logistic results reported in accelerated failure-time form

In terms of the differences between the Logistic and Log-Logistic models in table 4-16 it is important to note that each water specific independent variable pointed in the same direction in both models except for the *River Crossings* variable. In the logistic model, an increase in the number of river crossings decreases the likelihood of conflict. The log-logistic model, however, is in line with the proposed hypothesis, since an increase in the number of river crossings has the opposite effect, and decreases the survival time of a dyad, therefore making dyadic conflict more likely.

4.7 Shared Freshwater Resources, Conflict, and Duration Dependence

By moving to a statistical model designed to specifically deal with the challenges and richness of event history data, this research has strengthened the results of previous research by producing similar results with different statistical tools. One of the further benefits of adopting this methodology has been to further explore duration dependence in the different models presented above. This section now turns to the third focus of the study, namely the relationship between time and the occurrence of conflict.

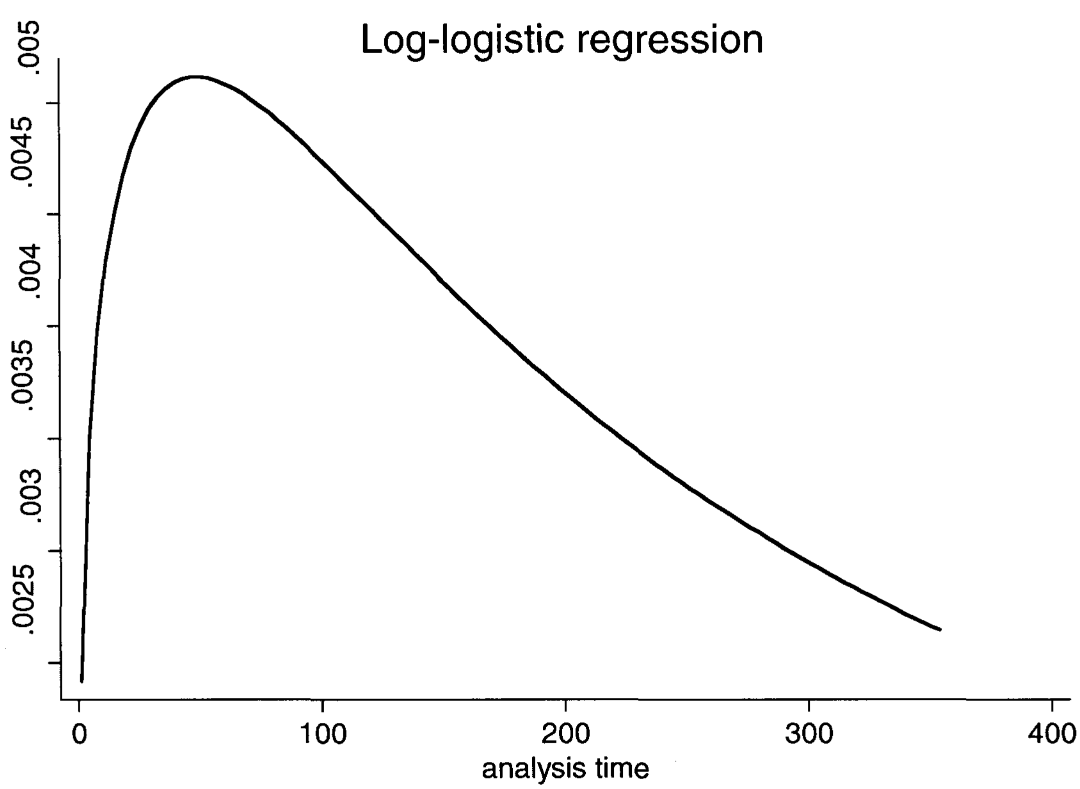
As discussed previously, the methodology adopted by Gleditsch et al. (2006) has numerous problems relating to the effect of time on the occurrence of conflict, primarily that the results are particularly difficult to interpret, and does not give very much detail on the duration dependence being observed. With the *peace-years* variable in the logistic models, the only inference that can be drawn is whether the longer a dyad spends in a state of peace will increase or decrease the likelihood of peace. As was indicated from the results in Table 4-3, the *peace-years* variable indicates that the longer a dyad spends in a state of peace, the less likely it is to experience conflict. However, this is about as far as the analysis can be taken.

