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Rebel group interactions in multi-party civil wars

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in

Security Science

by

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Declaration

I, Lucy Burton, confirm that the work presented in this thesis is my own. Where information has been derived from other sources, I confirm that this has been indicated in the thesis.

Signed......................................

Date..

Abstract

Previous studies of civil war have considered how the dynamics of multi-party conflicts differ from those involving a single rebel group. But few studies have examined the interdependent relationships that exist between the rebel groups themselves. Some groups form alliances, while others engage in inter-group conflict. This thesis contributes to the empirical literature on civil conflict by exploring the understudied area of rebel group interactions. Chapter I reviews the literature, highlights the gaps in previous research and outlines the hypotheses to be tested. Chapter II examines the driving forces for rebel group interactions by testing two competing theories using empirical data. Results suggest that power considerations are the primary driving force behind group interactions, but identity considerations are also found to play an important role. Chapter III explores the conditions that facilitate cooperative versus conflictual interactions. A set of theoretical arguments, based on credible commitments, are proposed and these are tested using empirical data. Results suggest that rebels with high levels of alliance credibility are more likely to cooperate with their peers, whereas groups who lack alliance credibility are more likely to engage in inter-rebel violence. Chapter IV examines the effect of interaction strategies on the survival and termination-type of rebel groups. Results of empirical data analysis show that interaction strategies have no effect on group longevity. Groups who engage in inter-rebel violence are more likely to terminate by peace agreement, whereas groups who form alliances are less likely to terminate by peace agreement. Allied groups are also less likely to suffer defeat. Chapter V investigates how computer based simulation techniques may be used to model rebel group interactions. A model of two-sided conflict is developed and extended so that multi-party conflict simulations can be performed. Suggestions regarding the modelling of interaction strategies are proposed and conclusions are drawn, which emphasise the relative advantages of differential equation modelling and agent-based simulation.

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Introduction

Multi-party civil conflicts pose a complex challenge for states. They last longer than two-sided wars and they are less likely to reach a resolution at the negotiating table via peace settlements (Cunningham 2006; Nilsson 2010). This complexity arises, in part, because of the interdependent relationships that exist between the groups involved. Some rebel groups form alliances and join forces in their quest to defeat the state, while other groups engage in inter-rebel violence, choosing instead to engage in armed combat with their peers.

An increasing number of studies have begun to explore how the dynamics of multi-party war differ from two-sided war, but few studies have examined the interdependencies that exist between the rebel groups themselves, even though interactions between non-state actors in multi-party civil wars are common. The dynamics of the Afghan civil war for example, which started over three decades ago and is still active today, has been altered considerably by the interactions that took place between the fourteen rebel groups involved. Some groups operated independently, some formed cooperative alliances, while others engaged in combat with their peers. In this case, fighting occurred between rival groups, such as the *Taliban* and *UIFSA*, but also between groups that had previously been allies, such as *Jamiat i-Islami* and another *Mujahedeen Alliance* member, *Hezb i-Islami*.

What factors determine the interaction decisions made by rebel groups? Why do some rebel groups form cooperative alliances, while others, under apparently similar circumstances, engage in combat with their peers? Do rebel groups who interact improve their chances of survival? Do they have a higher likelihood of achieving a decisive victory? How can the underlying mechanisms of multi-party conflicts be explored? The chapters presented in this thesis contribute to the civil conflict literature by addressing these unanswered questions. Answering these questions is important because they are central to understanding the dynamics of multi-party civil war; an aspect that is crucial, if multi-party conflicts are to be successfully managed at both the national and international levels.

The first part of this thesis (Chapter I) reviews the theoretical and empirical contributions to the literature on rebel group interactions. Since this field of study is relatively new, most of the theories discussed do not directly address interactions between rebel groups in civil war. Instead, they consider interactions that take place between sovereign states or between political parties within a nation state. It is proposed however, that useful analogies can be drawn from these theories if it is assumed that non-state actors in civil wars behave like nation states in the international system. The two dominant theories explored in Chapter I provide competing explanations for the motivations (or driving forces) responsible for rebel group interactions and these are tested empirically in Chapter II. The first theory is based on the notion that *power considerations* are dominant in shaping the interaction decisions made by warring groups. According to this theory, interactions are viewed as being purely tactical and rebel groups are expected to interact in a way that maximises their military capabilities (i.e. size). In contrast, the second theory is based on the notion that *identity considerations*, such as ideology, ethnicity or religion are dominant in shaping the interaction decisions made by rebel groups. According to this theory, rebel groups are expected to interact with others on the basis of their shared identity. The prevailing opinion among civil war scholars is that power considerations are the primary driving force behind interactions. As such, few studies have empirically tested the role of social ties in encouraging rebel group interactions and the role of ideology has been almost entirely overlooked. This aspect is explored in Chapter II.

As mentioned above, few empirical studies have explicitly examined rebel group interactions in multi-party wars. The studies that have examined rebel group interactions, have either considered alliance formation, or inter-rebel violence, but few studies have examined both types of interaction strategy at the same time. Thus, by examining each strategy separately, previous research has overlooked the possibility that the root causes of each outcome might be identical. Indeed, the literature review presented in Chapter I, suggests that there is good theoretical reason to anticipate that shared identity will encourage alliance formation in some cases, whilst facilitating inter-rebel violence in others. The question of why some rebel groups form alliances with their peers, while others, driven by the same identity-based motives, engage in combat with their peers is addressed in Chapter III.

The theoretical explanations for rebel group interactions discussed in Chapters I-III are based on the assumption that groups adopt strategies to maximise their returns, such as bargaining power, chance of victory, survival or profits. But empirical studies in the rebel group dynamics literature have not yet established whether groups who adopt interaction strategies do indeed have improved prospects in civil war, such as an increased chance of survival or an increased chance of attaining a favourable outcome against the state. This aspect is important because from the viewpoint of conflict resolution, gaining knowledge on the determinants of interactions is only of value to policy-makers if it is known how these interactions affect a rebel group's chance of success. If groups who engage in inter-rebel violence get eliminated quickly or achieve less favourable outcomes such as government defeat, policy-makers may be less concerned about the onset of conflict between rebel groups. But, if violence between non-state actors increases the chance of survival for some groups (which have survived at the expense of others), and if this longevity results in favourable outcomes for the surviving group, such as rebel victory, then policy-makers might take the opposite view. These aspects are explored in Chapter IV.

The empirical contributions reviewed in Chapter I, and the analyses presented in Chapters II-IV, use statistical modelling methods to empirically test theories relating to rebel group interactions. The main issue with these approaches is that they do not provide any information regarding the underlying mechanisms of the phenomenon under study. Statistical models allow us to draw conclusions regarding the macro-level effect of rebel group interactions on civil war dynamics, but since they are observational methods, they can only provide indirect information regarding the underlying mechanisms responsible for these effects. The final chapter of this thesis (Chapter V) attempts to overcome this issue by investigating the potential uses of differential equation modelling and agent-based simulation for the modelling of rebel group interactions. These simulations are used to illustrate a variety of hypothetical conflicts and to demonstrate how computer based simulation techniques could be used to test the micro-level mechanisms underpinning rebel group interactions.

The focus of this thesis is rebel group interactions. As such, a great deal of consideration is given to characteristics at the rebel group-level. This aspect is advantageous as it addresses the limitations of previous conflict research, which has tended to focus solely on state attributes. It is important to point out however, that rebel group interactions (and other rebel group dynamics such as splintering and defection) should not be considered as being independent from the state. Indeed, the state is likely to influence the nature of the interactions that take place between rebel groups (an aspect which is considered in Chapters III and V). The state is also likely to influence the number of rebel groups that are willing to participate in conflict in the first place (an aspect that is considered briefly in Chapter II). Other studies have also demonstrated the influence of the state in terms of encouraging rebel defection (Kalyvas 2008). Thus, whilst the primary focus of this thesis is to consider the effect of rebel group-level attributes (such as identity and group size) on group interactions, future research should ensure that both state and rebel group-level attributes are considered.

Chapter I

Context and theory

1.1 Relevant literature

The national-level correlates of civil war are well understood. Civil wars are more likely to occur in countries with poverty and economic instability, in countries with weak institutions, in sparsely populated peripheral regions and in countries with mountainous terrain (Collier and Hoeffler 2000, 2004, 2007; Fearon and Laitin 2003; Hegre and Sambanis 2006). The mechanisms underpinning these relationships however, are not well understood. One reason for this is that traditional studies of civil conflict have tended to focus exclusively on the role of state attributes. While many of these studies have emphasised the importance of rebel group characteristics, most have failed to specify group-level attributes in empirical models.

A number of recent studies have attempted to overcome this issue by focusing on *dyadic interactions*. These are interactions that take place between the state and a rebel group (Cederman, Girardin and Gleditsch 2009; Cunningham, Gleditsch and Salehyan 2009). Dyadic studies represent a positive shift away from the state-centric approaches favoured previously. However, their main shortcoming is that they conceptualise war as a two-party phenomenon between the state and a single rebel group. This approximation is limited since over one-half of all civil conflicts occurring after 1945 involved more than one rebel group (Harbom, Melander and Wallensteen 2008). In response to this empirical observation, an increasing number of studies have started considering how conflict dynamics (namely duration and termination) might be affected by the presence of multiple rebel groups. Research in this field has shown that civil wars involving multiple groups last longer because they are substantially more resistant to resolution (Cunningham 2006) and that the inclusion of all rebel groups in negotiations does not necessarily ensure peace (Nilsson 2008).

Most recently, research on multi-party conflicts has moved beyond the study of conflict dynamics to the study of rebel group dynamics. This relatively new branch of literature has sought to understand the causes and effects of a range of *within-group* and *between-group* behaviours. Studies which have looked at within-group dynamics have considered group fragmentation (or splintering), where a rebel group splits into two separate groups as a result of internal dispute (Cunningham, Bakke and Seymour 2012; Warren and Troy 2014) and group defection, where segments of a rebel group break away to join the state or an opposing rebel group (Kreutz 2012; Staniland 2012). Studies which have looked at between-group dynamics have considered alliance formation, where rebel groups cooperate with each other and join forces against the state (Akcinaroglu 2012) and inter-rebel violence, where rebel groups fight with each other simultaneously to fighting the state (Christia 2008; Lilja and Hultman 2011; Fjelde and Nilsson 2012). The primary focus of this thesis is between-group dynamics. These will be referred to hence forth as rebel group interactions.

Research on rebel group interactions has sought to explain the motives (or driving forces) for cooperation, or fighting, between rebel groups. Some theorists suggest that power-based considerations are the primary driving force behind rebel group interactions, whilst other theorists suggest that identity-based considerations are dominant. Power scholars argue that group interactions are purely tactical and that rebels are motivated solely by a desire to win the war and maximise returns. Identity scholars argue that these rationalist explanations are too simplistic. They argue that identity-based factors (such as shared ideology, ethnicity or religion) are also important in determining the interaction decisions made by rebel groups.

The aim of the first part of this chapter is to review the theoretical and empirical literature relating to rebel group interactions. This review will begin by discussing power-based theories. These theories will be explained and the empirical contributions to the conflict literature will be reviewed. An explanation of identity-based theories will then be provided and the empirical contributions will be reviewed. A discussion of alternative competing theories of rebel group interactions (which consider institutional and geographic factors) will be included. This review will finish by discussing the merits, shortcomings and compatibility of power-based and identity-based theories.

1.1.1 Power-based theories of rebel group interactions

Several prominent theories in the political science literature argue that power considerations are the primary driving force behind group interactions (Waltz 1979; Walt 1987; Schweller 1994). These theories suggest that cooperation between groups, or indeed conflict between groups, arise as a result of tactical decisions motivated purely by a desire for victory or for maximising returns (Collier and Hoeffler 2000; Fearon and Laitin 2003; Christia 2008; Fjelde and Nilsson 2012). As such, power-based theories tend to disregard the notion that identity-based factors, such as ideology or ethnicity, play a role in motivating the behaviour of warring groups. Some theorists have gone as far as to say that identity-based factors are irrelevant, they suggest that identity is used merely to justify tactical decisions made on the basis of power-balancing (Riker 1962; Christia 2012).

Broadly speaking, power-based explanations can be categorised into three main branches of political science and international relations theory. These are; power balancing and bandwagoning theory; economic viability theory and; minimum winning coalition theory. Most of these theories do not directly address interactions between rebel groups in civil war. Instead, they consider interactions that take place between sovereign states or between political parties within a nation state. Useful analogies however can be drawn from these theories if it is assumed that non-state actors in civil wars behave like nation states in the international system (Posen 1993; Fearon 1995, 1998). These theories, their civil conflict analogies and the related empirical research are reviewed below.

Balancing and bandwagoning theories

Balancing theory suggests that international security is achieved only when the military capabilities of nation states are distributed in such a way that no one state is strong enough to dominate all others (Waltz 1979). The theory predicts that if one state gains a disproportionate amount of power, it is likely to attack its weaker neighbours thereby providing an incentive for them to unite in a defensive coalition. As such, balancing theory implies that the driving force behind alliance formation is power-balancing, whereby actors choose to balance against their most powerful rivals.

One criticism of this theory is the assumption that the dominant state would automatically be perceived by the weaker states as posing a threat. Walt (1987) proposes a modification which overcomes this issue, arguing that power-balancing occurs only when the dominant state is perceived as being threatening. Walt (1987) defines *threat* as a function of a nation state’s offensive power, military capabilities, geographic proximity and perceived aggressive intentions. Balancing theory does not account for the possibility that power-balancing may not be the optimum solution for weak states, as highlighted by the empirical reality of bandwagoning, where a weak state aligns with a stronger power at the expense of balancing with its weaker peers. Schweller (1994) argues that bandwagoning may be a preferable alliance strategy if the objective of the weak actor is profit and not security. Walt (1987) argues that bandwagoning is optimal when a state is particularly weak or if it is proximate to a strong power, whilst Mearsheimer (2001) likens bandwagoning to capitulation, suggesting that bandwagoning occurs when a weak state recognises imminent defeat against the stronger power in an on-going war.

One implication of balancing theory in the context of civil war is that rebel groups might align to balance power against a stronger state. Akcinaroglu (2012) argues that alliances might enable rebel groups to increase their military capabilities to a point where the power-balance shifts away from the state. She concludes that this shift in power-balance might explain why some weak groups survive against extremely low odds or why some strong states may be defeated by seemingly less capable enemies.

In her empirical study, Akcinaroglu (2012) analyses Uppsala Conflict Data Program (UCDP) data on civil war outcomes between 1946 and 2008. She tests the effect of alliance formation and cumulative alliance capabilities on war outcomes using competing risks regression. Her results show that rebel groups who form alliances are less likely to suffer defeat, while groups who have access to high levels of alliance capabilities (i.e. groups who form alliances with larger military capabilities) are more likely to be the victors of war. As such, this study provides some evidence that alliances might be motivated by power-based motives. In her discussions, Akcinaroglu (2012) also hints at the suggestion that identity-based factors are unlikely to play a role. Specifically, she points out that alliances are often forged despite differences in ideological and territorial aspirations between groups. But since power-balancing mechanisms are not directly tested (i.e. the effect of relative rebel group size on the likelihood of alliance formation is not tested), the main contribution of Akcinaroglu’s study is that it yields useful insights into the effect of rebel group alliances on civil war outcomes.

If power-based theories of alliance formation are correct, there should be a higher likelihood of cooperation between groups that are small relative to their peers. Smaller groups have high incentives to form alliances because they are more vulnerable to elimination, meaning they will be more willing to share the spoils of war with their alliance partner, compared to larger groups who may be unwilling to share their returns as a result of their high degree of power.

> *Hypothesis: The relative size of a rebel group affects the likelihood that they will cooperate. Groups who are militarily small relative to others will form alliances to balance their power against the state or other rebel groups.*

Another implication of balancing theory in the context of civil war is that strong rebel groups might have an incentive to attack weaker rebel groups, thereby providing an incentive for weaker groups to unite and balance power against them. In their empirical study on inter-rebel violence, Fjelde and Nilsson (2012) find evidence which supports this case. They argue that strong rebels have increased abilities and incentives to eliminate their weaker peers. These increased incentives arise because smaller groups have potential to act as veto-players by blocking settlements (Cunningham 2006) and because small groups often stand to gain a disproportionate share of the spoils of war (Nilsson 2010). The latter occurs because in multi-party conflicts, the state seeks to reduce the number of battles they fight. As such, governments will often offer concessions to small groups as a means of *winning away pieces* (Zartman 1995).

Fjelde and Nilsson (2012) analyse UCDP data on non-state actor conflict using logistic regression models and find that militarily small and militarily large rebel groups are most likely to engage inter-rebel violence. This finding provides some evidence that strong rebel groups may attack their weaker peers, although there is ambiguity regarding this conclusion because the data analysed does not distinguish between the targets and initiators of non-state violence. Another limitation of this study is that it does not consider group alliances or the effect of social ties on inter-rebel violence, however the authors do point out that identity-based factors are likely to play an important role in motivating the interaction behaviour of warring groups. In summary, if power-based theories of inter-rebel violence are correct, we would expect a higher likelihood of fighting for small and large groups. Larger groups have the capacity to engage in inter-rebel violence, whereas smaller groups are obvious targets.

> *Hypothesis: The relative size of a rebel group affects the likelihood that they will engage in inter-rebel violence. Groups who are militarily large relative to others will target groups who are militarily small relative to others.*

Economic viability theories

Economic viability theories are based on the notion that opportunity and economic viability are the dominant explanations for civil war. Theorists in this school of thought argue that the risk of civil conflict is increased when there is an opportunity for rebels to make a financial gain or when there is an opportunity for rebels to generate profits through the control or extortion of natural resources such as drugs, diamonds, timber or oil (Collier and Hoeffler 2000; Fearon and Laitin 2003). In the context of rebel group interactions, economic viability theories are practically in agreement with the international relations theories of power-balancing discussed above. They suggest that rebel groups will interact with each other in a way that maximises profit without regard to identity considerations.

One implication of this is that rebel groups operating in conflict zones with natural resources may seek to form alliances to generate profits. In his empirical study on natural resources, Ross (2004) uses a case-study approach to examine the influence of natural resources on civil war. In this study, seven hypotheses regarding the influence of natural resources on civil war are described and the observable implications of each hypothesis are specified. Ross (2004) then reports which mechanisms are observed in a sample consisting of thirteen cases. Ross (2004) finds that some civil conflicts experience lower casualty rates as a result of cooperation between non-state actors. In eight of the thirteen case-studies considered, Ross (2004) finds that rebel groups laid down their arms to cooperatively exploit the same resources. This occurred in Sierra Leone, where rebels cooperatively extorted diamonds, and in Sudan, where profitable alliances were struck between the groups who guarded the countries oilfields and pipelines that they had opposed.

Conversely, Ross (2004) finds in other cases, that the presence of natural resources increases conflict intensity as a result of conflict between non-state actors. This type of fighting occurred in Peru, where the hard-line Maoist group *Sendero Luminoso* clashed with rival groups over control of the coca trade, and in Myanmar, where rebel groups in the Shan region fought to control the heroin trade. The main strength of Ross's study is that it considers alliance formation and inter-rebel violence simultaneously, unlike the majority of previous research which has considered these two types of interactions separately. The main criticism of this study is that the sample size is small, meaning that the results may not be reflective of civil wars more generally. Another criticism is that Ross (2004) does not address the question of why some groups cooperatively exploit natural resources, whilst other groups engage in conflict over resources. As such, further research is needed to address this aspect.

Another empirical study which finds evidence supporting economic viability arguments is the study by Fjelde and Nilsson (2012) discussed earlier. The results of their logistic regression analyses show that drug cultivation in conflict zones increases the likelihood of inter-rebel violence and that gemstone production decreases the likelihood. With regards to the latter, Fjelde and Nilsson conclude that groups who seek to generate profits through natural resources may have to divide their time between fighting the state and extracting resources.

In turn, they agree with Addison, Le Billon and Murshed (2003) who argue that this substitution between activities may, in some circumstances, lead to increased incentives for groups to align with their peers and cooperatively generate profits. Collier (2000) also supports the suggestion that group interactions are motivated by the desire of groups to maximise returns. He provides anecdotal evidence which suggests that armed conflicts between non-state actors are a direct consequence of rebel groups' efforts to create a monopoly over natural resources in areas where the economic returns are high.

The main criticism of these studies, and of power-based theories more broadly, is that they disregard the role of identity-based factors entirely. This is limited because some theorists argue that shared identity reduces the costs of alliance formation (Fearon and Laitin 1996; Weinstein 2007). Others argue that shared identity increases the payoff for groups who eliminate their ideologically or ethnically similar peers (Christia 2008; Lilja and Hultman 2011; Fjelde and Nilsson 2012). If it is true that identity-based factors result in cost savings which maximise returns for rebel groups, then the economic viability approaches which overlook identity considerations are arguably incomplete.

Minimum winning coalition theories

Another set of power-based theories that are analogous to rebel group interactions in civil war come from the comparative politics literature on political parties and voting. The literature on comparative politics is extensive, with most theories seeking to predict which political parties will align. In multi-party contexts, coalition theory emphasises the idea of a minimum winning coalition, in which there is a mix of parties that are willing to align who have the minimum number of representatives required to form a majority. As with the theoretical viewpoints discussed so far, this theory suggests that political parties make alliance decisions irrespective of their ideological agenda (Riker 1962). It is worth noting that some approaches to comparative politics do take ideology into account. These emphasise policy-viable coalitions, in which it is argued that political parties care more for their policies than for being in power (De Swaan 1973). These theories are discussed in a later section of this review.

Applied to a civil war context, minimum winning coalition theory suggests that rebel groups will seek to achieve a victory against the state with the minimum number of allies (i.e. a group will seek to form alliances with the smallest possible number of other rebel groups). The rationale behind this is based on the assumption that rebel groups seek to maximise their returns. If a rebel group is able to align with a few partners, they may increase their chance of victory at the same time as maximising their share of returns on the spoils of war. Additionally, a weak rebel group may not wish to align with a more powerful player because the stronger player cannot credibly commit (or guarantee) that it will not turn on the weaker rebel group once victory is secured (Fearon 1995, 1998; Lake and Rothchild 1996; Walter 1997; Powell 2006).

In her empirical study of rebel group alliances, Christia (2012) proposes that rebel groups align on the basis of minimum winning coalitions. She argues that identity-based factors do not play a role in alliance formation, citing case-study examples of Afghanistan and Bosnia, where alliances were forged despite ethnic and ideological disparities between rebel groups. By analysing novel interview data collected from the leaders and generals of several Afghan rebel groups, Christia (2012) shows that changes in relative power-balances between rebel groups over the course of the Afghan war, resulted in alliance fractionalisation and subsequent fighting between rebel groups. She concludes that alliances are less prone to fractionalisation (and subsequently less likely to result in inter-rebel violence) when the rebel groups face a strong state or when the allied groups experience a series of battlefield wins.

The study by Christia (2012) is arguably the most comprehensive empirical study of rebel group interactions in civil war. It makes a significant contribution to the field by presenting novel qualitative data collected via interviews of rebel group commanders in the Afghan war. In addition, the study considers a number of rebel group behaviours simultaneously and produces findings which support many long-standing theories based on power considerations. Despite these strengths, there are a few criticisms of her study.

Firstly, Christia (2012) entirely dismisses the role of identity on the basis that ideological and ethnic ties were contradicted when alliance configurations in the Afghan war changed. But, she overlooks the fact that many alliances were originally formed on the basis of shared goals (the *Mujahedeen* alliance was formed by groups who opposed Soviet occupation for example). As such, her findings do not support her overall conclusion that identity-based factors are irrelevant in alliance formation. Instead, her findings suggest that alliance preferences are likely to evolve over the duration of war. Another issue is that the study suffers from selection bias. Christia (2012) uses case-studies on the Afghan and Bosnian conflicts to produce evidence which supports her claims. But, the selection of these two cases means that other possible interaction strategies are overlooked (for example, many rebel groups do not interact with their peers at all, they choose instead to operate independently for the entire duration of the conflict).

Christia (2012) also considers inter-rebel violence only as a function of alliance fractionalisation. This is empirically limited, as is evident in the studies by Fjelde and Nilsson (2012) and Lilja and Hultman (2011), which show that many groups engage in inter-rebel fighting for reasons beyond acrimonious splits. Finally, as with all power-based theories of interactions, Christia assumes that rebel groups make alliance choices purely on the basis of tactical decisions regarding the military capabilities of other groups. But, as Fearon (1995) points out, actors in civil war have a strategic incentive to misrepresent their capabilities. If groups have incomplete information, it could be argued that they are more likely to make interaction decisions on the basis of other preferences (such as identity) instead of relying on uncertain estimations regarding the military capabilities of other groups.

1.1.2 Identity-based theories of rebel group interactions

Contrary to the power-based theories discussed above, a number of political scientists argue that identity considerations are the dominant explanation for within-conflict dynamics such as rebel group interactions. Identity scholars argue that the rationalist explanations for civil war (summarised earlier) are overplayed (Rokkan 1999; Kaufmann 2001; Buhaug, Cederman, and Rød 2006; Cederman and Girardin 2007; Cederman, Wimmer, and Min 2010). They argue that the decisions and behaviours of non-state actors are determined, either in whole or in part, by factors such as ideology, political stance, ethnicity, caste, tribe, religion, social-class or language (Bates 1983; Horowitz 1985; Platteau 1994; Fearon and Laitin 1996; Miguel and Gugerty 2005; Habyarimana, Humphreys, Posner, and Weinstein 2007).

Some theorists argue that rebel groups with a distinct identity may gain organisational advantages which govern their behaviour (Selznick 1952; Pye 1956; Huntington 1968; Bates 1983; Kalyvas and Balcells 2010a), whilst others argue that identity-based interactions satisfy individuals' evolutionary need to belong to a group (Horowitz 1985; Van Den Berghe 1981; Van Evera 1994, 2001; Petersen 2001, 2002). Most identity-based theories do not directly address between-group interactions in civil war. Instead, they consider how identity-based factors shape within-group dynamics (such as recruitment, cohesion, fragmentation and defection). But as before, useful analogies can be drawn if these theories are extended by assuming that within-group dynamics are akin to between-group dynamics. These identity-based theories, their implications for rebel group interactions and the related empirical studies are reviewed below. A third identity-based theory on policy-viable coalitions which was mentioned in the previous section is also discussed.

Organisational efficiency explanations

Many theories argue that identity plays a crucial role in civil conflict because it enables rebel groups to gain organisational advantages which govern their behaviour. These organisational advantages include increased mobilisation capabilities, improved cohesion and a decreased likelihood of defection. Rebel groups with a distinct identity may gain recruitment advantages because they are able to motivate or coerce individuals to fight on the basis of ethnic or religious justifications or loyalty (Gates 2002; Zartman 2005; Weinstein, 2007; Eck 2009). Groups may also derive cohesive benefits, because identity provides a readily available shared code for communication (such as language, social norms, custom or religious practice), which provides an opportunity for repeated exchanges and information sharing between group members. These repeated exchanges lead to an understanding of reciprocity that, along with reputation costs, facilitates in-group policing and sanctioning. In turn, these features decrease the likelihood of internal group dispute, splintering or defection (Selznick 1952; Pye 1956; Huntington 1968; Bates 1983; Kalyvas and Balcells 2010a).

One implication of these theories for rebel group interactions is that shared identity might facilitate alliance formation by reducing the costs of coordinating operations (Fearon and Laitin 1996). Shared identity is likely to improve communication between groups, enabling them to initiate alliances. It might also strengthen alliance bonds by reducing the incentive for each group to renege on their alliance deal. There are very few empirical studies that test the effect of social ties on alliance formation. The main reasons for this are a lack of conceptual clarity regarding identity variables (such as ideology) and paucity in appropriate data. One of the first studies of to explore the effect of social ties on alliance formation in civil war is the study by Bapat and Bond (2012).

In their study, Bapat and Bond (2012) identify certain conditions under which rebel groups may be able to overcome commitment problems and form alliances. They present two game-theoretic models, which differentiate between two types of alliance. The first model captures *bilateral alliances*, which involve cooperation between domestic rebel groups. The second model captures *asymmetric alliances,* which involve cooperation between domestic groups and external groups or sponsors. Bapat and Bond (2012) present the theoretical predictions obtained from their game-theoretic models and test them empirically using UCDP data. Their results show that bilateral alliances are more likely when a state's repressive capabilities are poor, whereas asymmetric alliances are more likely when a state's repressive capabilities are strong. Bapat and Bond (2012) argue that social ties between rebel groups are a function of the repressive capabilities of a state. Thus, rebel groups facing weak governments are able to form strong bilateral alliances with high degrees of social connectedness, whereas rebel groups facing strong governments are only able to form asymmetric alliances, which are weaker with lower degrees of social connectedness. The main criticism of this study is that social ties between groups are not quantified; the authors simply assume that bilateral alliances do indeed have higher degrees of social connectedness compared to asymmetric alliances. As a result, the study arguably provides evidence in support of an alternative hypothesis, that involvement of an external sponsor decreases the likelihood of alliance formation between domestic rebel groups.

If shared identity reduces the costs of cooperating and increases the likelihood of alliances between rebel groups, it might be expected that rebel groups with different identities are more likely to fight. Interestingly, a number of empirical studies find evidence which supports the opposite argument that shared identity increases the likelihood of inter-rebel violence (Christia 2008; Lilja and Hultman 2011; Fjelde and Nilsson 2012). Fjelde and Nilsson (2012) argue that there are good theoretical reasons for this. They suggest that multi-party conflicts are more likely to take on a *zero-sum* character because each rebel group is in competition with its peers for recruits and civilian support. If the recruitment pool is sufficiently small, or if the number of rebel groups operating in the conflict is sufficiently large, a rebel group may have to resort to fighting other groups as a means of eliminating its competition (Cunningham, Gleditsch and Salehyan, 2009).

In their empirical study on violence between co-ethnic groups, Lilja and Hultman (2011) find that the Sri Lankan rebel group, *Liberation Tigers of Tamil Eelam* (*LTTE*), targeted their co-ethnic peer groups so that they could establish dominance over their ethnic constituency. Christia (2008) also finds that Muslim groups in Bosnia engaged in fighting over resources despite their shared religious beliefs. She concludes that identity-based factors are not important in motivating rebel group behaviour.

Based on these discussions, it is evident that empirical research has produced divergent results regarding the effect of social ties on rebel group interactions. Some studies suggest that shared identity facilitates cooperation between rebel groups, whilst others argue that shared identity creates dispute between groups. In reality, it seems that shared identity facilitates alliance formation in some instances, whilst encouraging inter-rebel violence in others. Ultimately, this question is an empirical one. As such, further research is needed to establish the conditions that lead to cooperative versus conflictual interactions.

> *Hypothesis: Shared identity increases the likelihood of interactions (cooperation and fighting) between groups. Rebel groups are more likely to interact when they share social ties (such as ideology) with other groups.*

> *Hypothesis: In the presence of a conditional variable, Z, rebel groups who share social ties with other groups will form alliances, but in the absence of Z, rebel groups who share social ties with other groups will engage in inter-rebel violence.*

Explanations of individual-belonging

The primordialist school of thought also supports the suggestion that identity-based factors govern the behaviour of rebel groups in civil war. Academics in this field argue that ethnic groups and other identity-based groups satisfy individuals' evolutionary need to belong to an *in-group*. Van Den Berghe (1981) argues that this *need-to-belong* results in the formation of kinship groups who use nepotism to propagate their line. Van Evera (2001) suggests that group identities, once constructed, are near impossible to reconstruct, whilst Salter (2001) and Van Den Berge (2002) argue that the desire of individuals' to protect their genetic relatives is so strong, that individuals are willing to sacrifice themselves, in battle for example, if it ensures survival of their ethnic kin.

These theories have a number of implications for civil war. Firstly, they suggest that heterogeneous societies are inevitable and that identity-based groups are unavoidable facets of social life. This could explain why multi-party conflicts arise in the first place. If individuals have a strong sense of belonging to a pre-existing identity-based group, then it follows that these groups may be un-willing to merge and form a single group if they enter into conflict against the state. The question of why some civil wars contain more than one rebel group is an interesting one that previous research has not addressed. Secondly, if individuals have a strong sense of belonging to a group, then it holds that rebel groups might be willing to fight other rebel groups, if those groups threaten the survival of their own group. This suggestion is supported by empirical research which shows that pre-existing identity cleavages encourage fighting between groups, even when those cleavages are based on non-genetic factors such as ideology (Balcells 2010, 2011).

In contrast to the above discussion, some scholars argue that the evolutionary need of individuals' to belong to a group could well be the basis for alliance formation (Tajfel, Bilig, Bundy and Flament 1971; Barkow, Cosmides and Tooby 1992; Kaufmann 1996a, 1996b; Petersen 2001, 2002). If individuals have a strong desire to protect their kin, then rebel groups with the same identity have increased incentives to accommodate each other in an alliance (and make sacrifices for each other) if the long-term survival of their common kin is ensured. This suggestion is supported by previous empirical research which has shown that kinship alliances are a common feature of many civil wars (Cederman, Girardin, and Gleditsch 2009; Cederman, Wimmer, and Min 2010). The growing literature on security communities also supports this theory. Security communities are formed when separate entities join forces and align in response to the same emerging threat. Scholars in this field propose that in normal circumstances these entities would not usually interact. But, when faced with the same emerging threat, these entities unite on the basis of a shared desire to survive (Starr 1992; Adler and Barnett 1998; Acharya 2001).

These discussions enhance the point made earlier, that identity-based theories can be used to explain opposing interaction behaviours. The majority of civil war research does not address this aspect. Most empirical studies avoid problematic discussions relating to theoretical contradictions by analysing cooperation and fighting in separate statistical models.

Policy-viable coalition theory

As mentioned earlier, a significant number of theories in the coalition politics literature argue that identity concerns, as opposed to power concerns, are the key predictor of alliance behaviour. These theories are based on policy-viable coalitions, which assume that political parties care more for their policies than for being in power. They predict that political parties who are most similar on the political spectrum are more likely to align (De Swaan 1973). Some scholars have shown that policy-viable coalition theories capture the empirical reality of cabinet coalitions more accurately than theories which disregard political agendas (Przeworski *et al.* 2000). Other scholars in the comparative politics literature argue that both power considerations and identity considerations are important in alliance formation. They propose the notion of a minimal connected winning coalition, in which political parties seek to form minimum winning coalitions, but being constrained by identity, they look first for alliance partners among their ideologically similar peers (Axelrod 1970; Grofman 1982).

1.1.3 Alternative theories of rebel group interactions

A number of studies advocate alternative explanations for rebel group dynamics in civil war. These studies suggest that factors unrelated to power-based or identity-based considerations are dominant in shaping the interaction decisions made by rebel groups. Some empirical research emphasises the importance of institutional factors, whilst other empirical research suggests that geography and technology are likely to play a role.

Institutional factors

Some civil war studies emphasise the role of institutional factors in shaping the decisions made by rebel groups. Empirical research has shown that state characteristics (such as administrative capabilities and legitimacy) and state responses to rebels (such as repression) have a direct impact on the interaction choices made by rebel groups. In their empirical study of inter-rebel violence, Fjelde and Nilsson (2012) define state strength in terms of the administrative capabilities and legitimacy of the government (e.g. *polity*). They examine UCDP non-state actor conflict data using logistic regression models and find that rebel groups engaged in conflict with a strong state are less likely to fight other groups, whereas rebel groups engaged in conflict with a weak state are more likely to fight other groups. Fjelde and Nilsson (2012) conclude that in cases where rebel groups face administratively weak states, the axis of conflict is likely to shift away from the government towards conflict between rebel groups. The rationale behind this is that each rebel group will be concerned about gaining political power in anticipation of the incumbent government being overthrown.

Other studies which emphasise the role of institutional factors consider how state repression might affect the choices made by rebel groups. Some scholars have argued that state repression increases group unity and spurs recruitment through a variety of mechanisms including revenge (which is grievance-based) and the desire to protect oneself (which is based on rational choice) (Goodwin 2001; Kalyvas 2006; Kalyvas and Kocher 2007). Other scholars have argued that sate repression may cause splintering and fighting between groups because it creates internal dispute over strategy and leads to a worsening of pre-existing tensions (Lawrence 2007; Lyall 2009). This last point has led to a more refined suggestion that state repression is likely to amplify pre-existing sentiments; internally unified groups will become more cohesive, whilst internally divided groups will become more likely to fragment (McLauchlin and Pearlman 2009). If it is assumed that within-group dynamics are akin to between-group dynamics, then it holds that state repression might facilitate rebel group alliances in some circumstances, whilst encouraging fighting between groups in others. This has been tested for the case of alliances in the study mentioned earlier by Bapat and Bond (2012) who find that state repression increases the likelihood of rebel group alliances.

Geographic factors

Previous research has shown that geography can either be a cause of civil war, or a context in which war can be analysed (Diehl 1991). Studies concerned with the geographic causes of war have found that civil war is more likely to occur in sparsely populated regions (Buhaug and Rød 2006) and in countries with mountainous terrain and resource wealth (Collier 2000; Collier and Hoeffler 2000; Angrist and Kugler 2008; Bellows and Miguel 2008). Studies concerned with the geographic contexts of war have shown that violent events cluster in space along geographic borders (Kirby and Ward 1987; Anselin and O'Loughlin 1990, 1992; O'Loughlin and Anselin 1991, 1992) and that the initiation, diffusion and spread of conflict can be explained by geographic factors (Braithwaite 2005, 2006; Gleditsch 2002; Ward and Gleditsch 2002). Recently, research in this field has started to consider how geographic factors might affect the behaviour of rebel groups.

Buhaug, Gates and Lujala (2009) use precisely dated duration data in event history models combined with geographic data on conflict location to show that the relative location of government and rebel forces can enhance as well as reduce the relative capabilities of each side. They argue that rebel groups without proximity to government forces are disadvantaged because they must use vital resources travelling to target the government stronghold. One obvious counter-argument to this is that rebel groups who have proximity to government forces might be more vulnerable to government attacks.

The relationship between rebel group interactions and geographic proximity has not been empirically tested, although some theoretical work in the economics literature, which focuses on governance costs and principle-agent relations, argues that geographic proximity is an important feature of within-group dynamics. Johnston (2008) investigates the organisational characteristics of rebel groups and the downstream effects that certain group-level characteristics have on civil war. Using evidence from field research conducted in Liberia and Sierra Leone, combined with comparative case-studies of armed groups fighting in those countries from 1989 to 2003, Johnston (2008) demonstrates that geographical and technological factors influence certain within-group dynamics. He shows that in cases where geographical distances are great and where technology is primitive, monitoring costs make rebel defection, opportunism and splintering more likely. This research does not directly consider interactions between rebel groups, but it does provide some indication that geographic proximity is likely to play a role.

One theory which is commonly referred to in the geography literature is the principle of *least-effort,* which suggests that *"given various possibilities for an action… [an entity]…. will select the action requiring the least expenditure of effort"* (Zipf 1965). The implication of this for rebel group interactions is that groups will interact with each other on the basis of geographic proximity simply because it is the option that involves the least effort. Gates (2002) points out that geographic proximity might also be important in its association with identity-based factors. He argues that the proximity of rebel groups might determine the attitudes that are felt within groups and between them. Gates (2002) suggests that proximate rebel groups will be more able to assess identity-based similarities which might facilitate alliance formation or encourage inter-rebel violence. Conversely, if two rebel groups are not proximate they have less information on which to base their interaction decisions. This lack of information, combined with the increased costs associated with coordinating operations over greater distances, may reduce the likelihood that groups will interact.

1.1.4 Power-based versus identity-based theories

The prevailing opinion among civil war scholars is that power considerations are the primary driving force behind rebel group interactions. Some of the most prominent and long-standing theories in the fields of political science and international relations have laid the foundations for power-based arguments and many empirical studies have produced evidence which shows that some rebel groups appear to be motivated solely by power considerations. Despite the substantial support for power-based arguments, there is mounting evidence which suggests that the role of identity-based factors should not be ignored.

The majority of previous research has reasoned in support of one theory over the other, but it could be argued that both theories are correct, they need not be mutually exclusive. As mentioned earlier, it might be the case that power concerns are constrained by identity concerns (Axelrod 1970; Grofman 1982). Alternatively, it might be the case that some rebel groups are driven predominantly by power concerns, whilst others are driven predominantly by identity concerns. The extent to which each rebel group favours one concern over the other could be a function of internal group characteristics or other external factors such as geography, technology or other conflict or state characteristics.

Rebel group preferences regarding identity and power considerations are likely to differ between groups and also, as Christia (2012) and Fjelde and Nilsson (2012) point out, they are likely to change over time. Some rebel groups might initially choose to interact on the basis of identity considerations for example, but as the conflict evolves and as circumstances change, group preferences may change such that power relations become paramount. Finally, it might be the case that power concerns are the dominant driving force behind some types of group interactions (such as fighting between rebel groups), whereas identity concerns are the dominant driving force behind other types of interactions (such as alliance formation).

In summary, both the power-based and identity-based theories go some way towards explaining the interaction decisions of rebel groups in civil war, although individually they are unable to encompass all aspects in their own right. Power-based arguments do not account for the fact that some rebel groups choose to operate independently in multi-party wars, whereas identity-based arguments do not account for cases where alliances are forged between groups with conflicting identities. As such, these theories should not be viewed as being mutually exclusive. Instead, research should seek to identify the extent to which each of these theories apply and the conditions in which they have the highest degree of influence.

1.2 Hypotheses to be tested

The review of empirical literature has shown evidence suggesting that power and identity-based factors are both likely to play a role in motivating the interaction behaviour of warring rebel groups. Specific hypotheses regarding the effect of power and identity-based factors on group interactions were highlighted in the first part of this chapter. These hypotheses, which are tested in the next chapter of this thesis (Chapter II), are listed below.

1.2.1 Hypotheses for rebel group cooperation

> *Hypothesis 1: Shared identity increases the likelihood of cooperation between groups. Rebel groups are more likely to form alliances when they share social ties (such as ideology) with other groups.*
>
> *Hypothesis 2: The relative size of a rebel group affects the likelihood that they will cooperate. Groups who are militarily small (relative to others) will form alliances to balance their power against the state or other groups.*

1.2.2 Hypotheses for rebel group fighting

> *Hypothesis 3: Shared identity increases the likelihood of fighting between groups. Rebel groups are more likely to engage in inter-rebel violence when they share social ties (such as ideology) with other groups.*
>
> *Hypothesis 4: The relative size of a rebel group affects the likelihood that they will fight. Groups who are militarily large (relative to others) will target groups who are militarily small.*

1.2.3 Hypotheses for conditional relationships

If the hypotheses regarding identity-based theories of rebel group interactions are correct, it is possible that a third, conditional variable might explain why one rebel group chooses to cooperate with its peers, while another rebel group, under apparently similar circumstances, chooses to fight. This suggests additional hypotheses to test.

> *Hypothesis 5: In the presence of a conditional variable, Z, rebel groups who share social ties with other groups are more likely to form alliances.*
>
> *Hypothesis 6: In the absence of a conditional variable, Z, rebel groups who share social ties with other groups are more likely to engage in inter-rebel violence.*

Chapter II

The determinants of rebel group interactions

Abstract

Numerous theories have sought to explain the motives for cooperation or fighting between rebel groups in civil conflicts. Some theorists argue that power considerations are the primary motivation, while others argue that identity considerations are dominant. The aim of this chapter is to test these theories empirically. The determinants of rebel group interactions are analysed statistically using recently published data on rebel group alliances and inter-rebel violence. A novel methodology based on a social network approach is developed so that identity-based arguments can be tested. Results show that rebel groups are more likely to form alliances when they are ideologically similar to their peers. Groups are also more likely to align when they are militarily weak relative to their peers or when they control territory. Results on inter-rebel violence show that rebel groups are more likely to fight other groups when they are militarily strong relative to their peers or when they receive foreign support from external actors. Overall, these findings suggest that inter-rebel violence is motivated predominantly by power considerations, although identity-based factors play some role. Cooperative interactions are also driven by power considerations, but in this case identity-based factors are found to play an important role.

2.1 Introduction

Previous empirical studies of civil conflict have considered how the dynamics of multi-group conflicts differ from those involving a single rebel group. But few studies have examined the interdependent relationships that exist between the rebel groups themselves, even though such interactions between groups in multi-party civil wars are common. Inter-rebel fighting has been well documented in Myanmar, Liberia and Sudan for example, so have cooperative alliances between rebel groups in Congo, Ethiopia and Guatemala.

Many theories have sought to explain the motives, or driving forces, for cooperation or fighting, between rebel groups. Some argue that interactions are driven by power considerations. These theorists argue that interactions between rebel groups are purely tactical and motivated solely by a desire to win the war and maximise returns. According to this school of thought, the expectation is that rebel groups will interact on the basis of their size, or the potential for profit, irrespective of identity-based considerations. Identity scholars argue that these rationalist explanations are too simplistic. They argue that interactions between rebel groups in multi-party civil wars are driven, either in whole or in part, by identity-based factors such as shared ideology, ethnicity, caste, tribe, class or religion.

The aim of this chapter is to test these two competing theories empirically. The determinants of rebel group interactions are analysed statistically using data on alliance formation and inter-rebel violence that has recently become available. In the present work, it is argued that both power-based and identity-based factors are likely to play a role in motivating the interaction behaviour of rebel groups. A novel methodology based on a social network approach is utilised and a quantitative index that measures the degree of ideological similarity between groups is developed. This index is examined using a large-*N* framework so that identity-based theories can be tested. A variable relating to relative rebel group size is also utilised so that power-based theories can be tested.

This chapter begins by revisiting the hypotheses outlined earlier in Chapter I. A detailed description of the mechanisms responsible for motivating rebel group interactions is provided using case-study examples. This is followed by a section describing the research design. Results of the statistical analyses are then presented and discussed. The chapter finishes by outlining the limitations of the present research and highlighting avenues for further research. Finally, conclusions are drawn and additional lines of enquiry intended for the subsequent chapters of this thesis are discussed.

2.2 Hypotheses and case-study examples

Specific hypotheses regarding the effect of power and identity-based factors on rebel group interaction strategies were outlined in Chapter I. A more detailed description of the mechanisms responsible for these relationships is provided below using case-study examples.

2.2.1 The determinants of rebel group cooperation

The first hypothesis outlined in Chapter I is based on the expectation that groups who are ideologically similar are more likely to form cooperative alliances. According to this perspective, if rebel groups have the same ideology they are more likely to have similar goals. Shared goals increase the appeal of an alliance because each group stands to gain an advantage against the state without having to accommodate the alternative goals of a dissimilar group. Shared goals also strengthen alliance bonds by reducing the chances of internal disputes and by increasing trust between groups. Groups who share ideological ties may also feel a stronger sense of loyalty or duty towards the alliance, thus reducing the incentive for each rebel group to renege on their deal. In these ways, social ties reduce the costs of coordinating operations.