The log-logistic model, however, provides greater insight into the nature of this duration dependency. Although the results provided by the *peace-years* variable in the logistic model make theoretical sense, I would argue that the hazard of a dyad engaging in conflict would resemble more closely the results obtained in the log-logistic model. In the logistic model it is logical that the longer a dyad spends in a state of peace, the less likely it is to experience conflict. Indeed, norms and practices develop between countries, and a culture of peace can develop which over time can lead to a decrease in conflict. This conclusion stands true for the log-logistic model as well since the hazard of a dyad lapsing into conflict decreases over time. What the log-logistic model does in this context is bring greater nuance to the duration dependence being observed. When a dyad first enters the dataset, or when a dyad has just experienced a conflict it is much more likely to experience a conflict in the first few years after this event. It is only over time that the hazard of conflict decreases after it has peaked. Indeed, in the years following a conflict between two countries, tensions can still remain high and issues that where not settled on the battlefield or addressed in peace treaties and settlements can flare up and cause a relapse into conflict. Memories of conflict and unsettled scores and issues often last a long time between countries, therefore making a return to conflict more likely. When looking at the graphs in Figures 4-1 and 4-2, it appears as though there is a tipping point (the apex of the curve) for dyads after a certain period of time where they move from a conflict relationship to one where the risk of conflict begins to steadily decline.

This phenomenon can be studied by observing how the value of gamma varies between the different models previously reported. In tables 4-4 through 4-15, the value of gamma, the variable indicating duration dependence is statistically significant in each model, and varies from a value of 0.680 in Tables

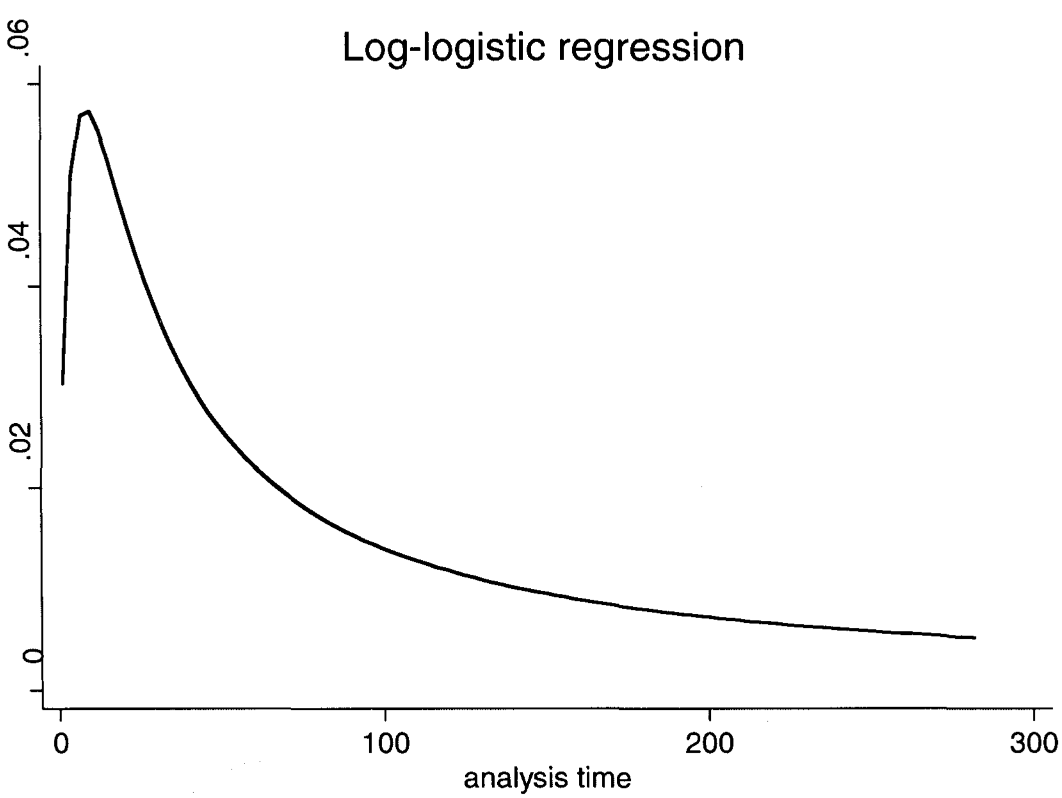
4-13 and 4-15 to a value of 0.802 in Table 4-7 indicating that the hazard of conflict first rises, and then drops over time in each model. Figure 4-2, representing the results of Table 4-7, and Figure 4-3, representing the results of Table 4-15 demonstrate how the hazard of conflict rises at first, but as peace becomes institutionalized within a dyad, the hazard of conflict begins to fall.

Figure 4-2: Hazard Function of Table 4-7



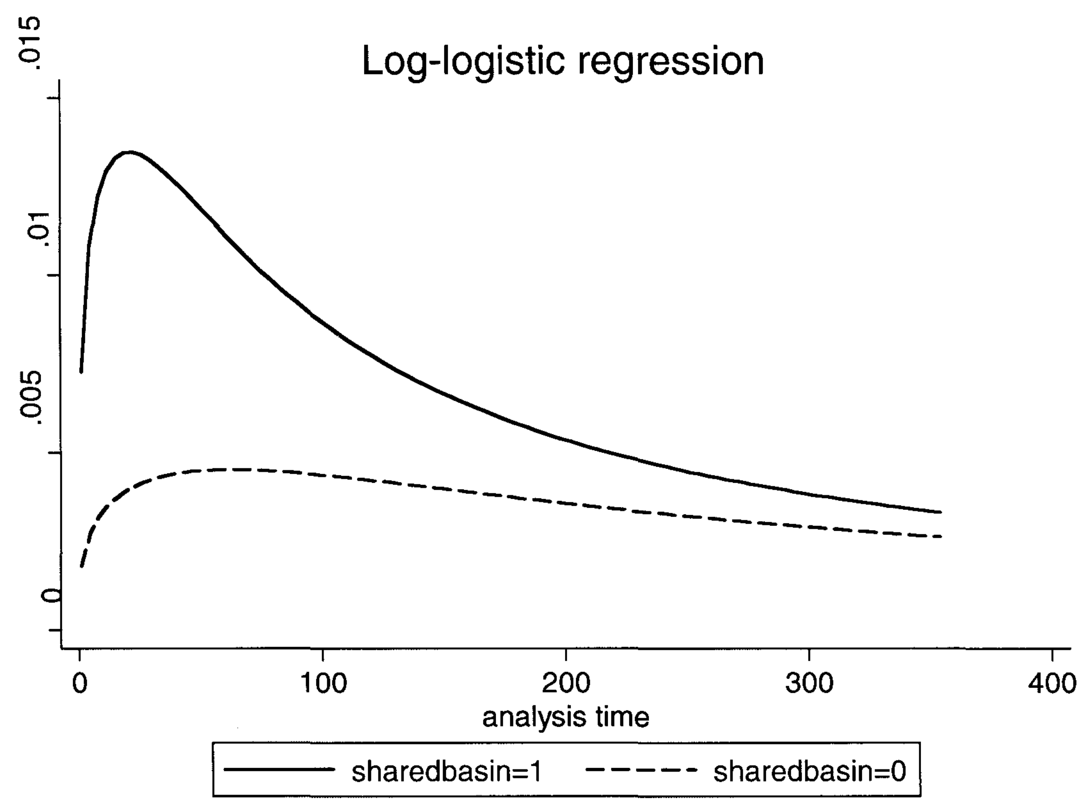
When looking closer at the graphs, one sees that in Figure 4-2 the hazard function begins very close to zero and rises and then falls much more gently than the hazard function in Figure 4-3. In Figure 4-3, the hazard function begins at approximately 0.03 and rises rapidly before beginning to drop rapidly. Also of note is the tipping point in both these scenarios. In both scenarios, the hazard functions begin to decrease before the 100 year mark. However, in Figure 4-3, where the value of gamma is 0.680 the hazard of a dyad experiencing conflict is at its highest at a much earlier point in time, somewhere around the 10-20 year mark. On the other hand, in Figure 4-2, where gamma has a value of 0.802 the hazard of a dyad experiencing conflict is at its highest at approximately the 20-30 year mark.

Figure 4-3: Hazard Function of Table 4-15



The implementation of the log-logistic model also allows the researcher to evaluate in greater detail how a change in a covariate affects the duration dependence being observed. In the case of this research it would be valuable to see how the presence of different water related variables affect duration dependence. For illustration purposes, the effect of the *Shared Basin* and *General Institution* variables will be used. Figure 4-4 illustrates the impact of the presence/absence of a shared basin within a dyad based on the results reported in Table 4-5.