> *Hypothesis 1*: *Shared identity increases the likelihood of cooperation between groups. Rebel groups are more likely to form alliances when they share social ties (such as ideology) with other groups.*

This type of alliance occurred in the Guatemalan civil war. After an unsuccessful coup in 1960, the state of Guatemala fought a left-wing insurgency for over 30 years. As the conflict progressed, a number of leftist groups emerged. All groups followed a communist doctrine - they fought for the interests of the poor, workers' rights and for agrarian reform. In 1982, after encountering fierce resistance from the state, the four major guerrilla organisations (*EGP*, *ORPA*, *PGT* and *FAR*) united to form the *Guatemalan National Revolutionary Unit* (*URNG*). The Guatemalan state initially responded with high levels of repression. However, when that strategy failed, the state entered into negotiations with the alliance and made concessions by increasing aid to peasants and indigenous communities (the main supporters of *URNG*). These concessions eventually led to a cease-fire and a peace settlement was signed in 1996. In this conflict the leftist groups were able to unite on ideological grounds. Their shared goals facilitated alliance formation, which in turn, enabled them to increase their bargaining power and successfully press their demands on the Guatemalan state.

The second hypothesis outlined in Chapter I is based on the expectation that groups are likely to form alliances on the basis of their relative size, irrespective of identity considerations. Groups who are militarily small relative to their peers will seek to balance their power by aligning against the state and other rebel groups. Smaller groups have higher incentives to form alliances because they are more vulnerable to elimination. This means they will be more willing to share the spoils of war with their alliance partner, compared to larger groups who have a lesser incentive to align and share their returns as a result of their capacity.

> *Hypothesis 2*: *The relative size of a rebel group affects the likelihood that they will cooperate. Groups who are militarily small (relative to others) will form alliances to balance their power against the state or other groups.*

This type of alliance occurred in the Afghan civil war. In 1978, insurgency broke out as a result of fierce opposition to the Soviet backed communist government. In 1979 the Soviet army responded by invading Afghanistan, and a number of insurgent groups who had organised in Pakistan, joined forces to balance their power against the Soviet regime. The alliance, known as the *Mujahedeen*, was formed between ten smaller groups who had different ethnic identities, including Pashtun, Hazara, Uzbeck and Tajik. The *Mujahedeen* alliance was unable to totally defeat the Soviet army, but they were able to make it increasingly costly for the Soviets to remain in Afghanistan and after ten years the Soviet army withdrew. By uniting and balancing their power against a stronger force, the members of the *Mujahedeen* were able to sustain conflict against the Soviet army and on the basis of their increased capacity they achieved their goal despite their conflicting ethnic identities.

2.2.2 The determinants of rebel group fighting

The discussions presented in Chapter I suggest there is good theoretical reason to expect that groups who share the same identity may be more likely to engage in inter-rebel violence. This type of fighting occurred between Muslim groups in the Bosnia-Herzegovina civil war during the 1990's. The Bosnian conflict involved three warring groups, the Bosnian Muslims who made up about 40% of the population, the Bosnian Serbs and the Bosnian Croats who each made up about 30% respectively. Tensions escalated in the country when Fikret Abdić, a Muslim member of the presidency set up an economic empire, which he declared as an independent economic region called the *Autonomous Province of Western Bosnia* (*APWB*). The newly declared independent region was opposed by the Serbs and Croats, but also by many Muslims and soon after the declaration of the *APWB*, intense fighting erupted between the Muslims, Serbs and Croats, but also between the Muslim groups. In this case, the Muslim population were divided by economic grievances irrespective of their shared ideological and religious beliefs. This led to inter-group fighting between Muslims despite high incentives for the Muslim groups to unite against the Serbs and Croats.

> *Hypothesis 3*: *Shared identity increases the likelihood of fighting between groups. Rebel groups are more likely to engage in inter-rebel violence when they share social ties (such as ideology) with other groups.*

The next hypothesis proposed in Chapter I, relates to the influence of how the relative size of a group affects the likelihood of inter-rebel violence. Groups who are militarily large relative to their peers will target groups who are militarily small. Large groups have the capabilities to attack their weaker peers and they also have increased incentives. These incentives arise because strong groups may seek to increase their capacity by eliminating weaker groups (which are easy targets) and absorbing their resources. They also arise because strong groups are disadvantaged by the presence of smaller groups in negotiated deals (Nilsson 2010). This means that large groups have an incentive to eliminate small groups to regain an upper hand in the bargaining over the future allocation of political power. This type of fighting occurred in Burundi when the militarily strong group, *Party for the Liberation of the Hutu People-Forces for National Liberation* (*Palipehutu-FNL*) was angered by the decision of the smaller, marginalised group, the *National Council for the Defence of Democracy* (*CNDD*) to initiate peace talks with the state.

> *Hypothesis 4*: *The relative size of a rebel group affects the likelihood that they will fight. Groups who are militarily large relative to others will target groups who are militarily small relative to others.*

2.3 Research design

This section describes the dataset, variables and methods of estimation used to test the above hypotheses (1 – 4).

2.3.1 Dataset

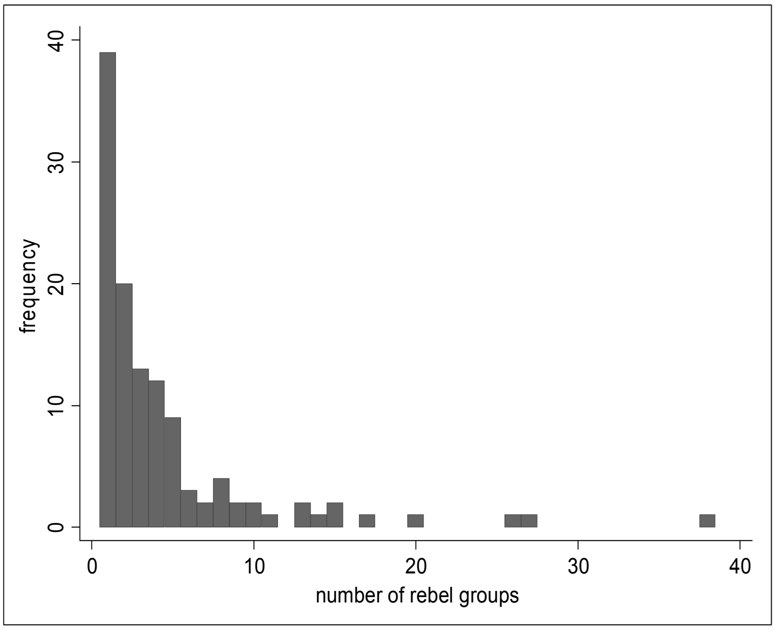
The above hypotheses are tested in a large-*N* framework using a data taken from the UCDP Dyadic Dataset (Harbom, Melander and Wallensteen 2008). This dataset contains dyadic information on all rebel groups involved in armed conflict with a recognised government between 1945 and 2008.

Two types of conflict are excluded from the analyses. Conflicts involving fighting between a state and a rebel group that operates outside its own territory are excluded because these types of conflict often involve aspects that are not generally representative of the rebel group interactions appropriate to the present study. That is, groups operating within the boundaries of a country are likely to interact in a different manner to rebel groups operating extra-territorially. These differences between intra-territorial and extra-territorial interactions have not been investigated in conflict research. This is an important area for future enquiry, but is not within the scope of the present work.

The second type of conflict excluded from the present study, concerns those involving inter-state armed conflict (i.e. between two more nation states). These types of conflict do not fit the scope of the present research, which examines rebel group interactions in civil war.

The frequency distribution of the number of armed civil conflicts (1945-2008) as a function of the number of rebel groups involved in each conflict is shown in Figure 2.1. Most civil conflicts involve a single rebel group, although a substantial proportion of civil wars are multi-party (~ *50%*).

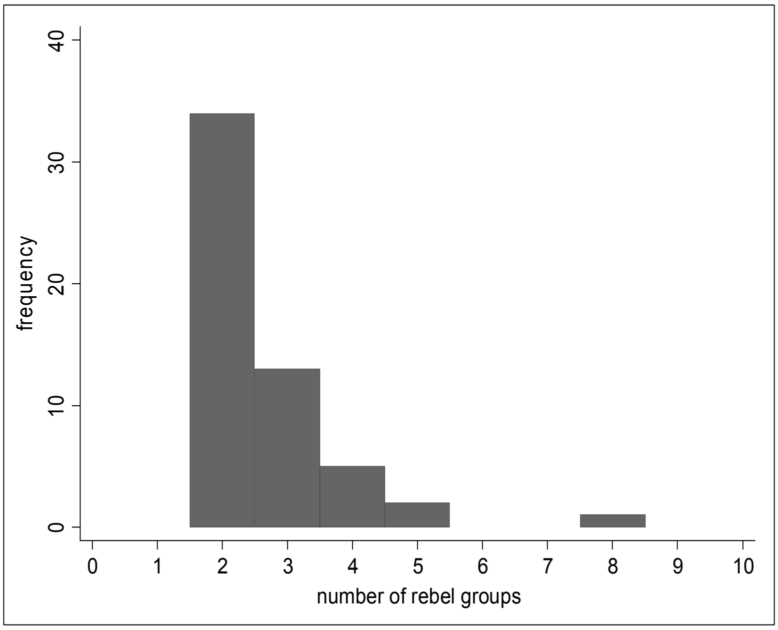
Figure 2.1 Frequency of armed civil conflicts (1945-2008) as a function of the number of rebel groups involved in the conflict



Some nation states experience multiple insurgencies which overlap in time but occur in different geographic regions. This is often the case when a state faces separatist groups who seek to gain independence or increase their autonomy over some geographic region. For example, the Indian government fought eleven insurgencies between the 1990 and 2000. Most of these conflicts occurred in different geographic regions (in Nagaland, Mizoram, Manipur, Assam and Kashmir for example) and involved disassociated rebel groups (i.e. Sikhs, Assamese, Kashmiri's) who fought for independence during the same period of time. As is evident from these discussions, rebel groups may be assumed to overlap if they operate in the same country and/or in same conflict/geographic region and/or if they operate in the same year. In this analysis, rebel groups are assumed to overlap only if they operate in the same conflict-year. Therefore, rebel groups operating in the same country but in a different conflict were assumed not to overlap. One potential issue with this conflict-year overlap criterion relates to the UCDP definition, namely that civil war is *"a contested incompatibility ... that results in at least 25 battle-related deaths a year"* (Harbom *et al.* 2008). This cut-off threshold means that any group failing to reach the threshold of 25 deaths in the same year as any other group is excluded from the analysis, even if the group existed in the same conflict, around the same time as other groups and had the potential to interact.

The main disadvantage of the overlap criterion used in the present analysis is that it results in a smaller sample size as a result of the exclusion of non-overlapping rebel groups. But this disadvantage is viewed as being less problematic than the alternative option, of adding additional conflict-years (say plus or minus five years) and generating pseudo observations for each rebel group that would otherwise have been excluded. Figure 2.2 shows the frequency of multi-party conflicts (1945-2008) and the maximum number of overlapping groups involved in each conflict (assuming the overlap criterion of conflict-year). The majority of conflicts involved two overlapping rebel groups in any single conflict-year. The maximum number of overlapping groups in any single conflict-year was eight, in the Afghan civil war for the conflict-years 1980 and 1984.

Figure 2.2 Frequency distribution of multi-party civil conflicts (1945-2008) as a function of the number overlapping rebel groups in each conflict



2.3.2 Dependent variables

Two interaction outcomes are considered; cooperative alliances and inter-rebel violence.

Definition of alliance formation (rebel group cooperation)

Rebel groups are assumed to be allied if they have a *"cooperative relationship in their quest to defeat the government"* (Akcinaroglu 2012). This relationship may be formal or informal and it must involve commitment and the exchange of benefits between two or more rebel groups. These benefits may be tangible (for example, groups may support others by providing training, engaging in tactical support, providing material or military support and coordinating their military operations), or they may be intangible (for example, groups may share information or intelligence). It is important to note that *alliances* differ from *mergers*. Mergers between rebel groups are formal, such that two groups become one. This is publicly acknowledged and the merged group is under a single command. Alliances however, may be informal and they do not result in joint command. Only a small fraction (~ *20%*) of cooperative interactions between rebel groups result in formal mergers, and since it is possible for cooperative interactions take place in the absence of a formal deal, the definition of *alliance* was selected as being more appropriate for testing hypotheses on rebel group cooperation.

Definition of inter-rebel violence (rebel group fighting)

Inter-rebel violence is defined as *"the use of armed force between two organised armed groups, neither of which is the government of a state, that results in at least 25 battle related deaths in a year"* (Sundberg *et al.* 2012). According to this definition, a *formally organised armed group* is a non-governmental group (or *non-state actor*) that has announced a name for its group and is using armed force against another formally organised group. Examples of non-state groups include political parties, rebel groups, clans, ethnic groups and civilian supporters of any of these groups. In many circumstances, these types of groups are not involved in armed conflict with the state. Since the aim of the present research is to examine rebel group interactions in civil war, only violence occurring between rebel groups or splinter groups that have fought against state forces are included in the analyses.

Coding of dependent variables

Cooperation: a binary variable taking the value *1* if the rebel group formed an alliance with one (or more) rebel group(s) in that conflict-year and *0* otherwise

Fighting: a binary variable taking the value *1* if the rebel group engaged in armed conflict with one (or more) rebel group(s) in that conflict-year and *0* otherwise

2.3.3 Independent variables

Previous research has not considered how social ties between rebel groups affect the likelihood of interactions in civil war. One objective of this chapter is to develop a novel quantitative index which can be used to measure the degree of ideological similarity between groups. The following section describes how the identity-based independent variable, *ideological ties*, was constructed.

Construction of the independent variable for ideological ties

Before describing how the independent variable, *ideological ties*, was constructed it is first necessary to clarify the use of the term 'identity' and discuss how effectively 'ideological ties' represents this concept. The term 'identity' (discussed in detail in Chapter I), is a broad term encompassing many aspects including ideology, ethnicity and religion. For this reason, 'ideology' may be regarded as a subset of identity. Sanín and Wood (2014) describe ideology as *"a set of more or less systematic ideas that identify a constituency, the objectives pursued on behalf of that group, and a program of action"*. But, on the basis of this description, it could be argued that ethnicity and religion are similar to ideology. For example, an individual who follows an organised religion is declaring their belief in a set of ideas shared by a religious community in which there is a program of action (such as prayer or visiting a place of worship). Similarly, an individual who identifies themselves as belonging to a particular ethnic group may share similar ideas and take similar actions on the basis of shared cultural norms. Thus, in the present research the term 'ideological ties' is used as proxy intended to represent the broader term of 'identity'.

To construct the independent variable, *ideological ties*, it was first necessary to define the term 'ideology'. Ugarizza and Craig (2012) propose that a rebel group's ideology is made up of three components: (*i*) *discourse* (the group's stated aims and objections), (*ii*) *emotional response* (the group's response to external events) and (*iii*) *attitude* (the group's underlying psychological orientation). This definition was utilised in the present analysis. The *discourse* component was assumed to be the main goals and stated opponents of the group (e.g. overthrow the government, oppose the Soviet occupation). The *emotional response* component was assumed to be the methods adopted by the group to achieve their goals (e.g. use brutal means by targeting civilians). The *attitude* component was assumed to be the political or religious stance of the group (e.g. Communist, Islamist) and the membership of the group (e.g. tribesmen, students, exiles, military officers).

Qualitative data were collected on each of these components for each rebel group in the sample. A novel qualitative data list was compiled from the case studies detailed in Cunningham *et al.* (2013), Google online book excerpts, journal articles and books on civil war. The data collection process was conducted as follows.

First, a rebel group was selected from the dataset, for example the *Taliban* in Afghanistan. Next, the relevant case study from Cunningham *et al*. (2013) was examined. All information relating to each component of the ideology definition was recorded in bullet point format. For example, in the case study of Afghanistan, Cunningham *et al.* (2013) state that:

> *"...... The Taliban controlled 10 of Afghanistan's 30 provinces. Within these provinces the group sought to overthrow warlords, remove existing political parties and implement Islamic law......."*

This statement clearly provides information on the goals of the *Taliban*. The three statements (*i*) *overthrow warlords*, (*ii*) *remove existing political parties*, (*iii*) *implement Islamic law* were recorded in the *goals* component of the ideology definition for the *Taliban*. Crucially, *all* statements that could be perceived as being a goal of the group were recorded. By recording all statements, subjective decision making was reduced (e.g. if the aim was to record the *main goal* of the group, instead of *all goals* of the group, then higher degrees of subjective decision making would have been introduced).

Having recorded all information from the case studies provided by Cunningham *et al.* (2013), the reliability of the data was checked by examining Google online book excerpts, journal articles and books on civil war. If new information emerged, new statements were added to the dataset. If conflicting information emerged, new statements were added to the dataset and the original statement was not removed or altered. This minimised subjective bias because decisions did not have to be made about the validity of the various sources.

Table 2.1 presents an example of the qualitative ideology data collected for two rebel groups in the Afghan civil war.

Table 2.1 Example of data collected on ideology for two of the thirteen Afghan groups

		Taliban	**Jamiat-i-Islami**
Ideology			
Stated goals and opposition	Group sought to...	• Control Kabul • Gain territory • Overthrow warlords • Abolish political parties • Implement Islamic law	• Control Kabul • Create independent state
	Group opposed to...	• US coalition government • Jamiat-i-Islami	• Communist government • Soviet occupation • Taliban
Method	Brutal approach	• Yes	• No
Attitude	Political/religious stance	• Islamic • Jihadist	• Islamic
	Membership	• Tribesmen • Students	• Students

By virtue, every group included in the UCDP dataset is an armed group that adopts violent means (instead of/as well as political means) to achieve its goals. Therefore, the method component was recorded as a binary response, signifying whether or not the rebel group adopted particularly brutal tactics (e.g. did the group target civilians, engage in other terrorist activity or commit rape, torture and/or kidnapping?). The membership component included group members, fighters and founders of the group.

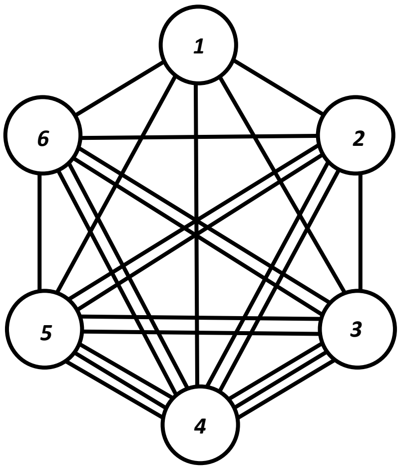
The qualitative data were next transformed into a quantitative index that measures the extent of ideological similarity between groups. This was achieved using a network approach. Such approaches have not been commonly used in conflict studies, although the existence of interdependent relationships between actors in civil war, have been noted (Cederman *et al.* 2009; Cunningham *et al.* 2009). The empirical method used previously in civil war research has been to consider multi-party conflicts as a set of parallel dyadic conflicts between each rebel group and the state (by using a dyadic data set-up in regression models). This imposes a fundamental limitation, since the interdependencies that exist between the rebel groups cannot be accounted for. In other areas of political science research, network approaches have been used to study interdependent relationships between different actors, but these have been limited to the study of the relationships that exist between nation states rather than rebel groups within a state (Maoz *et al.* 2006; Maoz 2009, 2010; Cranmer *et al.* 2011, 2012).

Network theory is concerned with the use of networks as a representation of the relationships that exist between discrete objects. It has played a central role in social science disciplines and has formed the basis of *Social Network Analysis*, which examines the structure of relationships between social entities (Wasserman 1994). These entities are often individuals, but may also be groups, organisations or nation states. Network analysis has a wide range of applications - it has been used to understand the diffusion of innovations (Valente 1995), news and rumours (Nekovee *et al.* 2007) as well as the spread of diseases and other health related behaviours (Newman 2002). In economics, it has been applied to the study of markets to examine the role of trust in exchange relationships and the social mechanisms responsible for price setting (Thompson 1991), and in the field of political science, it has been used to study recruitment and participation in political movements (Wasserman 1994).

Network analysis involves the use of various measures of *centrality*, which determine the relative importance of each *node* (or vertex) within a network (Newman 2010). The simplest measure is *degree centrality*, defined as the number of ties stemming from each node. Another measure is *eigenvector centrality*, which measures the degree of influence that an individual node has on the dynamics of an entire network (Newman 2010). Other relevant concepts in network analysis include the notion of *reciprocity*, when the connections (or ties) between nodes are mutual such that the relationship between entities is two-way (Garlaschelli *et al.* 2004) and finally, network *density*, which measures the degree of connectedness of the network as a whole (Hanneman and Riddle 2005). In the present work, a network technique was applied by producing graphical network representations of all conflicts in the sample. These networks are made up of nodes, which represent rebel groups involved in a single conflict. The nodes are connected by lines (or ties), which represent ideology attributes. If two rebel groups shared the same attribute (e.g. Islamist) the groups were connected by a single line. Ties between groups were added only when there was reciprocity (i.e. when the ideology attribute was present in both groups). The advantage of this method is that obscure or irrelevant information recorded in the qualitative ideology data is, in effect, removed and the most important aspects of ideology naturally emerge in the form of network connections.

An example of this graphical network method is shown in Figure 2.3 for the case of N_I groups with N_J possible shared attributes (these attributes are the qualitative statements collected for each group, such as *tribesman, Islamist* etc). The example is chosen for six groups ($N_I = 6$) and five possible attributes ($N_J = 5$), with a specific assumed distribution of shared attributes used as an illustration. In this example, the number of ideological ties that each group has with its peers (the degree centrality of each node) can be obtained by counting the number of lines that stem from each node. In Figure 2.3 the degree centrality $Z_i = 5, 7, 9, 11, 9, 7$ for groups $i = 1$ to 6 respectively (the max. hypothetical degree centrality for each node = *25*).

Figure 2.3 Graphical network representation of a hypothetical distribution of five attributes shared between six rebel groups, distributed as shown



An alternative way of calculating the degree centrality of each node is illustrated by the matrix shown in Table 2.2. The various attributes are represented as N_J columns labelled $j = 1$ to N_J and N_I groups as rows labelled $i = 1$ to N_I. Groups are coded with *1* if they have a particular attribute, and *0* if not. The distribution of shared attributes shown in Table 2.2 corresponds to the graphical representation shown in Figure 2.3.

Table 2.2 Matrix of hypothetical attributes ($j = 1$ to N_J) for rebel groups ($i = 1$ to N_I), where $N_J = 5$ and $N_I = 6$

	$j = 1$	$j = 2$	$j = 3$	$j = 4$	$j = 5$
$i = 1$	**0**	**1**	**0**	**0**	**0**
$i = 2$	**0**	**1**	**0**	**1**	**0**
$i = 3$	**1**	**1**	**1**	**0**	**0**
$i = 4$	**1**	**1**	**1**	**1**	**1**
$i = 5$	**0**	**1**	**1**	**1**	**0**
$i = 6$	**1**	**1**	**0**	**0**	**0**

A connection factor η_j can then be defined for each attribute j. For example, column 2 (corresponding to attribute $j = 2$) is coded entirely with 1's meaning that all groups in the network have attribute $j = 2$. Thus, each individual group shares attribute $j = 2$ with five other groups in its column, so that $\eta_2 = 5$. For another example, this time for groups having attribute $j = 1$, each of these share this attribute with just two other groups in its column and therefore $\eta_1 = 2$. Thus, the connection associated with the j^{th} attribute can be written in the form:

$$\eta_j = \sum_{i=1}^{N_I} \alpha_{ij} - 1 \tag{2.1}$$

where α_{ij} takes the value 0 or 1 as shown in Table 2.2. The values of η_j are thus 2, 5, 2, 2, 0 for attributes $j = 1$ to 5 respectively. Having calculated the connection associated with the j^{th} attribute, the degree centrality can then be calculated. Take for example the group $i = 2$. This group is connected to all other groups according to the relationship: $Z_2 = (0 \times \eta_1) + (1 \times \eta_2) + (0 \times \eta_3) + (1 \times \eta_4) + (0 \times \eta_5) = 7$. Thus, the degree centrality of each node in the network can be written in the form:

$$Z_i = \sum_{j=1}^{N_J} \alpha_{ij} \eta_j \tag{2.2}$$

This matrix method reproduces the results obtained from the network node counting method, but is more convenient for large values of N_I and N_J.

To construct the independent variable, *ideological ties,* the degree centrality Z_i for each rebel group in the dataset was calculated from a matrix corresponding to each conflict-year. This index produces high values of Z_i for groups that are heavily tied ideologically to their peers and low values of Z_i for rebel groups that are ideologically dissimilar to their peers.

The above method represents a novel and simple approach for quantifying rebel group ideology ties, but a limitation is that *Zi* is assumed to depend solely on how many groups share a given attribute. Thus, *Zi* does not account for the fact that different attributes may carry different weightings in terms of encouraging group interactions, or for the fact that rebel group sizes are generally not equal. With respect to the latter, the attributes can be weighted for the numbers in each group with relative ease (so long as the group numbers are known). A more difficult task would be to provide a weighting to the importance of the attributes themselves. In view of this, an attribute weighting was not attempted because the influence of group size is incorporated as an independent variable in the analyses.

Before moving on to discuss the coding of the independent variable, *rebel size*, there are a few more important points to make regarding the conceptualisation, coding and data collection of the *ideological ties* variable. Firstly, as discussed above, only the attribute 'ideology' has been included as a proxy for 'identity' in statistical models. But the network methodology proposed can be used to code ethnic or religious ties (or any other type of identity ties) between groups. In the present research, a novel dataset on the ethnicity of rebel groups was also compiled using the same data collection method described above and an *ethnic ties* index was calculated for each rebel group in the dataset. An index for *religious ties* was also calculated using the network method using data from Lindberg (2008). An interesting finding that emerged from this analysis was that the indices for ideology, ethnicity and religion were highly correlated and so, they could not be used together in statistical models. This finding adds further weight to the suggestion put forward earlier in this chapter, that, *ideological ties,* is a sufficient proxy for identity when used alone.

A second important point concerns the nature of the network method and how it compares to alternative definitions and operationalisations of the term 'ideology'. In the comparative politics literature, the traditional approach to modelling political ideology has been to model left-right political scales and consider the difference in ideological stance that exists between different political parties (Castles and Mair 1984; Kitschett and Hellemans 1990; Gabel and Huber 2000; Anderson and Matthew 2008). The advantage of these left-right spectrum approaches is that the *polarity* between ideological stances is captured, unlike the network method proposed in the present research, which captures the degree of ideological similarity between groups, but not opposing (or polar) views. Although not attempted in the present research, this limitation could be overcome by incorporating negative ties (that act as *repulsion* attributes) into the network index calculation.

Construction of the independent variable for relative rebel size

Rebel size: a continuous variable representing the military capabilities of each rebel group relative to others. The size of each group is expressed as a percentage of the total size of all groups warring in the same conflict-year. A percentage value is used (instead of the absolute value of group size) to capture the *relative difference* in size between the rebel groups. Using the percentage in this case also has the added advantage of producing values that are comparable across countries. Troop size data are used from Cunningham *et al.* (2009).

2.3.4 Control variables

Ethnic conflict: a binary variable taking the value *1* if the rebel group operated in an ethnic conflict and *0* otherwise. Data are taken from the UCDP Dyadic Dataset (Harbom *et al.* 2008). This is included as a control variable because ethnic conflicts are more likely to include identity-based groups.

Foreign support: a binary variable taking the value *1* if the group received foreign support (either from foreign governments or external non-state actors) and *0* otherwise. Data are taken from Cunningham, Gleditsch and Salehyan (2009). This is included as a control because the provision of foreign support is likely to affect the interaction decisions made by rebel groups. Fjelde and Nilsson (2012) have shown that groups who receive foreign support are more likely to engage in inter-rebel violence. Rebels who receive support also have lower incentives to align with other groups (Bapat and Bond 2012).

Territorial control: a binary variable taking the value *1* if the rebel group controlled territory and *0* otherwise. Data are taken from Cunningham, Gleditsch and Salehyan (2009). This is included because rebel groups who control territory may be more likely to interact. Collier (2000), Lilja and Hultman (2011) and Cunningham *et al*. (2013) all provide anecdotal evidence that rebel groups engage in inter-rebel violence with the aim of gaining and increasing their control of territory.

Number of groups: a continuous variable signifying the number of overlapping groups that are listed in the dataset for each conflict-year. This is included as a control because group interactions might be more likely to occur simply as a result of increased opportunity when there are large numbers of groups operating in the same conflict. This variable also controls for the fact that the *ideological ties* variable is sensitive the number of overlapping groups.

GDP (expressed as the natural logarithm, ln[GDP]): a variable equal to the gross domestic product of a state. Higher GDP indicates larger state capacity. Fjelde and Nilsson (2012) have shown that the likelihood of inter-rebel violence is increased when rebel groups fight weak sates. Rebel groups fighting strong states also have higher incentives to align (Akcinaroglu 2012). Data are taken from Fearon and Laitin (2003).

Population (expressed as the natural logarithm, ln[Pop]): a variable corresponding to the population of a country. This is included as a control because countries with large populations have higher recruitment opportunities for rebels. Groups are more likely to engage in inter-rebel violence if they are in competition over limited resources such as recruits (Fjelde and Nilsson 2012). Groups who have access to large recruitment pools may also be less willing form alliances. Data are taken from Fearon and Laitin (2003).

Ethnic fractionalisation: a widely used variable in empirical studies of civil conflict, which represents the degree of ethnic heterogeneity in a society. The ethnic fractionalisation index, defined as the probability that two individuals selected at random from a country will be from different ethnic groups, ranges between *0* and *1*, where *0* indicates that the society is entirely homogenous and *1* indicates that the society is entirely ethnically heterogeneous (see Fearon (2003) for a detailed description of the ethnic fractionalisation index). This is included as a control because conflicts occurring in ethnically heterogeneous societies are more likely to involve identity-based rebel groups. The data are taken from Fearon and Laitin (2003).

Intensity: a widely used variable in empirical studies of civil conflict, which corresponds to the intensity of conflict. A value *1* signifies low intensity (*25 - 999* battle related deaths per conflict year) whereas a value *2* signifies high intensity (≥ *1000* battle related deaths per year). Data are taken from the UCDP Dyadic Dataset (Harbom *et al.* 2008). This is used as a control because rebel groups who encounter heavy losses have high incentives to form alliances and might be more vulnerable to attack from other rebel groups.

2.3.5 Methods of estimation

The determinants of rebel group cooperation and of rebel group fighting are examined using logistic regression models. In the first instance, a sample containing only multi-party conflicts is analysed. This sample was selected because rebel group interactions can only occur if there is more than one rebel group engaged in a conflict.

To examine the sensitivity of the model to two issues that might lead to errors of statistical inference, two additional forms of model are used and the results are compared to the logistic regression models. First, multi-level mixed-effects logistic regression models (described in more detail below) are used to control for the lack of independence between rebel groups operating in the same conflict, and the lack of independence between conflicts occurring in the same country.

Second, to control for potential sample-selection bias that may arise from the analysis of a sample containing multi-party conflicts only, a larger sample containing all conflicts (i.e. two-sided and multi-party conflicts) is analysed using two-step Heckman selection models (which are also described in more detail below).

Finally, to control for the lack of independence between the annual observations for each rebel group, additional variables which control for time-dependence are included in the statistical models. These are:

Previous coop: a variable signifying the number of years elapsed since the rebel group cooperated with one or more other rebel group(s).

Previous fight: a variable signifying the number of years elapsed since the rebel group engaged in inter-rebel violence with one or more other rebel group(s).

The squared and cubed terms for both variables are also included, instead of time dummies or splines, as proposed by Carter and Signorino (2010).

Table 2.3 Descriptive statistics

Level	Variable	Obs.	Mean	SD	Min	Max
Dependent variables	**Cooperation**	*1126*	*0.67*	*0.47*	*0*	*1*
	Fighting	*1126*	*0.10*	*0.29*	*0*	*1*
Independent variables	**Ideological ties**	*1126*	*6.47*	*4.77*	*0*	*24*
	Rebel size	*1126*	*0.41*	*0.26*	*0.006*	*0.976*
Control variables	**Ethnic conflict**	*1126*	*0.37*	*0.48*	*0*	*1*
	Foreign support	*1126*	*0.88*	*0.32*	*0*	*1*
	Terr. control	*1126*	*0.44*	*0.50*	*0*	*1*
	***N* groups**	*1126*	*3.82*	*1.61*	*2*	*8*
	***ln* [GDP]**	*1126*	*4.77*	*4.90*	*0.15*	*24.54*
	***ln* [Pop]**	*1126*	*16.76*	*1.36*	*14.46*	*20.89*
	Ethnic frac.	*1126*	*0.55*	*0.27*	*0.04*	*0.90*
	Intensity	*1126*	*1.22*	*0.41*	*1*	*2*

2.4 Results and discussions

Descriptive statistics for all variables used in the analysis are presented in Table 2.3. The final sample consisted of *1128* conflict-years, *209* rebel groups, *49* conflicts and *39* countries. The minimum number of rebel groups involved in a single conflict was two, the maximum number was eight and the mean was close to four (*3.8*). *67%* of the rebel groups formed an alliance, whereas only *10%* of rebel groups engaged in inter-rebel violence.

To check for multicolinearity (e.g. if one variable is linearly dependent on the other), it is necessary to check the correlations between all the pairs of the independent variables. Severe multicolinearity between independent variables is problematic when fitting regression models because it can increase the variance of the coefficient estimates and make the estimates very sensitive to minor changes in the model. The result is that the coefficient estimates are unstable (for example they can switch signs) meaning that they become difficult to interpret. As such, multicolinearity makes it more difficult to specify the correct model.

The degree of association between all pairs of the independent variables is shown in Table 2.4 using the Spearman rank correlation. Unlike other tests for correlation, such as Pearson correlation, which assumes a linear relationship between two variables and is based on the assumption of normal distributions, Spearman rank correlations are not based on any distributional assumptions. As such, Spearman rank correlations test for monotonic relationships between two variables (as opposed to linear relationships) and therefore allow greater flexibility in establishing association between variables. All variables except two are shown to be independent of one another. These exceptions are *ideological ties* and *N groups* (*0.57*) and *ethnic fractionalisation* and *GDP* (*-0.55*), which are underlined in Table 2.4.[*]

2.4.1 Modelling the determinants of rebel group cooperation

Table 2.5 shows logistic regression estimates for the determinants of rebel group cooperation. In line with the expectations of hypothesis 1, *ideological ties* is statistically significant (at the <0.01 level) with an odds ratio ($OR = 1.15$). The *OR* represents the odds that an outcome will occur given a particular exposure, compared to the odds of the outcome occurring in the absence of that exposure. Thus if $OR = 1$ the independent variable has no effect on the outcome, if $OR > 1$ the independent variable has a positive effect on the outcome and if the $OR < 1$ the variable has a negative effect on the outcome. The *OR* for *ideological ties = 1.15*. This indicates that there is a *15%* increase in the odds of cooperation per unit increase of *ideological ties* (assuming all other variables are at fixed values).

The *95%* confidence intervals (*CIs*) show that if the experiment was repeated a hundred times, the estimated parameter would fall *95%* of the time, within the lower and upper bounds defined by the *CI*. If the *CIs* are small (i.e. close to the estimated parameter value), then there is a high degree of confidence that the estimate is close to its real value. For *ideological ties*, this is the case since the lower and upper intervals are (*1.09, 1.21*).

The result for *rebel size* is also significant (at the <0.01 level) and the effect is negative, as signified by an $OR = 0.36$. This indicates that there is a *64%* decrease in the odds of cooperation per unit increase of *rebel size* (assuming all other variables are at fixed values). This result provides evidence in support of hypothesis 2, as it indicates that rebel groups who are militarily small relative to their peers are more likely to form alliances. In this case the *CIs* are larger, so there is slightly less confidence regarding the estimate. However, the upper bound is well below *1*, which confirms that the effect of *rebel size* on cooperation is negative and statistically significant.

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[*] These correlations do not create an issue with the fitting of the regression models, which are run in the software package STATA that automatically drops variables when multicolinearity exists.

Table 2.4 Correlation matrix determined using the Spearman rank correlation method

	Ideology ties	**Rebel size**	**Ethnic conflict**	**Foreign support**	**Territorial control**	***N* Groups**	***ln* [GDP]**	***ln* [Pop]**	**Ethnic frac.**	**Intensity**
Ideological ties	*1.0*									
Rebel size	*-0.32*	*1.0*								
Ethnic conflict	*-0.17*	*0.09*	*1.0*							
Foreign support	*0.06*	*0.02*	*0.09*	*1.0*						
Territorial control	*-0.07*	*0.08*	*0.01*	*0.11*	*1.0*					
***N* groups**	*0.57*	*-0.27*	*-0.07*	*0.24*	*0.13*	*1.0*				
***ln* [GDP]**	*0.07*	*0.02*	*0.40*	*0.02*	*-0.09*	*0.04*	*1.0*			
***ln* [Pop]**	*-0.11*	*0.04*	*0.12*	*-0.16*	*-0.03*	*-0.19*	*-0.24*	*1.0*		
Ethnic frac.	*-0.00*	*-0.03*	*-0.10*	*-0.10*	*-0.10*	*-0.05*	*-0.55*	*0.38*	*1.0*	
Intensity	*0.21*	*0.02*	*-0.15*	*0.06*	*0.23*	*0.25*	*-0.22*	*-0.09*	*0.09*	*1.0*

Table 2.5 Logistic regression results for the determinants of cooperation

Variable	**Odds ratio**	***95%* CI**	**Standard error**
Ideological ties	**_1.15_****	*1.09, 1.21*	*0.030*
Rebel size	**_0.36_****	*0.19, 0.68*	*0.117*
Ethnic conflict	*0.77*	*0.52, 1.13*	*0.152*
Foreign support	*0.80*	*0.48, 1.37*	*0.217*
Territorial control	**_2.03_****	*1.41, 2.93*	*0.380*
Number of groups	*0.93*	*0.81, 1.07*	*0.068*
***ln* [GDP]**	*0.99*	*0.95, 1.04*	*0.023*
***ln* [Pop]**	**_1.32_****	*1.15, 1.51*	*0.092*
Ethnic fractionalisation	*0.70*	*0.32, 1.51*	*0.275*
Intensity	*1.53*	*0.97, 2.42*	*0.357*
Previous coop	**_0.18_****	*0.14, 0.24*	*0.026*
Previous coop^2	**_1.23_****	*1.17, 1.29*	*0.031*
Previous coop^3	**_0.99_****	*0.99, 1.00*	*0.001*
Constant	*0.03*	*0.01, 0.41*	*0.043*
Number of obs.		*1126*	
LR χ^2 (13)		*508.70*	
Log likelihood		*-460.736*	
Pseudo R^2		*0.36*	

Note: ** denotes significance at $p \leq 0.01$, * denotes significance at $p \leq 0.05$

The above results show that groups operating in countries with large populations are more likely to form alliances *OR = 1.32* (significant at the *<0.01* level), as are groups who control territory *OR = 2.03* (significant at the *<0.01* level). One explanation for the latter effect might be that groups who control territory are, by virtue, well-established. Such groups may gain efficiency through increased abilities to organise their operations, which may increase their ability to form alliances. Groups who control territory are also more able to make their presence known to potential allies and are more able to offer benefits related to territorial control, such as base-camps, training facilities and access to trade routes. These features may increase a group's ability to form alliances.

The results shown in Table 2.5 are illustrated as a Forest Plot in Figure 2.4. The square points on the plot show the odds radio for each statistically significant result and the horizontal bars around each point show the *95%* confidence intervals. Predicted probabilities for cooperation as a function of *ideological ties* and *rebel size* are shown in Figures 2.5 and 2.6. These were created using the **margins** command in STATA, which generates predicted probabilities for each value of the independent variable, while holding all other independent variables constant at their mean value. The predicted probabilities at each margin (i.e. value of the independent variable) can then be plotted in STATA using the **marginsplot** command.

Figure 2.4 Forest plot of odds ratios calculated from logistic regression estimates

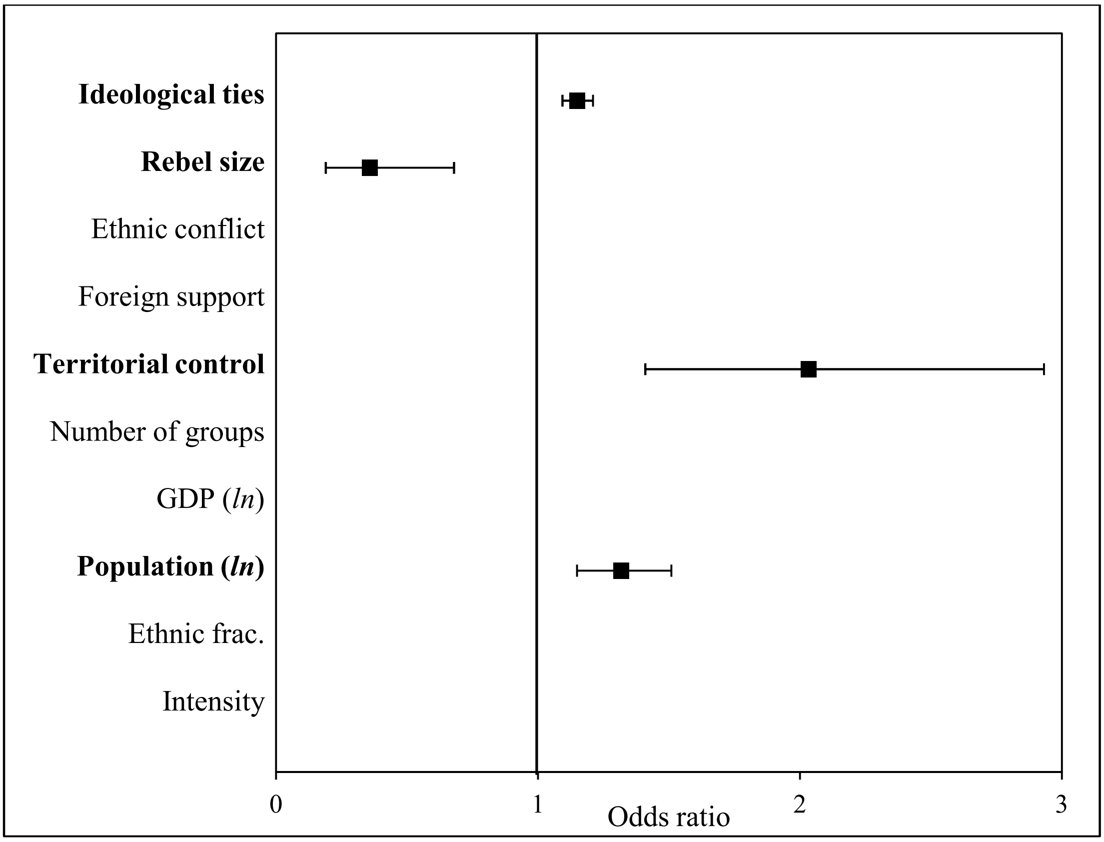


Figure 2.5 Predicted probabilities for group cooperation as a function of ideological ties (range = 0:24) generated from logistic regression

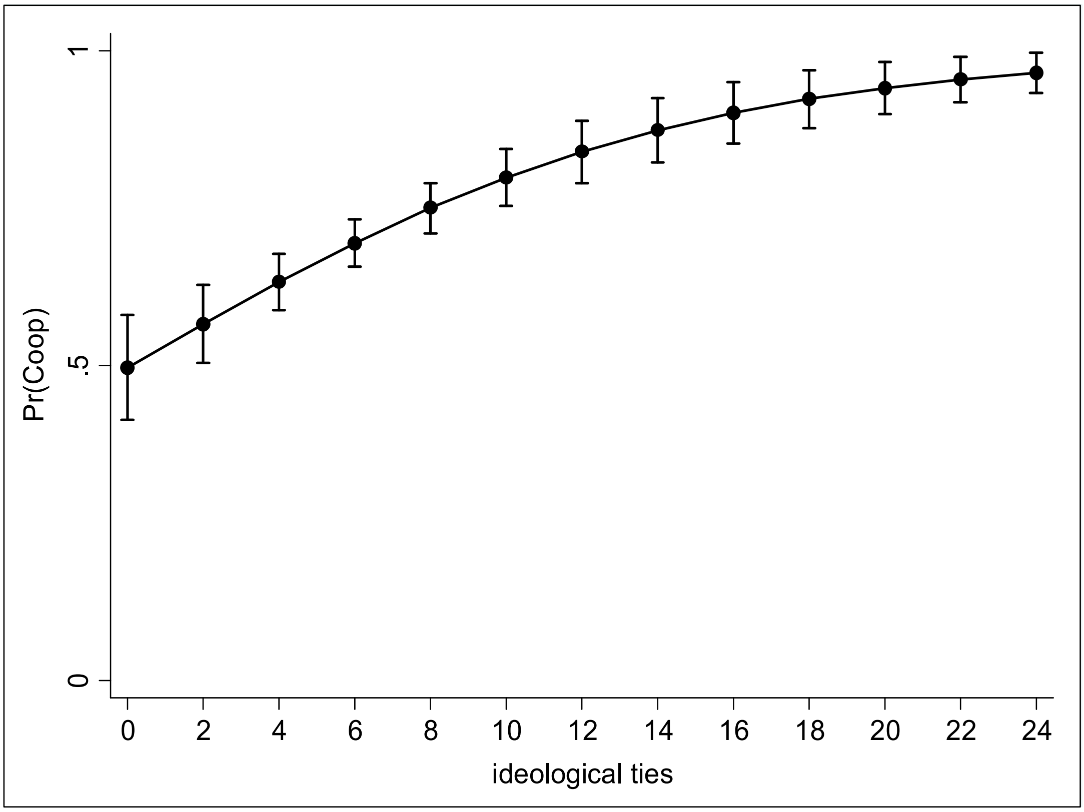
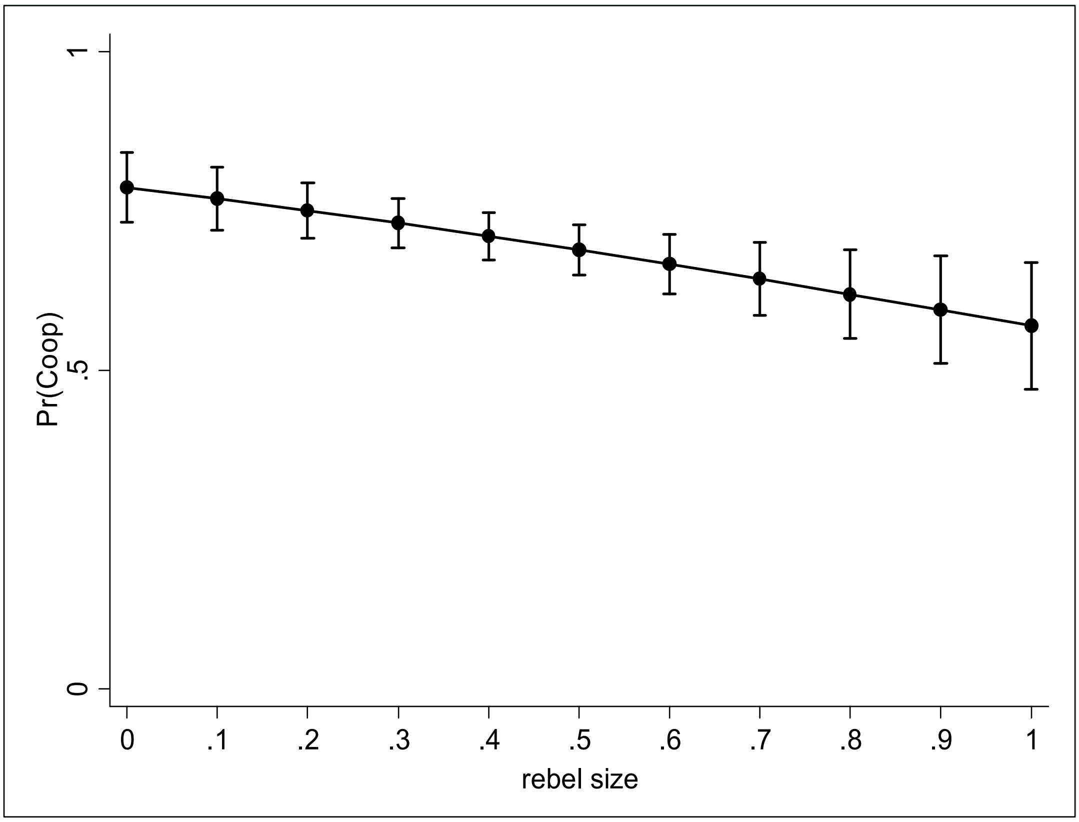