Figure 4-4: Comparison of Hazard Functions of Table 4-5



As expected, Figure 4-4 confirms graphically what has already been reported in Table 4-5, mainly that the presence of a shared freshwater basin will decrease the survival time of a dyad. In this case, the hazard function for a dyad with a shared basin is originally much steeper than a dyad without a shared freshwater basin. Moreover, the hazard function reaches a higher point for dyads with a shared basin, implying that they are more likely to experience conflict.

Figure 4-5: Comparison of Hazard Functions of Table 4-15

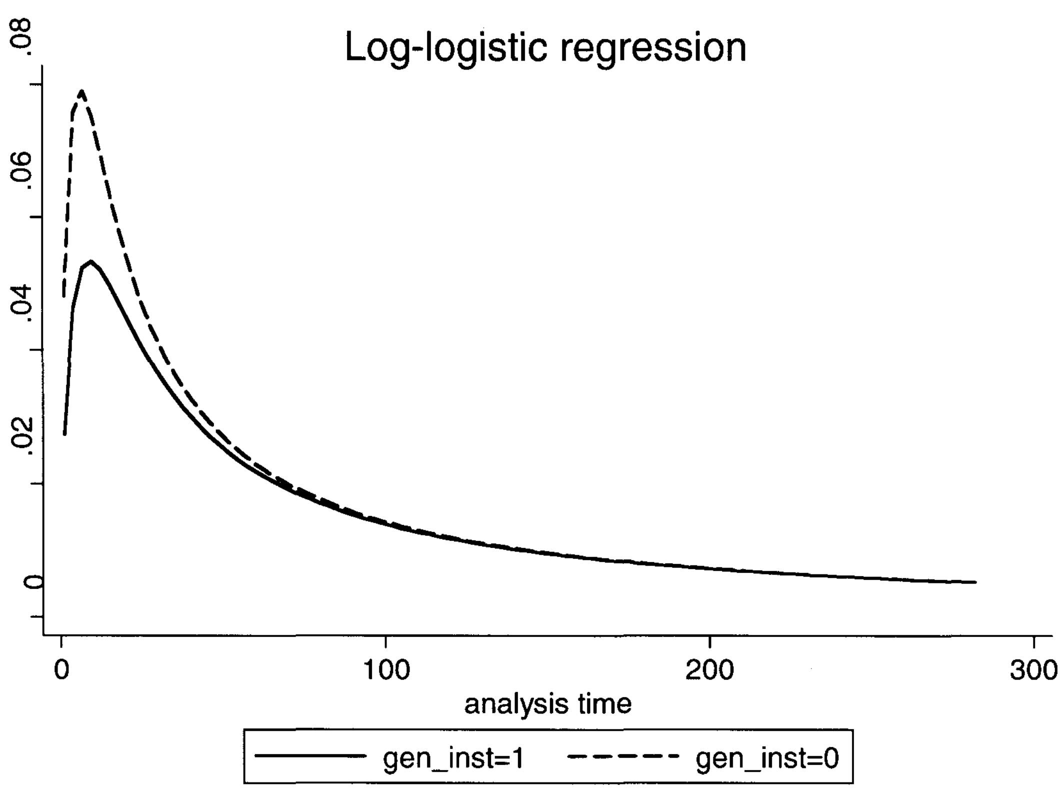


Figure 4-5 also confirms graphically what has been reported in Table 4-15. Again the presence and absence of general international institutions (GII) alter the duration dependence being observed. The presence or absence of a general international institution does not alter the time point when a dyad is most likely to experience conflict. However, as illustrated by the graph, the hazard function for dyads that have GIIs is much lower than that of dyads that do not. This holds true for almost all points in time.

CHAPTER 5: CONCLUSIONS AND FURTHER RESEARCH

With a rise in the political rhetoric over the possibilities of water wars, and the increasing number of examples of conflict and cooperation over shared freshwater resources, the academic study of this phenomenon has grown over the years. One notable area of research has been the study of conflict over shared freshwater resources using large *N* data sets and statistical methods to examine how different aspects of shared freshwater resources affect the occurrence of conflict between two states. This study adopted this general methodology and framework of analysis and built upon it in order to strengthen the understanding of the relationship between shared freshwater resources and conflict.