Figure 2.6 Predicted probabilities for group cooperation as a function of relative rebel group size (range = 0:1) generated from logistic regression



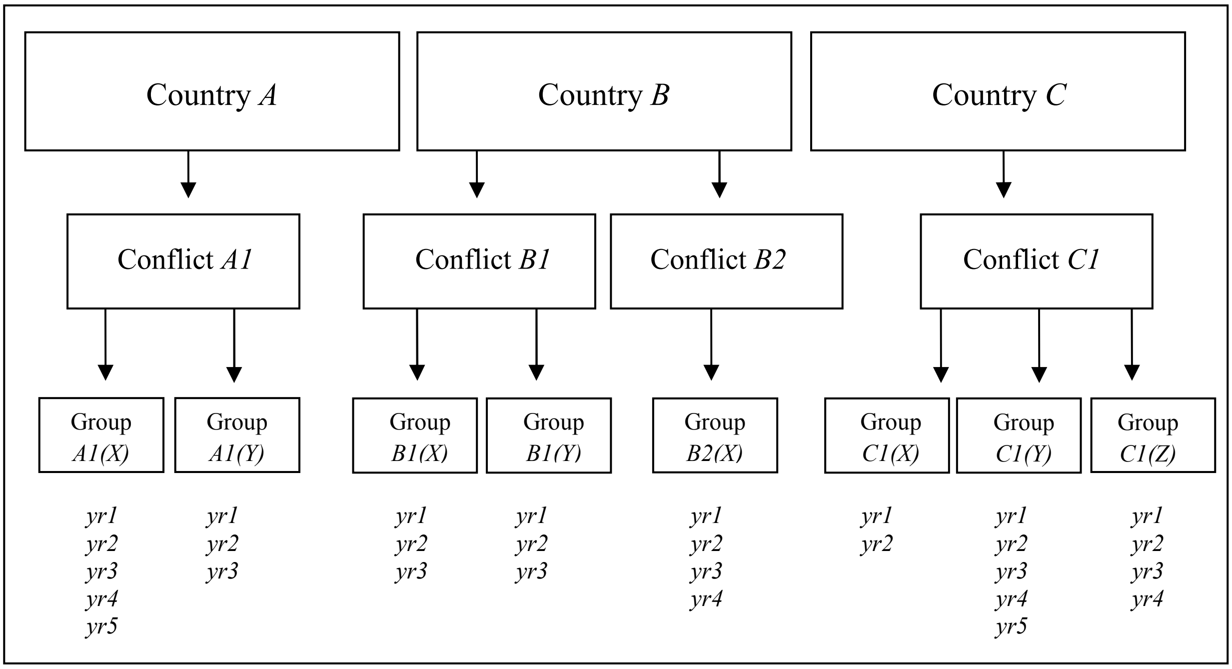
Inspection of Figure 2.5 shows a positive effect of *ideological ties* on alliance formation and the predicted values have relatively small *CIs*, indicating a high degree of confidence in these predicted values. The slope is initially steeper, particularly between lower values of *ideological ties*. Figure 2.6 shows a negative effect of *rebel size* on alliance formation, and once again the *CIs* are relatively small. The predicted probability curve in Figure 2.6 is flatter than in Figure 2.5 and not so curved at higher values of *rebel size*.

2.4.2 Robustness checks for results on rebel group cooperation

Clustering effects

One of the assumptions made in regression analysis is that the observations in the sample analysed are independent of each another. The sample used in the above analysis violates this assumption in the sense that the conflict-years for a single rebel group are related and also that the rebel groups operating in the same conflict are related. Similarly, the civil conflicts occurring in the same country are not independent of one another in the sense that they have the same national-level attributes. A graphical depiction of these nested (or clustered) levels is shown in Figure 2.7.

Figure 2.7 Nested levels for eight rebel groups, four conflicts and three countries



This aspect is important to bear in mind when considering statistical results, because in cases when observations are clustered, there could be effects that vary across clusters that are not explained by the covariates in the model. This is known as *unobserved heterogeneity* (Skrondal and Rabe-Hesketh 2004). For instance, in civil wars, different countries are likely to have different unobserved features that could influence rebel group interactions, such as societal, economic and political aspects. This means that two observations belonging to the same country could be more highly correlated than two observations belonging to different countries (Skrondal and Rabe-Hesketh 2004). These dependencies can be controlled for by using multi-level models (also known as hierarchical linear models or mixed-effects models). The main difference between multi-level models and ordinary linear regression models (and also logistic models), is that the intercepts, slopes, or both intercepts and slopes, can be allowed to vary across contexts (i.e. country, conflict or group). In the present analysis, random intercept modelling is deemed most appropriate, since it is regarded that the slopes of the regression lines are more likely than intercepts to be constant across different contexts.

Results of a multi-level logistic regression analysis are shown in Table 2.6. The levels of analysis used were as follows: *country* (level 1) and *rebel group* (level 2). Note that two levels were used instead of the three in the illustration given in Figure 2.7. This is because few countries in the sample encountered more than one civil war. The random-effects parameters are shown in the first part of Table 2.6. The estimated standard deviations in the intercepts are *5.68* for level 1 (*country*) and *2.15* for level 2 (*rebel group*). Both estimates are *>0*, indicating that there is variation between both countries and between groups. The standard deviation between countries is higher than between rebel groups, indicating a higher degree of variability between countries than there is between groups (although the standard errors for the country-level are also larger, indicting a lower degree of precision in the estimate). The main implication of this is that multi-level models are more appropriate than logistic regression for modelling rebel group cooperation. This is further confirmed by the likelihood ratio test (LR test) versus logistic regression result ($\chi^2 = 122.24$, significant at the < 0.01 level).

The second part of Table 2.6 shows the fixed-effects estimates (i.e. the logistic regression coefficients transformed into odds ratios). Results for *ideological ties, rebel size, territorial control* and *population* are all robust at the *<0.01* level, with the exception of *rebel size* which decreases in significance to the *<0.05* level. The coefficient for *intensity* gains significance compared to the earlier logistic regression analysis at the *<0.01* level.

Table 2.6 Multi-level logistic regression estimates for the determinants of cooperation

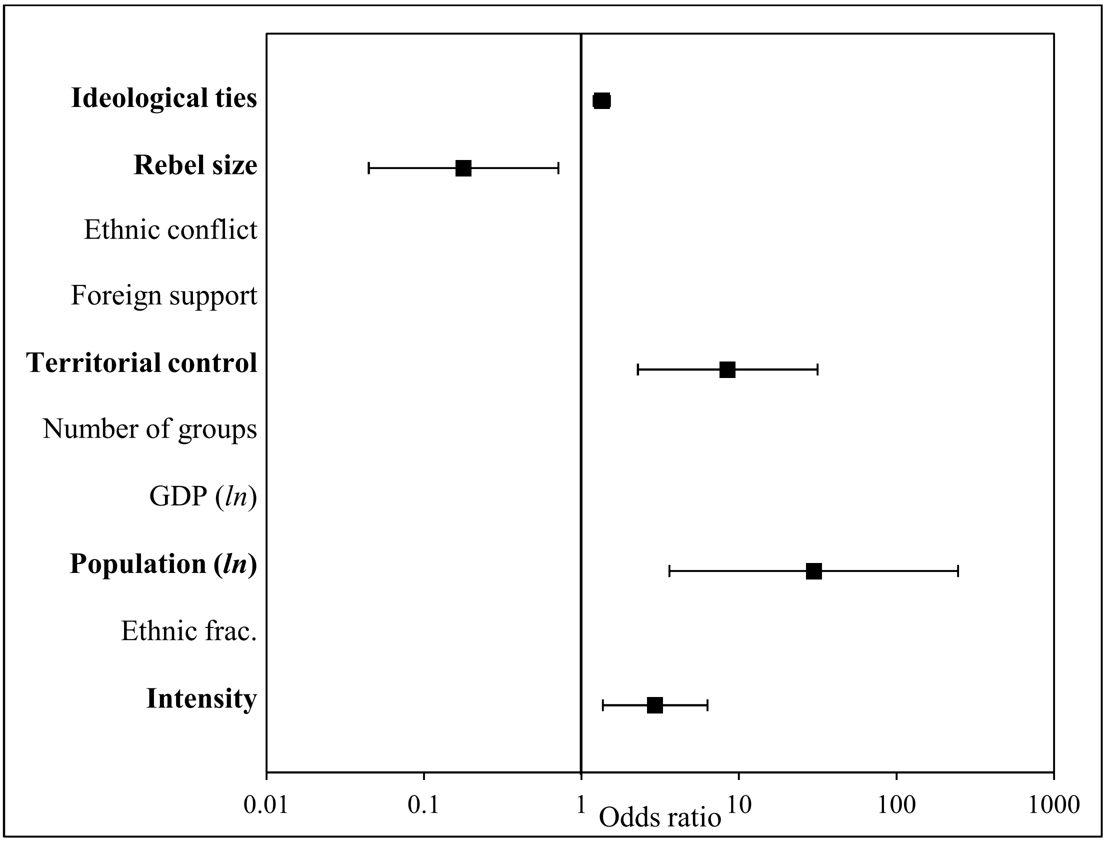
Level	N	Intercept Est. SD	Standard error
Level 1 (country)	38	5.675	1.820
Level 2 (rebel group)	200	2.147	0.509

Variable	Odds ratio	95% CI	Standard error
Ideological ties	1.34**	1.19, 1.51	0.080
Rebel size	0.18*	0.04, 0.71	0.126
Ethnic conflict	3.01	0.58, 15.76	2.543
Foreign support	0.32	0.08, 1.24	0.222
Territorial control	8.46**	2.28, 31.50	5.674
Number of groups	0.57	0.16, 2.02	0.368
***ln* [GDP]**	1.09	0.89, 1.33	0.112
***ln* [Pop]**	29.80**	3.61, 245.78	32.082
Ethnic fractionalisation	0.01	$5.36e^{-09}$, 2.44	0.001
Intensity	2.93	1.36, 6.29	1.143
Previous coop	0.24**	0.16, 0.34	0.045
Previous coop^2	1.20**	1.11, 1.28	0.040
Previous coop^3	0.99**	0.99, 1.00	0.001
Constant	$2.14e^{-22}$**	$1.61e^{-35}$, $2.85e^{-09}$	$3.30e^{-21}$
Number of obs.		1126	
Wald χ^2 (13)		143.26	
Log pseudo likelihood		-399.615	
LR vs. log.reg. χ^2 (2)		122.24**	

Note: ** denotes significance at $p \leq 0.01$, * denotes significance at $p \leq 0.05$

These results are plotted as a Forest Plot in Figure 2.8. The odds ratio for *ideological ties OR = 1.34*. This is increased compared to the logistic estimates, where the *ideological ties OR = 1.15*. The odds for *rebel size* in the multi-level model *OR = 0.18*. Once again, the effect of *rebel size* on cooperation is larger than in the logistic regression model, where the *OR = 0.36*.

Figure 2.8 Forest plot of odds ratios calculated from mixed-effects logistic regression



Selection effects

The analyses presented so far were conducted on a sample of multi-party civil conflicts, simply because group interactions can occur only if there are two or more groups operating in the same conflict. This potentially leads to the issue of sample selection bias because all conflicts containing a single rebel group are excluded. One way to check and control for this bias is to use the Heckman selection model (Heckman 1979).

Heckman selection modelling involves two stages. First, a model is formulated which predicts the probability of some outcome using observations from the entire population. Estimation of the first model yields results that can be used to generate predicted probabilities for each observation. In the second stage, selection bias is corrected by incorporating a transformation of these predicted probabilities as an independent variable in a second model.

This second model predicts the probability of a different outcome, but this time using observations from a selected sample of the population (Heckman 1979; Puhani 2000).

In the present work a two-stage Heckman selection was performed to check the robustness of results obtained in the previous analyses. As before, the unit of analysis was the conflict-year. The dependent variable for the first stage of the model is:

Multiple groups: a binary variable where *0* signifies that the rebel group operated in a two-sided conflict (i.e. a conflict involving a single rebel group) and *1* signifies that the rebel group operated in a multi-party conflict (i.e. a conflict involving two or more rebel groups).

Selecting appropriate independent variables for the first stage (to predict the outcome *multiple groups*) is tricky because previous research has not addressed the specific question of why multi-party wars arise in the first place, or indeed, why some conflicts involve larger numbers of rebel groups. As such, the stage 1 independent variables used in the present analysis are selected on the basis of their association with the likelihood of civil war. If an independent variable is highly associated with an increased likelihood of civil war, it is possible that the same independent variable will also be associated with larger numbers of groups. This argument is based on the notion that if some factor increases the *opportunity* for civil war, it may also increase the opportunity for the numbers of rebel groups. On this basis, three independent variables were selected and used in the first stage to predict multiple groups. The coding and description for why these variables were used, is provided below.

Military quality (expressed as the natural logarithm, ln[military quality]): a proxy for state strength that is widely used and recommended by Bennett and Stam (1996). Military quality is calculated by taking the military expenditure of a country divided by the number of military personnel, transformed by taking the natural log. Data are taken from Lacina (2006). This variable is included because state strength is associated with conflict opportunity. Previous research has shown that poorer states are more likely to experience civil war (Collier 2000, Collier and Hoeffler 2004; 2007, Fearon and Laitin 2003). Thus, if state weakness provides more opportunity for civil conflict, it could be argued that weak states would be more likely to have larger numbers of rebel groups.

Democracy: a continuous variable ranging between *0* and *10*, where *10* signifies that the country is entirely democratic and *0* signifies that the country is entirely undemocratic. Data are taken from Lacina (2006). This variable is included because democracy is also associated with conflict opportunity. Hegre *et al.* (2001) have shown that mixed regimes, which are neither fully democratic, nor extremely repressive, are most likely to experience internal conflict. This argument is based on the notion that highly authoritarian states are less likely to experience civil war because potential rebels are less likely to mobilise when they perceive the cost of group formation to be high. Highly democratic states are also less likely to experience civil conflict because they have institutionalised channels through which opposition groups can be accommodated (Tilly, 1978). In the middle of the range however, where regimes are not repressive enough to prevent mobilisation but also not accommodative enough to channel opposition through institutional mechanisms, conflict is most likely (Muller and Weede 1990; Hegre *et al*. 2001; Fearon and Laitin 2003). Thus, if intermediate levels of democracy are associated with increased opportunity for conflict, it could be argued that these states will be prone to conflicts with higher numbers of rebel groups.

Ethnic fractionalisation: coded as before. The association between ethnic heterogeneity (either polarisation or fractionalisation) and the likelihood of civil war has been an area of hot debate. Polarisation occurs when a society is divided into a small number of large groups, whereas fractionalisation occurs when a society is divided into a large number of small groups. Some research has shown that the likelihood of civil war is increased when states are highly ethnically fractionalised, but not when they are ethnically polarised (Collier and Hoeffler 2004). Other research has shown that the relationship between ethnic fractionalisation and the likelihood of civil war is weak, but that civil war is most likely when societies are highly ethnically polarised (Garcia-Montalvo and Reynal-Querol 2004; Østby 2008). The rationale behind these arguments is that heterogeneous societies, which are divided along ethnic lines, are more prone to grievances arising between groups. In turn, these grievances increase the likelihood of war. If ethnic heterogeneity increases the likelihood of war, it could also be argued that it increases the numbers of rebel groups that are motivated to participate in war.

In the present analysis, the second stage of the Heckman selection model is the same as the logistic regression model presented earlier except that a term containing the transformed predicted probabilities from the first stage is included. Descriptive statistics for all variables used in the analysis are presented in Table 2.7.

The sample used in the Heckman selection model consisted of *1434* conflict-years (*+308*), *276* rebel groups (*+67*), *116* conflicts (*+67*) and *86* countries (*+47*), where the parentheses relate to the addition of data for two-sided wars.

Table 2.8 displays the Spearman rank correlations between the variables. The variables are broadly independent of one another, with the exception of three pairs of variables, which are underlined in Table 2.8. These pairs are *ideological ties* and *rebel size* (*-0.59*), *ideological ties* and *number of groups* (*0.77*) and *rebel size* and *number of groups* (*-0.64*). The presence of multicolinearity in these pairs is not a confounding issue however. Only multi-party conflicts are analysed in the second stage of the model, and the independent variables used in the second stage do not co-vary (as demonstrated in Table 2.4).

Table 2.7 Descriptive statistics of variables used for the Heckman selection model

	Variable type	Variable	Obs.	Mean	SD	Min	Max
Stage 1	**Dependent variable**	Multiple groups	*1434*	*0.79*	*0.41*	*0*	*1*
	Independent variables	*ln*[Mil. quality]	*1183*	*7.74*	*1.17*	*0.92*	*11.12*
		Democracy	*982*	*3.36*	*3.85*	*0*	*10*
		Ethnic frac.	*1431*	*0.52*	*0.28*	*0.01*	*.90*
Stage 2	**Dependent variable**	Cooperation	*1434*	*0.53*	*0.50*	*0*	*1*
	Independent variables	Ideological ties	*1434*	*5.08*	*4.99*	*0*	*24*
		Rebel size	*1434*	*0.41*	*0.26*	*0.06*	*1*
	Control variables	Ethnic conflict	*1434*	*0.42*	*0.49*	*0*	*1*
		Foreign support	*1433*	*0.88*	*0.33*	*0*	*1*
		Terr. control	*1433*	*0.43*	*0.50*	*0*	*1*
		N groups	*1434*	*3.21*	*1.83*	*1*	*8*
		ln [GDP]	*1434*	*4.99*	*5.16*	*0.15*	*40.70*
		ln [Pop]	*1434*	*16.74*	*1.37*	*12.85*	*20.89*
		Ethnic frac.	*1431*	*0.52*	*0.28*	*0.01*	*0.90*
		Intensity	*1434*	*1.22*	*0.41*	*1*	*2*

Results of an analysis using a two-stage Heckman selection model are shown in Table 2.9. In stage 1, all three independent variables have a statistically significant effect on the ’*multiple groups’* outcome. *Military quality* has a negative effect *OR = 0.77* (at the *<0.01* level), indicating that there is an inverse relationship between state strength and the number of groups in a conflict. The causality of this effect is not easy to envisage however. It could be argued that the presence of a weak state encourages more rebel groups to engage in conflict in the first place. Alternatively, it could be argued that the presence of multiple groups could weaken a state more than if it was fighting a single rebel group.

Democracy has a positive effect *OR = 1.04* (at the *<0.01* level), indicating that democratic states are more likely to have multi-party conflicts. *Ethnic fractionalisation* also has a positive effect *OR = 3.83* (at the *<0.01* level), indicating that multi-party conflicts are more likely to occur in ethnically heterogeneous countries. These results are illustrated in a Forest Plot in Figure 2.9. Predicted probabilities are plotted for *military quality* and *ethnic fractionalisation* in Figures 2.10 and 2.11. Overall, these results suggest that societal factors, as opposed to state factors, are the dominant explanation for why multi-party conflicts might arise in the first place.

Table 2.8 Correlation matrix for Heckman selection model (Spearman rank correlation)

	Ideol. ties	Rebel size	Ethnic conflict	Foreign support	Terr. control	*N* groups	GDP *ln*	Pop *ln*	Ethnic frac.	Intens.	Mil. qual. *ln*	Democ.
Ideological ties	*1.00*											
Rebel size	*-0.59*	*1.00*										
Ethnic conflict	*-0.33*	*0.26*	*1.00*									
Foreign support	*0.04*	*0.05*	*0.18*	*1.00*								
Terr. Control	*-0.03*	*0.02*	*0.22*	*0.11*	*1.00*							
***N* groups**	*0.77*	*-0.64*	*-0.28*	*0.14*	*0.16*	*1.00*						
***ln* [GDP]**	*-0.14*	*0.11*	*0.09*	*0.05*	*0.01*	*-0.26*	*1.00*					
***ln* [Pop]**	*-0.14*	*0.04*	*0.32*	*0.00*	*-0.11*	*-0.10*	*-0.13*	*1.00*				
Ethnic frac.	*0.15*	*-0.20*	*-0.06*	*-0.07*	*-0.14*	*0.20*	*-0.35*	*0.14*	*1.00*			
Intensity	*0.19*	*-0.02*	*-0.04*	*0.07*	*0.24*	*0.22*	*-0.18*	*-0.13*	*0.03*	*1.00*		
***ln* [Mil. quality]**	*-0.22*	*0.17*	*-0.16*	*-0.28*	*-0.11*	*-0.27*	*0.09*	*-0.01*	*0.25*	*-0.08*	*1.00*	
Democracy	*-0.15*	*0.04*	*-0.08*	*-0.03*	*-0.18*	*-0.19*	*0.19*	*0.37*	*-0.14*	*-0.21*	*0.14*	*1.00*

Table 2.9 Heckman selection model estimates for the determinants of cooperation

Stage	Variable	Coefficient	Standard error
1	**Military quality *ln***	***-0.266*****	*0.046*
	Democracy	***0.041*****	*0.016*
	Ethnic fractionalisation	***1.342*****	*0.187*
	Constant	*2.069*	*0.286*
2	**Ideological ties**	***0.023*****	*0.004*
	Rebel size	***-0.171*****	*0.057*
	Ethnic conflict	***-0.075****	*0.037*
	Foreign support	*-0.042*	*0.051*
	Territorial control	***0.179*****	*0.034*
	Number of groups	***-0.043*****	*0.014*
	***ln* [GDP]**	*0.005*	*0.007*
	***ln* [Pop]**	*0.024*	*0.014*
	Ethnic fractionalisation	*0.121*	*0.105*
	Intensity	*0.037*	*0.035*
	Previous coop	***-0.331*****	*0.023*
	Previous coop^2	***0.040*****	*0.004*
	Previous coop^3	***-0.001*****	*0.001*
	Constant	*0.199*	*0.292*
	Mills (lambda)	*0.179*	*0.155*
	Number of obs.	*798*	
	Censored / uncensored obs.	*174 / 624*	
	Wald χ^2 (13)	*535.60*	
	Rho, Sigma	*0.496, 0.362*	

*Note: ** denotes significant at $p \leq 0.01$, * denotes significant at $p \leq 0.05$*

One limitation of the stage 1 model is that the outcome variable, *multiple groups*, is coded as a binary variable instead of a continuous variable. This is a requirement of the Heckman selection model, which uses observations coded with *'1'* (i.e. multi-party conflicts) in the second stage. As a result of this, information regarding the possible effect of the independent variables on the number of groups in a conflict may be lost. A further discussion of this issue with some additional statistical modelling that considers the number of rebel groups as a continuous variable is given in Appendix I. The possibility of a curvilinear relationship between *democracy* and *number of groups* is also discussed in Appendix I.

A second limitation of the stage 1 model is the potential for endogeneity (that is, where an uncontrolled endogenous variable is correlated with the error term). In this case, endogeneity may arise because there is potentially an unspecified confounding variable that has an effect on the number of groups (the dependent variable), and the independent variables in stage 1, and/or the variables in stage 2. As such, future research that seeks to investigate the causes of multi-party conflict should take this aspect into account.

For stage 2, the results for *ideological ties*, *rebel size* and *territorial control* are robust, although the size of the effect for all variables has decreased. The negative coefficients for *ethnic conflict* and *number of groups* both gain significance (at the *<0.05* and *<0.01* levels respectively). These results are plotted as Forest Plot in Figure 2.12.

Figure 2.9 Forest plot of odds ratios calculated from Heckman selection model stage 1

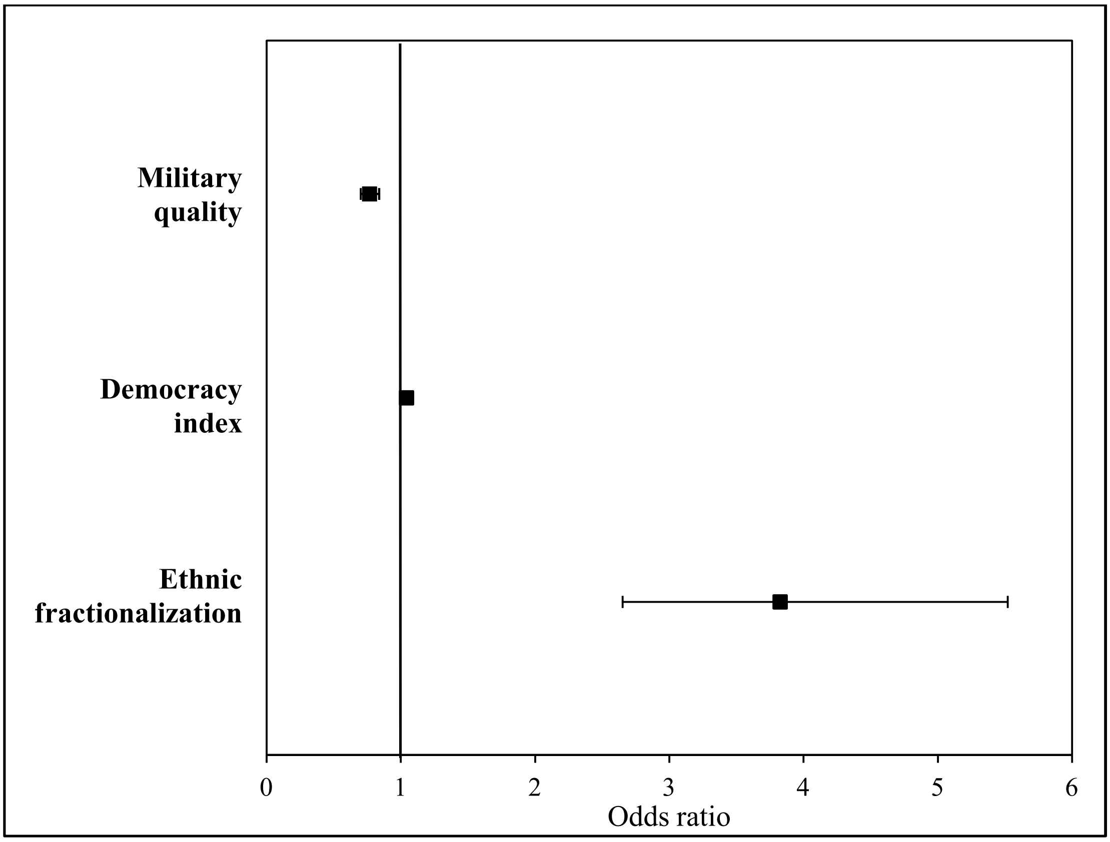


Figure 2.10 Predicted probabilities of multi-party conflict as a function of military quality (range = 0:12) generated from Heckman selection estimates

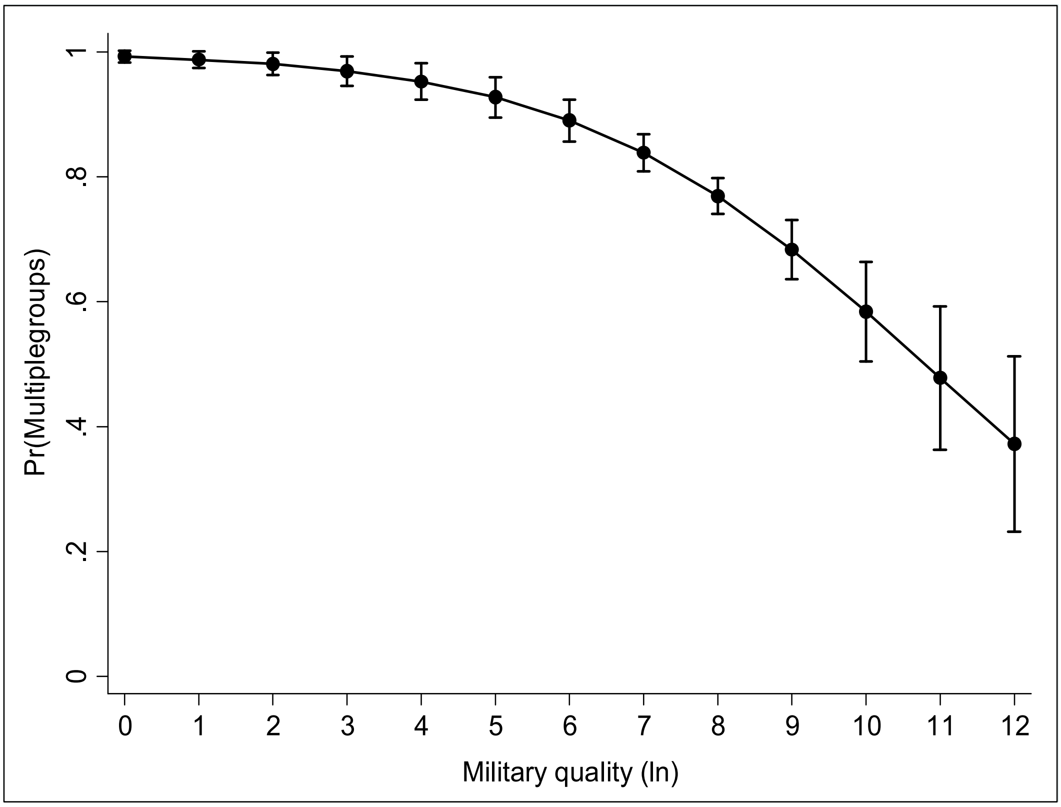


Figure 2.11 Predicted probabilities of multi-party conflict as a function of ethnic fractionalisation (range = 0:1) generated from Heckman selection estimates

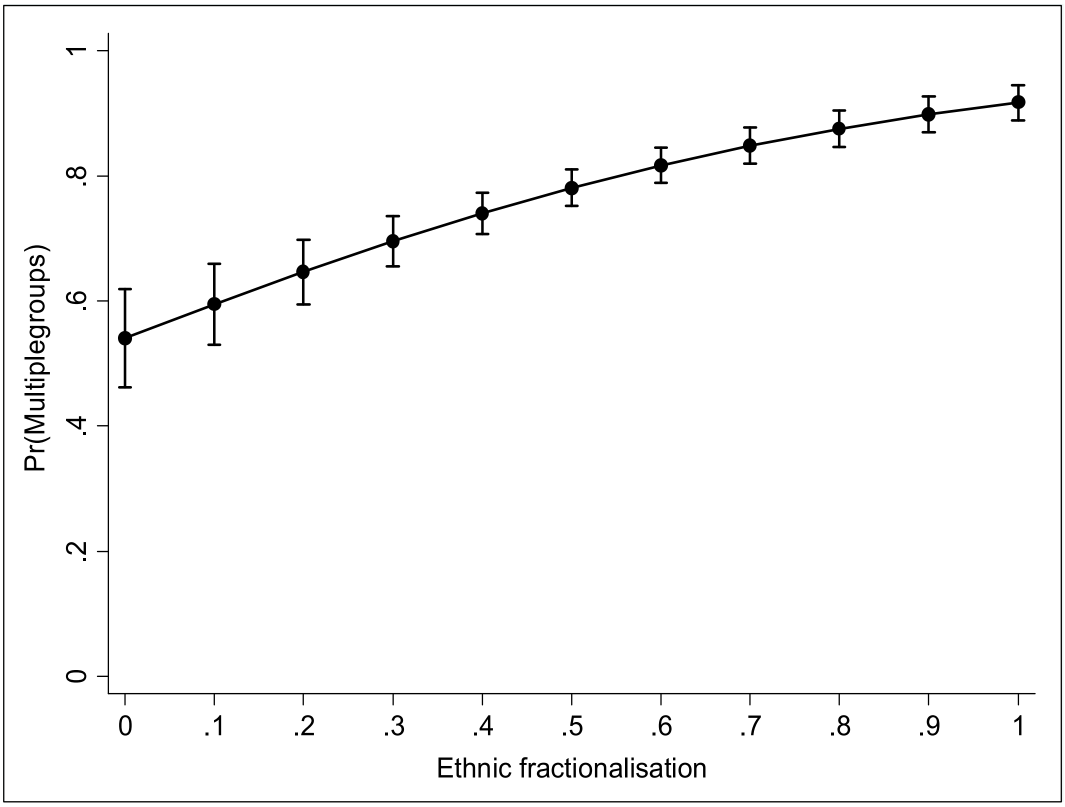
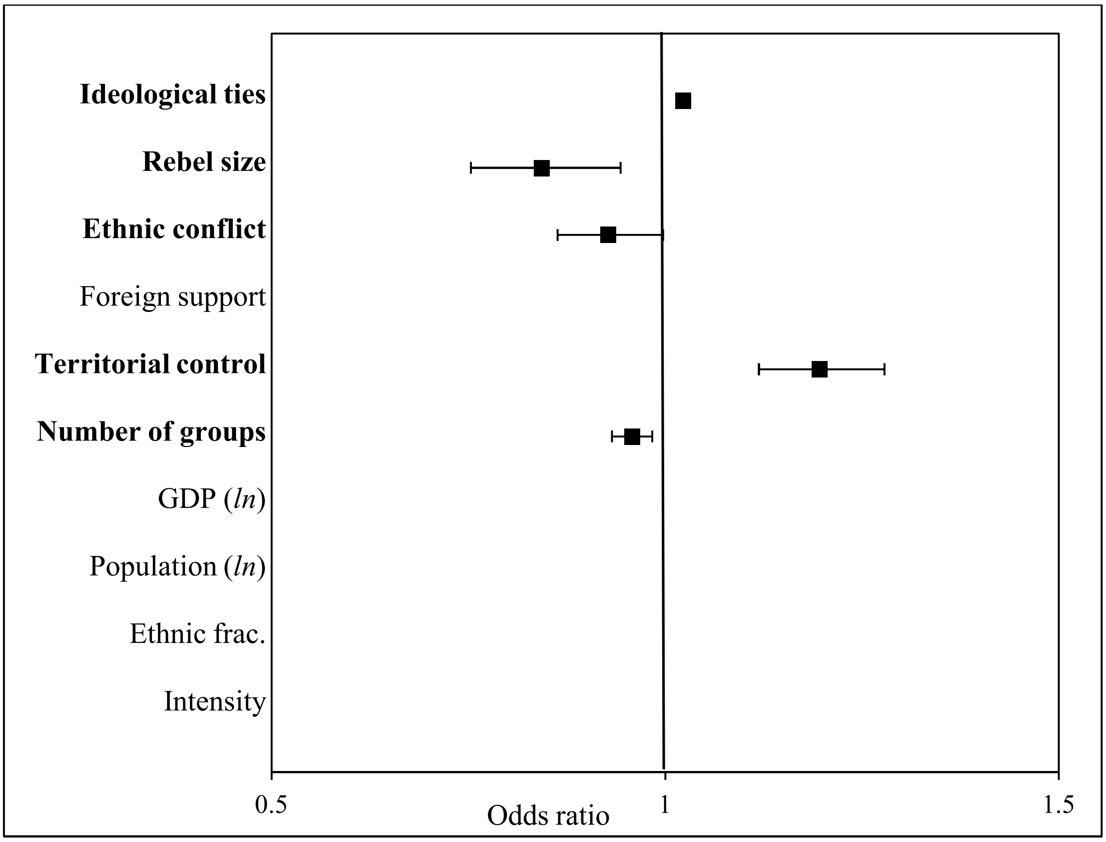


Figure 2.12 Forest plot of odds ratios calculated from stage 2 of the Heckman model



Overall, the above analysis confirms that there is no effect of selection bias in the sample analysed. The estimated selection coefficient, *lambda* $= 0.179$, $p > 0.05$ is not statistically significant, which means that rebel groups operating in multi-party conflicts have the same characteristics (with regards to cooperation) as observed in a sample drawn randomly from the entire population. The implication of this is that the results obtained in previous models are not influenced by sample selection bias.

2.4.3 Modelling the determinants of rebel group fighting

The analyses presented so far have considered rebel group alliances. The following consider inter-rebel violence. Table 2.10 shows logistic regression estimates for the determinants of rebel group fighting. Descriptive statistics and correlations relating to the independent variables are the same as in the previous logistic regression analysis.

The odds ratio for *ideological ties* is not statistically significant, so that no evidence is found in support of hypothesis 3. The result for, *rebel size*, is significant (at the <0.01 level) and the odds ratio $OR = 3.96$. This means that there is about *300%* increase in the likelihood of inter-rebel violence for every unit increase in *rebel size*.

Table 2.10 Logistic regression results for the determinants of fighting

Variable	Odds ratio	*95%* CI	Standard error
Ideological ties	1.03	0.98, 1.10	0.031
Rebel size	3.96**	1.76, 8.91	1.639
Ethnic conflict	1.06	0.64, 1.76	0.275
Foreign support	2.16*	0.98, 4.73	0.865
Territorial control	1.16	0.73, 1.81	0.265
Number of groups	1.14	0.97, 1.33	0.089
***ln* [GDP]**	0.99	0.93, 1.04	0.027
***ln* [Pop]**	1.07	0.88, 1.31	0.107
Ethnic fractionalisation	0.32*	0.13, 0.80	0.150
Intensity	1.24	0.73, 2.11	0.337
Previous fight	0.51**	0.42, 0.63	0.054
Previous fight^2	1.04**	1.02, 1.06	0.011
Previous fight^3	0.99**	0.99, 1.00	0.001
Constant	0.02*	0.01, 0.55	0.030
Number of obs.		1126	
LR χ^2 (13)		123.10	
Log likelihood		-292.030	
Pseudo R^2		0.17	

Note: ** *denotes significance at* $p \leq 0.01$, * *denotes significance at* $p \leq 0.05$

With regards to the control variables, the result for *foreign support* is positive (*OR = 2.16*) and significant (at the <*0.05* level), indicating that rebel groups who receive support from external actors are more likely to engage in inter-rebel violence. There is over *100%* increase in the likelihood of inter-rebel violence for every unit increase in *foreign support*. This analysis supports the findings of Fjelde and Nilsson (2012).

The coefficient for *ethnic fractionalisation* is also significant (at the <*0.05* level) with an *OR = 0.32*, indicating that rebel groups operating in countries with ethnically heterogeneous societies are less likely to fight with other groups.

The results shown in Table 2.10 are plotted as a Forest Plot in Figure 2.13. Predicted probabilities for a range of assumed values of *rebel size* are shown in Figure 2.14.

Figure 2.13 Forest plot of odds ratios calculated from logistic estimates for fighting

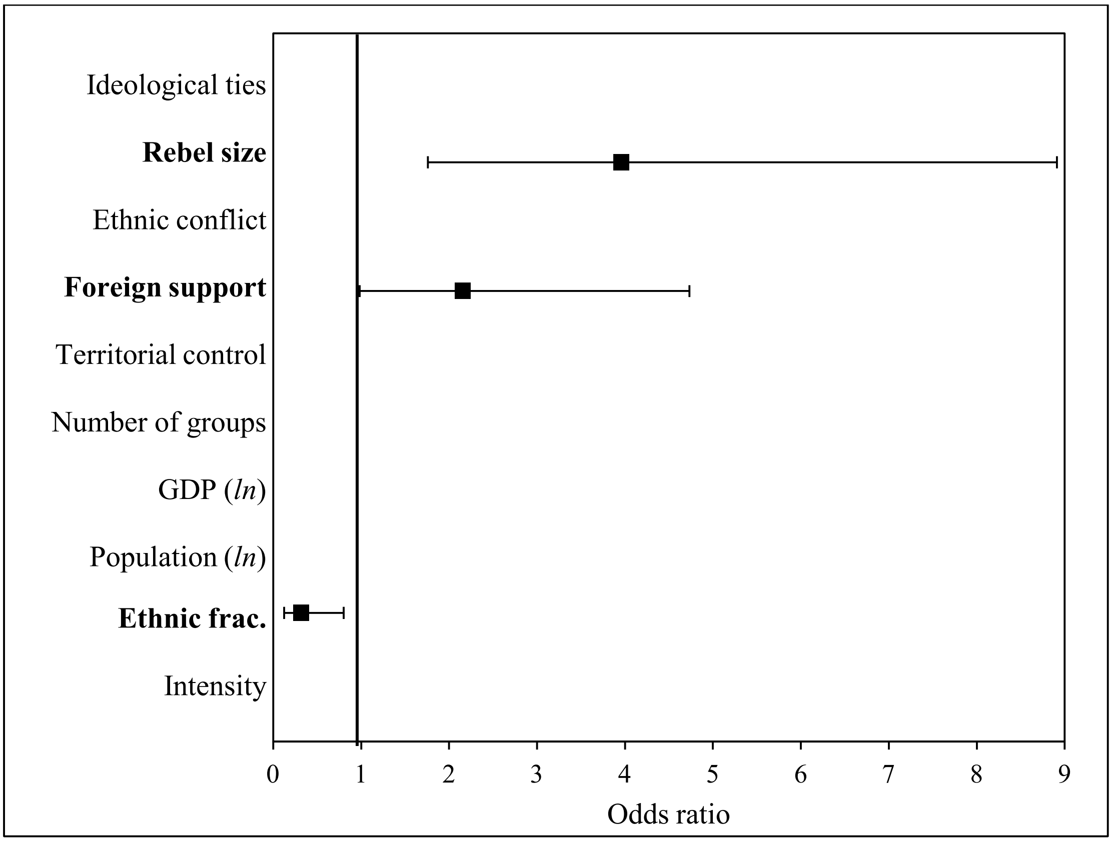
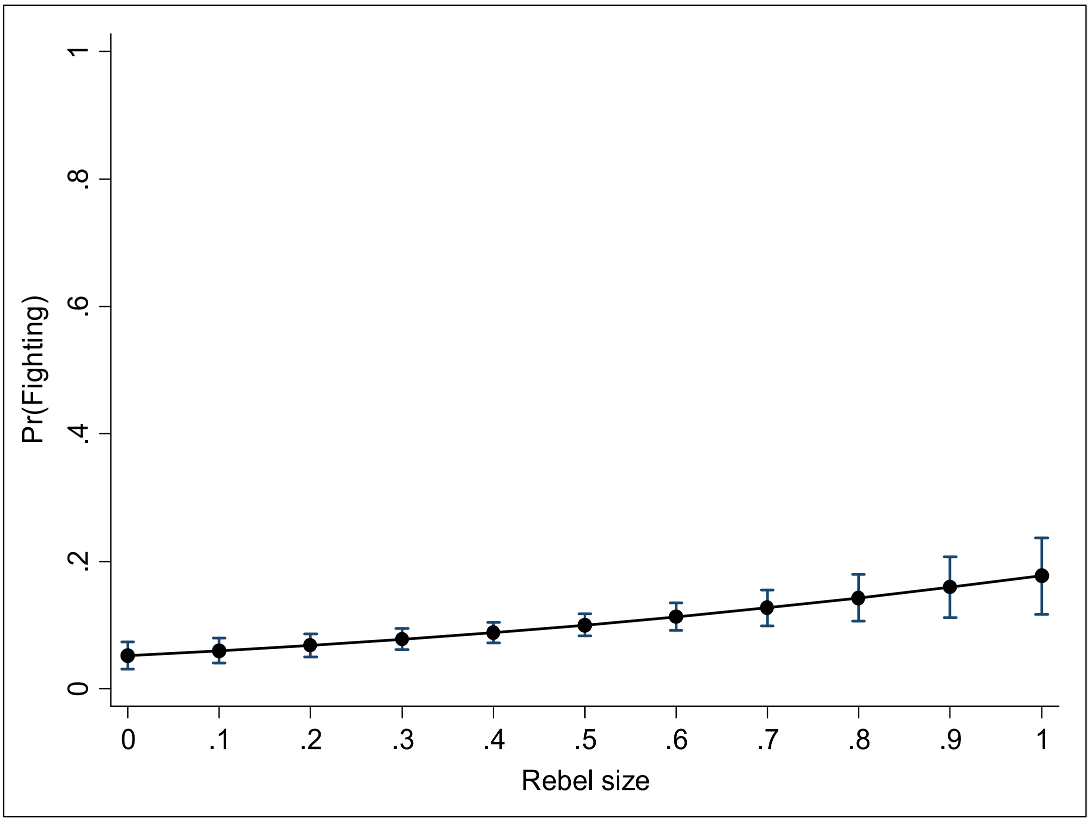


Figure 2.14 Predicted probabilities of inter-rebel violence for a range of assumed values of relative rebel group size (range = 0:1) generated from logistic regression estimates



To test hypothesis 4, namely that both larger groups *and* smaller groups have an increased likelihood of engaging in inter-rebel violence, the independent variable, *rebel size*, was coded into two separate independent variables as follows:

Strong rebels: a binary variable where *1* signifies that the group size was ≥ *75%* of the sum of all group sizes in the conflict, and *0* signifies that the group size was < *75%* of the sum of all group sizes.

Weak rebels: a binary variable where *1* signifies that the group size was < *25%* of the sum of all group sizes in the conflict, and *0* signifies that the group size was ≥ *25%* of the sum of all group sizes.

Descriptive statistics of these two variables are shown in Table 2.11, which shows that *14%* of rebel groups were strong relative to their peers, whereas *36%* of the groups were weak relative to their peers.

Table 2.11 Descriptive statistics for the variables strong rebels and weak rebels

Level	Variable	Obs.	Mean	SD	Min	Max
Rebel group-level	Strong rebels	*1126*	*0.14*	*0.34*	*0*	*1*
independent variables	Weak rebels	*1126*	*0.36*	*0.48*	*0*	*1*

The results of a logistic regression analysis performed with these two independent variables are shown in Table 2.12. The odds ratios for *strong rebels* and *weak rebels* are both greater than *1* and significant at the *<0.01* and *<0.05* levels respectively. This indicates that there is an increased probability of inter-rebel violence for both large and small rebel groups, thus providing evidence in support of hypothesis 4. The standard errors on these two variables are lower than the standard errors observed on the *rebel size* variable in the previous model which is indicative of a better fit.