In order to build on this body of knowledge, this research first identified three principal gaps in the current literature. Having canvassed the literature on the relationship between shared freshwater resources and conflict, this research argued that one of gap was the lack of understanding of the role of institutions. It was argued that anecdotal and case study evidence existed to support the argument that international institutions play an important role in mitigating conflict between countries that share freshwater resources; however, no large *N* statistical studies using the COW dataset had been undertaken to explore this area of research. This research argued that past studies using COW data have focused primarily on geographic/physical factors and their impact on the relationship between shared rivers and conflict. By undertaking an initial exploration of the role of institutions in conflict over shared water resources, this project moved away from the geographic/physical aspect of the relationship of previous research and began to explore the more social aspects, that is, the role of international institutions.

Secondly, this research has argued that given the time-series nature of the data, it was necessary to move away from the use of logistic regression to analyze the relationship between shared freshwater resources and conflict and adopt the statistical tools of event history analysis, in the form of a parametric model with a log-logistic specification. Despite the use of a new methodology, it was not expected that the results would be significantly different than those previously reported because past research had adopted a statistical method to deal with time-series data without adopting event history methodologies. Rather it was argued that this research would strengthen the current body of knowledge by using a more appropriate methodology.

Thirdly, because of the nature of the data there was a possibility to further explore the impact of time on the occurrence of conflict. It was argued that for several reasons time could in fact be an important factor in the occurrence of conflict and that methodologies should be used to explore this relationship further. Although previous studies had modelled time in a rudimentary fashion the use of event history methodologies would allow the researcher to explore the phenomenon in even greater detail. Therefore, adopting a new methodology not only provided methodological refinement as described in chapter 3, but also provide a deeper insight into the role of time in the occurrence of conflict.

Chapter 4 reported the results of the statistical models and generally supported the need to adopt a new methodology. The results also provided initial insight into the role of international institutions in the relationship between conflict and shared freshwater resources, and further insight into the impact of time on the occurrence of conflict. The results were in line with all the hypotheses when the models included only the control variables and the one water specific variable related to shared freshwater resources. When comparing the results of the logistic and log-logistic models the results are comparable amongst all models.

When all the water specific variables were included in a single model as illustrated in table 4-16; the results were slightly different. In this case the results were in line with the listed hypothesis except for hypothesis 4, 7, and 9, where the results were in direct contrast to the proposed hypothesis. In terms of the difference between the logistic and log-logistic models, the results were in the same direction for each water specific variable except the *River Crossings* variable.

The greatest difference between the logistic and log-logistic models, however, was found in the interpretation of the effect of time on the occurrence of conflict. As discussed, the use of a parametric model with a log-logistic specification provided more insight into the nature of duration dependence. The implementation of this model highlighted, like the logistic model that the longer two countries spend in peace, the less likely they are to experience conflict. However the log-logistic model showed that this phenomenon is not strictly linear but fluctuates over time. Rather than the risk of conflict occurring steadily declining, it first rises, and then begins to decline. As previously argued, this interpretation is not only more detailed, but may actually be more intuitive and theoretically sound than the results provided by the logistic model. Moreover, it was shown that the use of a parametric log-logistic model allows the researcher to graphically illustrate how different variables, particularly water specific variables impact the duration dependence being observed.

Having identified three gaps in the literature and addressed them by including variables related to international institutions and moving away from logistic regression to a parametric log-logistic model, further research in this field must still be undertaken to understand the relationship between shared freshwater resources and conflict. As previously discussed, one of the primary problems with this area of research is the lack of understanding of the pacifying effect of institutions on the occurrence of conflict over shared freshwater resources. Having identified numerous researchers who argue that cooperation rather than conflict is likely to occur when two states share freshwater resources, this research attempted to begin exploring this relationship by including variables relating to the existence of general and water specific international institutions and their relationship with the occurrence of conflict.

Further research is necessary to better understand the relationship between shared freshwater resources, conflict and the role of international institutions. The results of this study pointed to the pacifying effects that general international institutions have on dyads that share freshwater resources. However, because the available data is not limited to water specific conflict, it is likely that what is being observed is the ability of international institutions to mitigate conflict between dyads that share freshwater resources, not necessarily that these institutions are mitigating conflict over shared freshwater resources. With a data set that explicitly identifies conflicts over shared freshwater resources, it would be possible to not only more clearly understand the relationship between conflict and shared freshwater resources, but also the role of institutions in mitigating conflict. As previously mentioned, Hensel has begun building the Issue Correlates of War which begins addressing this problem by building a dataset that specifically identifies conflict over shared freshwater resources. It will therefore be the task of future research to explore this relationship in further detail with the help of this new data.

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