The overall model fit has also improved (as is evident in the pseudo R^2 parameter which has increased from *0.17* in the previous model to *0.21*). The result for *foreign support* is robust but the coefficient on *ethnic fractionalisation* loses statistical significance. Odds ratios for the significant relationships are plotted as a Forest Plot in Figure 2.15. The predicted probabilities for *strong rebels* and *weak rebels* are plotted in Figures 2.16 and 2.17 respectively. Both figures show increases in the probabilities of fighting for groups that are relatively strong and relatively weak compared to their peers. The slope of the curve in Figure 2.16 is steeper than that in Figure 2.17, indicating that the probability of inter-rebel violence increases more markedly for *strong rebels* than for *weak rebels*.

Table 2.12 Logistic regression estimates for the determinants of fighting with inclusion of the independent variables *strong rebels* and *weak rebels*

Variable	**Odds ratio**	***95%* CI**	**Standard error**
Ideological ties	*1.03*	*0.97, 1.09*	*0.032*
Strong rebels	***6.21*****	*3.33, 11.56*	*1.971*
Weak rebels	***1.79*****	*0.99, 3.21*	*0.535*
Ethnic conflict	*0.89*	*0.52, 1.52*	*0.242*
Foreign support	***2.27****	*1.02, 5.06*	*0.928*
Territorial control	*0.95*	*0.59, 1.52*	*0.227*
Number of groups	*1.09*	*0.93, 1.28*	*0.090*
***ln* [GDP]**	*0.99*	*0.93, 1.04*	*0.027*
***ln* [Pop]**	*1.11*	*0.90, 1.36*	*0.116*
Ethnic fractionalisation	*0.50*	*0.19, 1.29*	*0.242*
Intensity	*1.11*	*0.65, 1.93*	*0.311*
Previous fight	***0.55*****	*0.45, 0.68*	*0.059*
Previous fight^2	***1.03*****	*1.01, 1.05*	*0.011*
Previous fight^3	***1.00****	*1.00, 1.00*	*0.001*
Constant	***0.01****	*0.00, 0.41*	*0.020*
Number of obs.		*1126*	
LR χ^2 (14)		*147.01*	
Log likelihood		*-280.08*	
Pseudo R^2		*0.21*	

*Note: ** denotes significance at $p \leq 0.01$, * denotes significance at $p \leq 0.05$*

Figure 2.15 Forest plot of odds ratios calculated from logistic estimates for fighting

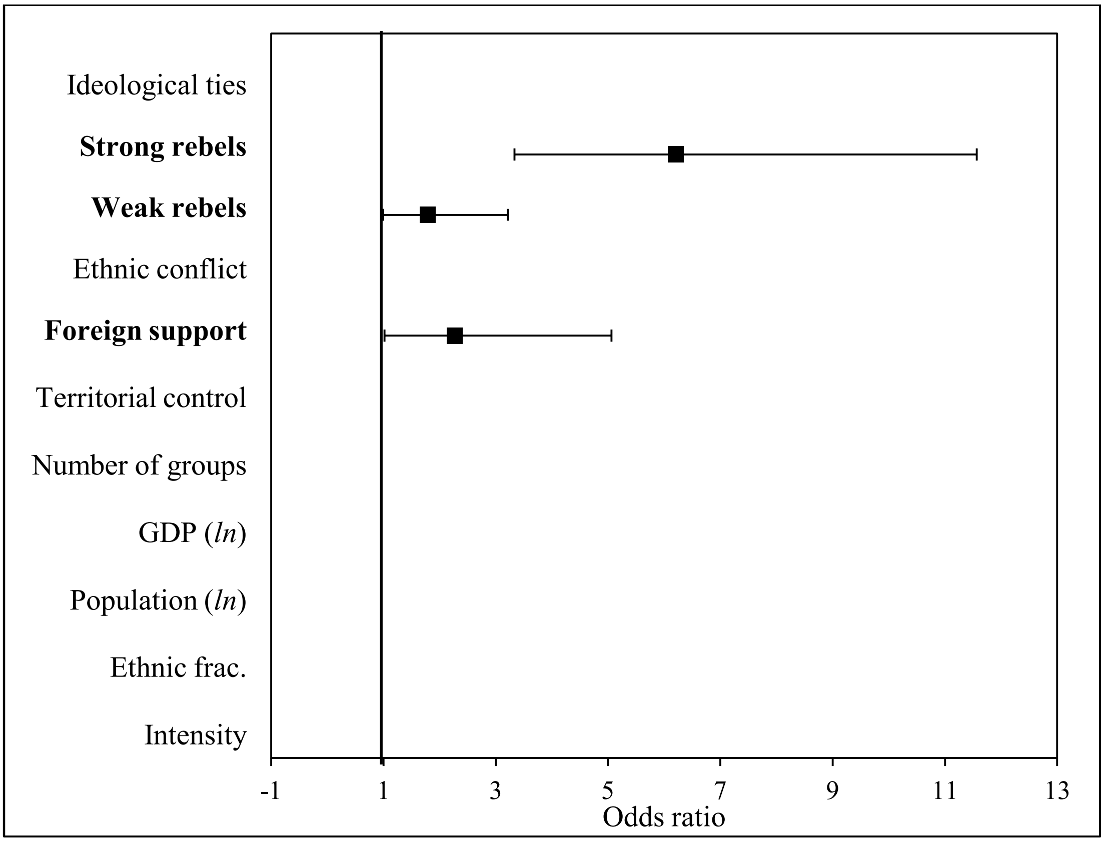


Figure 2.16 Predicted probabilities of inter-rebel violence for a range of assumed values of the variable strong rebels (range = 0:1) generated from logistic regression estimates

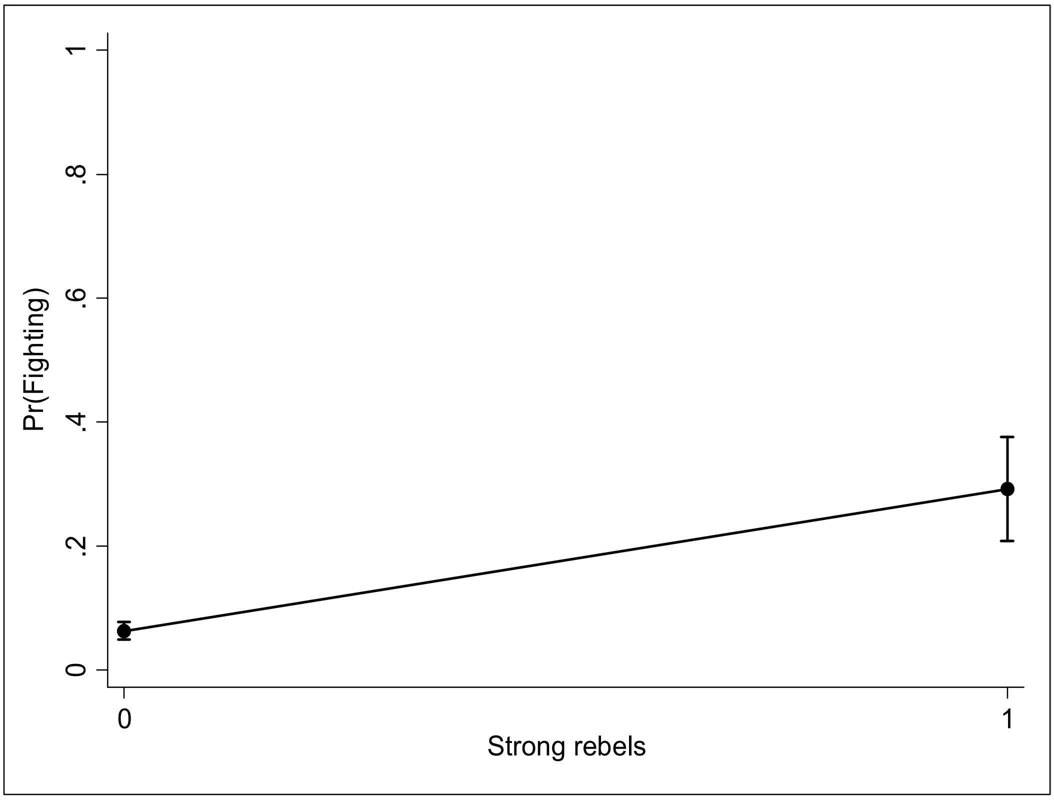
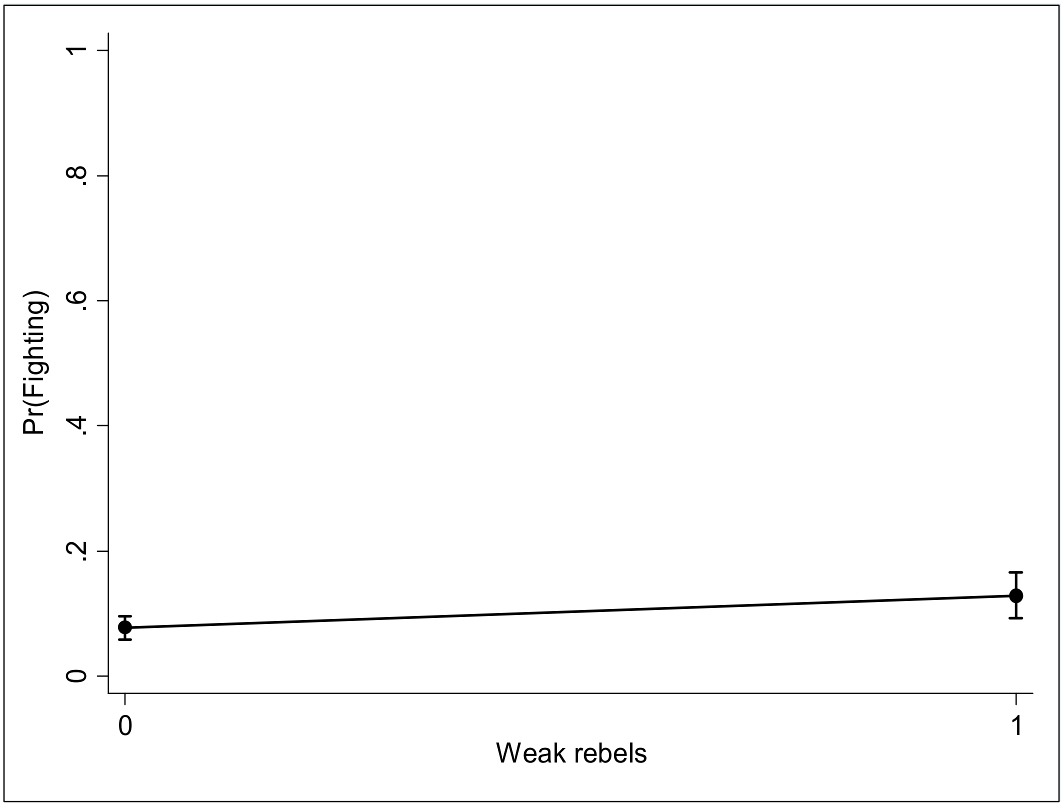


Figure 2.17 Predicted probabilities of inter-rebel as a function of the variable weak rebels (range = 0:1) generated from logistic regression estimates



An alternative way to test for a *U-shape* effect is to include the squared term of *rebel size*. The model was re-run (as shown in Table 2.10) but with the inclusion of the term, *rebel size*^{2}. The result for *rebel size*^{2} was significant at the <0.05 level with an odds ratio = *53.50*. But the confidence intervals were very large (*2.16, 1323.80*) indicating a low degree of confidence over the estimate. The inclusion of the term, *rebel size*^{2} improved the pseudo R^2 parameter from *0.17* to *0.18* (compared to the original model shown in Table 2.10) but worsened the fit from the previous model (shown in Table 2.12), which had a pseudo $R^2 = 0.21$.

2.4.4 Robustness checks for results on rebel group fighting

Clustering effects

Results of a multi-level logistic regression are shown in Table 2.13. The significant effects for the variables, *weak rebels, foreign support* and *ethnic fractionalisation*, are lost from the previous logistic regression analyses. Only the variable, *strong rebels*, which has an odds ratio $OR = 10.18$ (significant at the <0.01 level) is robust when clustering effects are controlled for.

This has implications for hypothesis 4, since it suggests that groups who are militarily large relative to their peers have an increased likelihood of inter-rebel violence, but that groups who are militarily weak relative to their peers do not. One possible explanation for this effect could be that large rebel groups target other large groups because there is a higher degree of competition between larger groups. As Fjelde and Nilsson (2012) point out, groups must compete for the spoils of war, for recruits and for power, so although large groups potentially have more to lose by engaging in combat with their larger peers, they also have more to gain if they emerge victorious.

The standard deviations of the intercept estimates are *3.18* for level 1 (*country*) and *1.03* for level 2 (*rebel group*). Once again, both estimates are >0, indicating that there is variability between countries and between groups.

Table 2.13 Multi-level logistic regression estimates for the determinants of fighting

Level	*N*	Intercept Est. SD	Standard error
Level 1 (country)	38	3.182	0.970
Level 2 (rebel group)	200	1.025	0.399

Variable	Odds ratio	*95%* CI	Standard error
Ideological ties	0.96	0.88, 1.06	0.046
Strong rebels	10.18**	3.61, 28.68	5.380
Weak rebels	2.12	0.87, 5.09	0.948
Ethnic conflict	0.57	0.14, 2.38	0.417
Foreign support	2.22	0.64, 7.75	1.416
Territorial control	0.60	0.24, 1.53	0.287
Number of groups	1.30	0.57, 2.95	0.544
ln [GDP]	1.05	0.90, 1.24	0.086
ln [Pop]	2.73	0.86, 8.52	1.602
Ethnic fractionalisation	0.04	0.01, 9.46	0.108
Intensity	0.70	0.31, 1.54	0.283
Previous fight	0.71**	0.54, 0.93	0.096
Previous fight^2	1.01	0.98, 1.04	0.013
Previous fight^3	0.99	0.99, 1.00	0.001
Constant	$2.49e^{-09}$*	$2.30e^{17}$, 0.27	$2.35e^{081}$
Number of obs.		1126	
Wald χ^2 (14)		43.72	
Log pseudo likelihood		-248.615	
LR vs. log.reg. χ^2 (2)		64.08**	

*Note: ** denotes significance at $p \leq 0.01$, * denotes significance at $p \leq 0.05$*

Results of a two-stage Heckman selection model for inter-rebel violence are shown in Table 2.14. The results obtained in stage 1 are identical to those obtained in stage 1 for the cooperation model. Unlike the Heckman selection model for cooperation however, the estimated selection coefficient lambda[†] is statistically significant (*lambda = 0.259*, significant at the <*0.05* level). This means that rebel groups operating in multi-party conflicts have different characteristics (with regards to fighting) than observed in a sample drawn randomly from the entire population. As such, sample selection bias is a confounding factor in the models presented earlier and hence the Heckman selection model provides superior estimates for predictions of rebel group fighting. Notice also that the standard errors on the coefficients have decreased; an outcome which is also indicative of an improved model.

[†] Lambda is calculated by multiplying the model parameters rho and sigma, where rho is the correlation coefficient between the unobserved variables that determine selection into stage 2 and the unobserved variables that determine rebel group fighting (= *0.825*) and sigma is the adjusted standard error for stage 2 (= *0.266*).

Results for *strong rebels* and *weak rebels* are robust with respective odds ratio *OR = 1.09* and *1.07* (both significant at the *<0.01* level). The previous result obtained on *foreign support* is also robust with an odds ratio *OR = 1.08* (significant at the *<0.05* level).

The result for *territorial control* gains significance (at the *<0.05* level) with an odds ratio *OR = 0.95*, indicating that groups who control territory are less likely to fight. The result for *intensity* also gains significance (at the *<0.05* level), with an odds ratio *OR = 1.05* indicating for each unit increase in *intensity* there is a *5%* increase in the likelihood of inter-rebel violence. Thus, groups operating in high intensity conflicts are more likely to fight. The causality on this effect is unclear, although it is likely that inter-rebel violence leads to increased casualties, which results in higher intensity conflict overall (Ross 2004).

The result for *GDP* also gains significance (at the *<0.01* level) with an odds ratio *OR = 0.99*, indicating that rebel groups fighting against strong states are less likely to fight among themselves. Fjelde and Nilsson (2012) obtained a similar result using *Polity* scores as a measure of state strength. They propose that if the state is weak, rebel groups are more likely to be concerned about their position relative to the other rebel groups who will all be vying for political influence. An obvious way for a group to improve their position and increase their political influence is to eliminate other rebel groups.

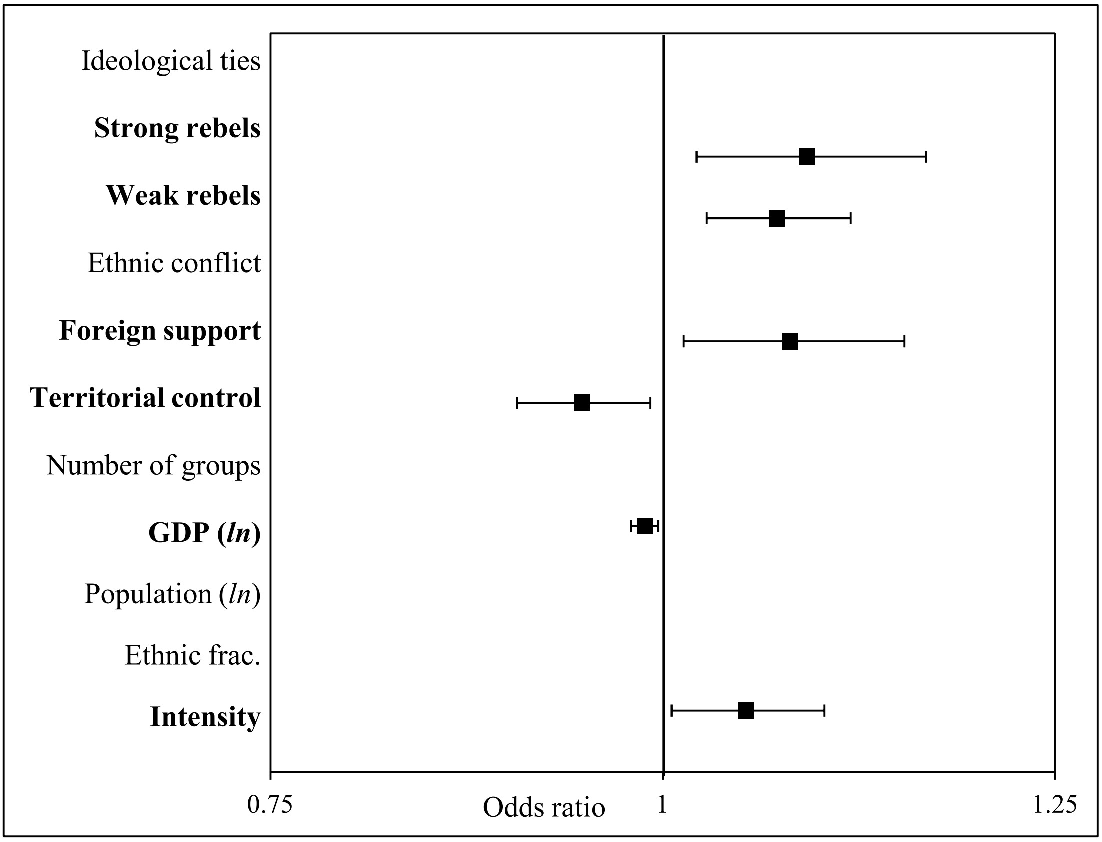
The results obtained from the Heckman selection model for rebel group fighting are plotted as a Forest Plot in Figure 2.18.

Table 2.14 Heckman selection model estimates for the determinants of fighting

Stage	Variable	Coefficient	Standard error
1	*ln* [Military quality]	-0.266**	0.046
	Democracy	0.041**	0.016
	Ethnic fractionalisation	1.342**	0.187
	Constant	2.069	0.286
2	Ideological ties	-0.002	0.003
	Strong rebels	0.088**	0.034
	Weak rebels	0.070**	0.022
	Ethnic conflict	0.040	0.025
	Foreign support	0.078*	0.033
	Territorial control	-0.053*	0.023
	Number of groups	0.008	0.009
	ln [GDP]	-0.012**	0.004
	ln [Pop]	-0.001	0.009
	Ethnic fractionalisation	0.048	0.076
	Intensity	0.052*	0.024
	Previous fight	-0.038**	0.008
	Previous fight^2	0.003**	0.001
	Previous fight^3	-0.001**	0.001
	Constant	-0.112	0.199
	Mills (lambda)	0.259*	0.113
	Number of obs.	798	
	Censored / uncensored obs.	174 / 624	
	Wald χ^2 (14)	72.00	
	Rho, Sigma	0.924, 0.280	

*Note: ** denotes significant at p ≤ 0.01, * denotes significant at p ≤ 0.05*

Figure 2.18 Forest plot of odds ratios calculated from stage 2 of the Heckman selection model estimates for rebel group fighting



2.4.5 Modelling alternative interaction strategies

The analyses presented so far have examined the effects of identity and power-based factors on two separate interaction outcomes: *cooperation* and *fighting*. But in reality, a group can adopt a wider range of strategies. A group can operate independently throughout the duration of a conflict, or they can adopt a strategy of alliance formation, or inter-rebel violence. A group may also cooperate with one or more other groups whilst simultaneously fighting with others. Alternatively a group might form an alliance at one point in a conflict then engage in fighting with their alliance partner at a later point in the conflict if the alliance breaks down (i.e. alliance fractionalisation). In this respect, the binary outcome models utilised so far in this chapter are limited. To overcome this approximation, a multinomial logistic regression model was employed using the dependent variable; *interaction strategy type*. The distribution of interaction strategy types is shown in Table 2.15.

The majority of groups tabulated in the dataset adopted a strategy of *cooperate only* (~ *60%*), whereas a much smaller fraction of groups adopted a strategy of *fight only* (~ *5%*). *11%* of groups operated independently for the entire duration of war. *13%* of the groups experienced alliance fractionalisation, which resulted in fighting with a previous ally. *11%* of the groups formed an alliance with one group, whilst simultaneously fighting with another group.

Table 2.15 Distribution of rebel group interaction strategy types

Outcome	***N***	**%**
Operate independently	*22*	*10.53*
Cooperate only	*126*	*60.29*
Fight only	*10*	*4.78*
Cooperate with one group, fight with another	*24*	*11.48*
Fight with a previous ally	*27*	*12.92*
Total	*209*	*100*

These interaction outcomes were coded using the cooperation and fighting data described in earlier in this chapter. Each interaction strategy type was coded as follows:

Operate independently: if the rebel group did not form an alliance or engage in inter-rebel violence with any other group at any point in their lifetime, they were assumed to operate independently and were coded with *0*.

Cooperate only: if the rebel group cooperated with one or more group(s) at some point in their lifetime but did not engage in inter-rebel violence, they were assumed to cooperate only and were coded using *1* for each conflict-year.

Fight only: if the rebel group fought with one or more group(s) at some point in their lifetime but did not form an alliance with any other group(s), they were assumed to fight only and were coded using *2* for each conflict-year.

Cooperate with one group, fight with another: if the rebel group was involved in an alliance in the same conflict-year as they engaged in inter-rebel violence, they were assumed to be cooperating with one group, whilst simultaneously fighting another and were coded using *3* for each conflict year.

Fight with a previous ally: if the rebel group was involved in an alliance at one point in the conflict and engaged in inter-rebel violence at later point in the conflict, they were assumed to be fighting with a previous ally and were coded using *4* for each conflict year.

A multinomial logistic regression model was employed using the same independent and control variables as before. The time-dependent controls and the squared terms were also included. Robust standard error estimates are reported, which take into account the nesting of observations within conflicts. This technique was used instead of multilevel models (which cannot be used to fit categorical outcome models) and is based on the Lin and Wei (1989) generalization of the Sandwich estimator, which is used commonly to control for the lack of independence within nested observations.

Results for each interaction strategy type are shown below in Tables 2.16 – 2.19. Results for the first outcome, *cooperate only*, are shown in Table 2.16. The previous results obtained on *ideological ties, territorial control* and *population* are all robust. The significant result on *rebel size* is lost however. In Table 2.17, the coefficients for *strong rebels* and *weak rebels* also lose significance for the second outcome, *fight only*. Instead, the coefficient for *ideological ties* gains significance (at the *<0.05* level) and is positive, indicating that groups who are ideologically similar to their peers are more likely to engage in inter-rebel violence (in-line with the expectations of hypothesis 3). The significant result for *foreign support* is lost, but the negative effects of *GDP* and *ethnic fractionalisation* on inter-rebel violence are robust (both at the *<0.01* level).

In Table 2.18, the coefficient for *ideological ties* is also positive and significant (at the *<0.05* level), indicating that groups who ideologically similar to their peers are more likely cooperate with one or more group(s) whilst simultaneously fighting with other groups. This result provides further evidence that shared identity encourages cooperation and fighting between groups. The coefficients for *foreign support* and *territorial control* are both positive and significant (at the *<0.05* and *<0.01* levels respectively), indicating that groups who receive external support or who control territory are more likely to cooperate with some groups, whilst simultaneously fighting with others. These results might be explained by the fact that this strategy requires organisational efficiency (derived from territorial control) and military capability (derived from foreign support). The coefficients for *GDP* and *ethnic fractionalisation* are both negative (and both significant at the *<0.05* level).

Results for the final outcome, *fight with previous ally*, are shown in Table 2.19. The coefficient for *weak rebels* is negative and significant (at the *<0.01* level), indicating that weak rebels are less likely to engage in fighting with a previous ally. One possible explanation for this could be that weak rebels are less likely to splinter from their alliance partner in the first place as a result of vulnerability arising from their small size. The coefficient for *foreign support* is positive and significant (at the *<0.01* level), indicating that groups who receive support are more likely to fight with a previous ally. One explanation for this could be that foreign support provides a source of dispute between groups, which leads to

Tables 2.16 – 2.19 Multinomial logistic regression estimates

Table 2.16 ***Cooperate only***

Variable	Coefficient	Standard error
Ideological ties	***0.216*****	*0.082*
Strong rebels	*-0.786*	*0.705*
Weak rebels	*-0.796*	*0.487*
Ethnic conflict	*-0.286*	*0.650*
Foreign support	*0.226*	*0.599*
Territorial control	***2.057****	*0.856*
Number of groups	*0.221*	*0.278*
ln [GDP]	*-0.080*	*0.060*
ln [Pop]	***0.405****	*0.202*
Ethnic frac.	*-0.377*	*1.258*
Intensity	*0.478*	*0.708*
Constant	*-6.957*	*3.513*
Number of obs.	*1126*	
Wald χ^2 (60)	*425.57*	
Log pseudo likelihood	*-661.900*	
Pseudo R^2	*0.51*	

*Note: ** denotes significance at $p \leq 0.01$, * denotes significance at $p \leq 0.05$*

Table 2.17 ***Fight only***

Variable	Coefficient	Standard error
Ideological ties	***0.309****	*0.158*
Strong rebels	*1.017*	*0.962*
Weak rebels	*0.180*	*0.883*
Ethnic conflict	*-0.869*	*0.955*
Foreign support	*3.218*	*1.758*
Territorial control	*1.503*	*1.136*
Number of groups	*-0.869*	*0.473*
ln [GDP]	***-0.356*****	*0.125*
ln [Pop]	*0.252*	*0.309*
Ethnic frac.	***-4.429*****	*1.372*
Intensity	*1.308*	*0.980*
Constant	*-5.216*	*5.704*
Number of obs.	*1126*	
Wald χ^2 (60)	*425.57*	
Log pseudo likelihood	*-661.900*	
Pseudo R^2	*0.51*	

*Note: ** denotes significance at $p \leq 0.01$, * denotes significance at $p \leq 0.05$*

Table 2.18 *Cooperate with one group, fight with another*

Variable	Coefficient	Standard error
Ideological ties	***0.269****	*0.138*
Strong rebels	*0.655*	*0.875*
Weak rebels	*0.862*	*0.836*
Ethnic conflict	*-1.163*	*1.084*
Foreign support	***1.952****	*1.158*
Territorial control	***3.947*****	*1.220*
Number of groups	*-0.111*	*0.495*
***ln* [GDP]**	***-0.159****	*0.117*
***ln* [Pop]**	***0.997*****	*0.299*
Ethnic frac.	***-4.449****	*2.186*
Intensity	*-0.406*	*0.996*
Constant	*-17.567*	*5.477*
Number of obs.	*1126*	
Wald χ^2 (60)	*425.57*	
Log pseudo likelihood	*-661.900*	
Pseudo R^2	*0.51*	

*Note: ** denotes significance at p ≤ 0.01, * denotes significance at p ≤ 0.05*

Table 2.19 *Fight with previous ally*

Variable	Coefficient	Standard error
Ideological ties	*0.119*	*0.114*
Strong rebels	*-0.298*	*0.955*
Weak rebels	***-2.209*****	*0.805*
Ethnic conflict	*-0.758*	*2.092*
Foreign support	***3.112*****	*1.110*
Territorial control	*2.009*	*1.293*
Number of groups	***1.902*****	*2.566*
***ln* [GDP]**	***-0.294*****	*0.120*
***ln* [Pop]**	***0.702****	*0.575*
Ethnic frac.	***6.593****	*5.806*
Intensity	*1.707*	*1.131*
Constant	*-30.037*	*13.289*
Number of obs.	*1126*	
Wald χ^2 (60)	*425.57*	
Log pseudo likelihood	*-661.900*	
Pseudo R^2	*0.51*	

*Note: ** denotes significance at p ≤ 0.01, * denotes significance at p ≤ 0.05* alliance fractionalisation and subsequent fighting. The coefficient for *GDP* is negative and significant (at the *<0.01* level), indicating that groups fighting strong states are less likely to fight with a previous ally. This might occur because the presence of a strong state improves cohesion, making alliance fractionalisation less likely. The coefficients for *N groups, population* and *ethnic fractionalisation* are positive and significant (at the *<0.01, <0.05, <0.05* levels respectively).

2.5 Limitations and avenues for further research

Several limitations have been revealed by the present approach, which suggest obvious avenues for further research. Firstly, the dependent variable, *cooperation*, is limited by the unavailability of specific data. The dataset does not specify which groups formed an alliance, only that the group formed an alliance with one or more rebel group(s) in that conflict-year. The dependent variable, *fighting*, is also limited because the dataset does not distinguish between initiators and targets. As a result, the positive relationship between foreign support and the likelihood of inter-rebel violence is ambiguous. The group receiving foreign support could become a target for attack because of its increased resources, or the group receiving foreign support could initiate fighting with another group as a result of its increased capacity. Should such data become available, it would be desirable to use a dyadic design so that the mechanisms responsible for rebel group interactions can be tested more directly.

Alternatively, future research may benefit from moving away from dyadic designs, shifting instead towards the use of network approaches since these provide an opportunity for multiple interdependencies to be explored. The network methodology proposed in this chapter has shown one possible way forward, although further research is needed to verify the ideology data and to validate the network methodology.

The primary purpose of this chapter has been to test theories relating to identity and power-based factors. Other factors, such as the previous interaction behaviour of groups and the role of geography or technology have not been considered. Since these features may also be important in determining rebel group interactions, the study of these aspects is an obvious extension to the present work. Another useful line of enquiry for future research is to investigate why some conflicts contain multiple rebel groups. This question was briefly addressed in this chapter but further research is needed and the theoretical explanations of why multi-party conflicts arise need developing.

2.6 Conclusions

This chapter has addressed an understudied aspect of the conflict literature by examining the determinants of two types of rebel group interaction strategy, namely alliance formation and inter-rebel violence. Two theories relating to group interactions were tested; one being identity-based and the other power-based. A novel methodology based on social network analysis was utilised so that a quantitative index, which measures the degree of ideological similarity between groups, could be developed. The potential use of network approaches for examining social ties between groups has been highlighted. The effects of ideological ties and relative rebel group size on alliance formation and inter-rebel violence were tested using logistic regression models. The robustness of the results was checked using mixed-effects models, two-step Heckman selection models and multinomial logistic regression models.

Findings suggest that power-based factors have greater utility in explaining rebel group interactions. Identity-based factors are found to play a role in motivating cooperative alliances but there is less convincing evidence found regarding their role in motivating inter-rebel violence. The results for each interaction strategy are detailed below.

2.6.1 Results for rebel group cooperation

It is shown that groups are more likely to cooperate with others when they are heavily ideologically connected to their peers, when they are militarily weak relative to their peers or when they control territory. These results were robust in all models. The implication is that power considerations are dominant in encouraging cooperative interactions between groups, but identity-based factors also play an important role.

2.6.2 Results for rebel group fighting

It is shown that groups are more likely to engage in inter-rebel violence with others when they are either militarily strong or militarily weak relative to their peers or when they receive foreign support from external actors. These findings were not robust in all models however. Results obtained from the multi-level models suggest that only strong groups have an increased likelihood of inter-rebel violence (the results obtained on weak rebels and foreign support were not robust). Some additional important and significant results were gained after controlling for sample selection bias. These results show that groups are less likely to fight others when they control territory and when they are engaged in conflict against a strong state. Some evidence was also found that supports the suggestion that identity-based factors also play a role in encouraging inter-rebel violence, although this evidence was found only in the multinomial logistic regression model. In summary, these results show that power considerations are dominant in encouraging violent interactions between groups. Identity-based factors may also play a role, but the evidence found to support this claim is weak.

2.6.3 Additional lines of enquiry

The analyses presented in this chapter provide insight on the determinants of rebel group interactions, although the reasons why a group might choose to cooperate with other groups instead of fight (or vice versa) remains unresolved. The theoretical discussions presented in Chapter I suggest that both types of interaction strategy, although directly opposite in nature, develop from the same root causes. The results presented in this chapter also shows some evidence that supports the argument that groups who share the same identity are more likely to interact. The salient question therefore is why does one rebel group choose to cooperate with its peers, while another group, driven by apparently similar identity-based motives, choose to fight with its peers? This aspect is addressed in more detail in Chapter III.

Chapter III

Friend or foe? Rebel group interactions and the role of credible commitments

Abstract

Why do some rebel groups form alliances with their peers while other groups, driven by apparently similar identity-based motives, engage in inter-rebel violence? In this chapter it is argued that groups who are ideologically similar to their peers are more likely to form alliances if they are perceived by other groups as being able to credibly commit to an alliance. If a group lacks alliance credibility in the eyes of their peers, it is argued that the group is more likely to engage in inter-rebel violence. The alliance credibility of rebel groups is measured against two criteria (*i*) the level of external threat faced by the rebel groups and (*ii*) the organisational characteristics of the groups themselves. Conditional hypotheses are tested using two contrasting but complimentary methodologies, namely logistic regression analysis and classification and regression tree analysis (CART). Results of the regression analysis suggest that groups who are ideologically similar to their peers are less likely to form alliances if they are also a new entrant to the conflict. Results of the CART analysis suggest that ideological ties are the most powerful predictor of rebel group interactions and that groups who are ideologically similar to their peers are most likely to base their interaction decisions on the organisational characteristics of other groups. These results provide some evidence in support of the theoretical proposition that rebel groups make interaction decisions on the basis of perceived alliance credibility.

3.1 Introduction

The findings presented in the previous chapter support the theoretical arguments put forward in the literature review (in Chapter I) in that they suggest the root causes of alliance formation and inter-rebel violence might be the same. Namely, that rebel groups who are heavily ideologically tied to their peers are more likely to form either alliances or to engage in inter-rebel violence than groups who are less ideologically tied. On first inspection these results may seem contradictory. They suggest shared identity increases the likelihood of two opposing outcomes. Thus, while the results described in the previous chapter provide general information regarding the determinants of rebel group interactions, they do not answer the specific question of why a group may choose one interaction strategy over the other. In other words, why does one rebel group, who is ideologically similar to their peers, choose to cooperate, while another group, driven by similar identity-based motives, chooses to fight? The aim of this chapter is to address this question.

3.2 Background

Previous civil war research has tended to model conflict as an *all-or-nothing* phenomenon, in which outcomes, such as *war* or *no war*, are predicted by a list of independent and control variables whose predictive power is assessed individually across all observations. Most studies have avoided discussions of how the effect of one variable may be conditional on the presence of another (i.e. one variable may have a moderating effect on the other). This has meant that researchers have identified independent variables which appear to predict outcomes under all conditions.

Most studies on rebel group interactions have avoided constructing statistical models with moderating effects to explain the different interaction strategies adopted by groups. Some research has examined the mechanisms responsible for alliance formation by applying one set of theories, while other research has used the same set of theories to focus on the mechanisms responsible for inter-rebel violence. Studies that have sought to test these theories have often used regression models to predict rebel group interaction outcomes, for example by comparing cases where the outcome did or did not occur (e.g. Fjelde and Nilsson 2012). The main issue with this approach is that regression modelling favours the analysis of one-to-one correlations between sets of variables and therefore it is not ideal for the complex situations that occur in rebel group interactions. Multi-dimensional statistical methods which measure the moderating effect of one variable on another are available, but they have not yet been utilised to their full potential in studies of rebel group interactions.

Few empirical studies have examined cases where rebel groups might cooperate or fight under seemingly similar conditions. An exception is the study by Ross (2004) who finds that in some civil wars, natural resource endowments lead to cooperation between non-state actors, but in other civil wars natural resource endowments lead to fighting. Another exception is the study by Christia (2012) who argues that changes in relative power-balances between rebel groups over the course of a conflict results in alliance fractionalisation and subsequent fighting between groups. She concludes that alliances are less prone to fractionalisation (and subsequently less likely to result in inter-rebel violence) when the rebel groups face a strong state or when the allied groups experience a series of battlefield wins. One of the main criticisms of this study is that Christia (2012) considers inter-rebel violence only as a function of alliance fractionalisation. This assertion is limited, given the results of several other studies (including the findings presented in Chapter II of this thesis), which suggest that many groups engage in inter-rebel fighting for reasons beyond acrimonious splits (Lilja and Hultman 2011; Fjelde and Nilsson 2012). Whilst these studies represent valuable contributions to the rebel group dynamics literature by providing insight into the causes of group interactions, they do not answer the specific and important question of why a rebel group chooses one type of interaction strategy over the other.

The aim of this chapter is to address this question. The main contribution made in the chapter is to propose a novel theoretical framework relating to rebel group interactions in multi-party civil wars, which is based on Walter's (1997) theory of *credible commitments*. Walter (1997) addresses the question of why peace settlements in civil wars occur infrequently compared to negotiated settlements made between nation states in inter-state wars. She argues that unlike in inter-state wars, the actors in civil wars lack the *credibility* to commit to peace deals. In this chapter, credible commitment theory is extended and applied to the case of rebel group interactions. On the basis of this extension it is proposed that *alliance credibility* is the conditional variable determining whether a group chooses to cooperate or fight with its peers. The chapter begins by outlining some theoretical arguments relating to why a rebel group might choose to cooperate instead of fight (and vice versa). A set of conditional hypotheses are derived and these are tested using both statistical modelling methods and machine learning techniques, namely classification and regression trees (CARTs), the application of which is novel in civil war research. A description of the research design is provided and results are presented and discussed. A comparison of the two methods used is provided and the limitations of each method are highlighted. Conclusions are drawn and the lines of enquiry intended for the subsequent chapter in this thesis are discussed.

3.3 Theory and hypotheses

In her seminal paper on critical barriers to civil war settlement, Walter (1997) argues that commitment problems are the main factor inhibiting negotiated settlements between states and rebel groups. Between 1940 and 1990, *55%* of inter-state wars were resolved at the bargaining table, whereas only *20%* of civil wars reached solutions in this way (Walter 1997). Walter argues that this occurs because parties are unlikely to enter into cooperative agreements if there is little expectation that such agreements will be fulfilled. Expressed differently, alliance formation relies on perceived *credibility* between the actors involved (Fearon 1995; Leeds 1999; Morrow 2000; Bapat and Bond 2012).

In civil wars, Walter (1997) has shown that successful negotiated peace settlements are most likely to be achieved when a third, stronger party acts as a mediator and agrees to enforce the terms of a peace treaty. The third party presence increases the credibility of both sides, which in turn, increases the likelihood of a peaceful resolution. In international affairs, nation states also assess potential alliance partners via their credibility. They develop expectations of credible commitments by assessing prospects for future interactions and by seeking assurance that there will be punishment for broken promises (Axelrod 1984; Fearon 1998; Kydd 2005).

The above types of credibility assessments are more difficult for rebel groups. Rebel groups often do not survive for extended periods and they seldom possess the transparent structures required for credibility assessments to take place (Stedman 1997; Walter 2002). A rebel group is also unlikely to be able to find a third party, or mediator, who will guarantee the terms of an alliance agreement between themselves and another non-state actor. Rebel groups must therefore assess the credibility of potential alliance partners in other ways. It is proposed in this chapter that *credibility* is the condition that determines whether a rebel group will choose to cooperate with its peers instead of fight. It is argued that rebel groups choose a strategy of cooperation instead of fighting, not because there is a third party to enforce an agreement, but because rebel groups in multi-party conflicts have a common enemy and potentially share the same fate. If the external threat faced by rebels is large (i.e. the state is strong) then rebel groups gain alliance credibility in the eyes of their peers because they have higher potential losses from not forming an alliance.

In this chapter, it is proposed that rebel groups also develop expectations of credibility by assessing certain organisational characteristics of potential partners. It is argued that cohesive groups who have strong and stable leadership are likely to gain credibility in the eyes of their peers. Effective leadership and group stability strengthens trust; the assumption being that if a leader is able to manage his own affairs, then he will be more able to manage alliance affairs. Additionally, cohesive groups are more likely to experience in-group policing, thus minimising the likelihood of dispute within a group. Cohesive groups may then be more likely to agree on the terms of an alliance and in turn, may be less likely to renege on their original alliance deal. These mechanisms and their effect on the alliance credibility of rebel groups are discussed in more detail below.

3.3.1 External threat faced by rebel groups

A long standing proposition in the field of political science is that external threat is conducive to group solidarity and cooperation (Kaplan 1957; Wolfers 1962; Liska 1962; Boulding 1962; Scott 1967; Rothstein 1968; Burgess and Moore 1973; Stein 1976; Sullivan 1976). The *'external threat-cohesion'* hypothesis originates from the socio-psychological literature on group behaviour (Sherif and Sherif 1953; Simmel 1955; Coser 1956; Sherif 2010). It suggests that in the absence of a common enemy, interactions between actors may or may not occur, but in the presence of a threat from a common enemy, things change. Groups rally to each other's defence and suppress any tendencies towards conflict between themselves. As the presence of any perceived threat diminishes, the actors return to their normal patterns of interaction, namely elevated levels of within and between-group dispute than was the case during the period under higher levels of external threat.

The implications of the above theory are far reaching. It has been applied in the field of international relations where studies have sought to identify a positive relationship between external threat and cohesion in the form of alliance blocs such as NATO (Tucker 1963; Holsti *et al.* 1973). Thompson and Rapkin (1981) point out that the theory can also be applied to cohesion within a nation state. For example, a desperate autocrat might choose to focus on external threats or enemies to divert attention away from domestic problems, thereby prolonging their position as leader. In a civil war context, the implication of this theory is that insurgent groups will adopt a strategy of alliance formation in response to a strong external adversary. In turn, alliances that were formed during the course of the conflict are more likely to disintegrate if the incumbent state is overthrown. If the external threat faced by rebel groups is relatively low at the start of the conflict then groups may select a strategy of inter-rebel violence instead of alliance formation.

One case in point is the Afghan civil war, which began in the 1970's. A coalition of guerrilla groups, referred to as the *Mujahedeen*, fought in violent protest against the Soviet-backed communist state. After ten years of insurgency the Soviet army withdrew and a power-sharing government was formed by the leader of *Jamiat i-Islami*, one of the insurgent groups who had formed the *Mujahedeen*. Within months of the Soviets leaving Afghanistan, fighting over leadership erupted between the various factions of the *Mujahedeen*. The country was left without a functioning government for several years until 1996 when the *Taliban* seized control of Kabul. In the face of this common enemy, members of the *Mujahedeen* ceased fighting and joined forces in an alliance with other *Taliban* opponents to form the *United Islamic Front for the Salvation of Afghanistan* (*UIFSA*). In this case the members of the *Mujahedeen* lost their alliance credibility once the external threat, the Soviet-backed government, was removed. The exiting of the Soviets meant that the members of the *Mujahedeen* were forced into a *prisoner's dilemma* situation, where all groups would benefit from cooperating but each individual group would be far worse off if they naively cooperated whilst another group exploited their trust and used force to take solitary control of Kabul.

In the international arena, states have military and economic mechanisms to maintain cooperation even under circumstances where incentives develop for individual states to renege or cheat. For rebel groups however, there is generally no way of ensuring that an alliance partner will stick to an agreement, since there are no real mechanisms in place for punishing a partner who reneges on a deal. One possible way that a rebel group might develop expectations regarding the alliance credibility of potential allies is by assessing the level of external threat posed by the state and using this as a gauge for risk. Rebel groups facing high levels of external threat are likely to gain alliance credibility in the eyes of their peers because they have higher potential losses from not forming an alliance; they are more at risk from being eliminated by the state and they have minimal bargaining power and therefore have a smaller chance of being offered concessions by the state (Nilsson 2010). High levels of external threat increase the need for a group to form an alliance and they reduce the incentive for a group to renege on an alliance deal. Conversely, rebel groups who face relatively lower levels of external threat are likely to lack alliance credibility in the eyes of their peers; they are less likely to be eliminated by the state and as a result they are more likely to be concerned about their position relative to other rebel groups, all of whom will be vying for political influence in anticipation of government collapse (Fjelde and Nilsson 2012). In this situation, the rebel groups lose their credibility as potential allies because they are more likely to view their peers as competition (Fjelde and Nilsson 2012).

> *Hypothesis 5a: Rebel groups who share social ties with other groups are more likely to form alliances, conditional on the presence of a strong state.*

Hypothesis 5b: Rebel groups who share social ties with other groups are more likely to engage in inter-rebel violence, conditional on the presence of a weak state.

3.3.2 Organisational characteristics of rebel groups

A number of studies in the conflict literature have examined *within-group* dynamics. A range of organisational characteristics have been studied including cohesion (Fearon and Laitin 1996; Kenny 2010) and leadership (Jones and Olken 2007; Tiernay 2013). Studies on cohesion suggest that cohesive rebel groups are more likely to experience *in-group* policing (Fearon and Laitin 1996), a feature that minimises the likelihood of dispute within a group and might facilitate cooperative deals between groups (Fearon and Laitin 1996). Other studies on within-group cohesion have shown that if a group is not cohesive, then some members of the group may act as *spoilers* by attempting to block peace settlements offered by the state (Stedman 1997; Kydd and Walter 2003; Greenhill and Major, 2006; Nilsson 2008; Pearlman 2009; Pearlman and K. Cunningham 2011). In many cases, these within-group disagreements erupt into violence and the peace settlement is abandoned simply because the rebel group lacks credibility regarding its commitment to the peace deal.

Studies on leadership have shown that the leaders of the rebel groups are also an important variable in civil war dynamics. Jones and Olken (2007) compare successful and unsuccessful assassination attempts of rebel group leaders in civil wars and find that the unsuccessful assassination of leaders tends to enflame low-intensity conflicts and diminish high-intensity conflicts. Tiernay (2013) on the other hand, finds that the unexpected removal of a rebel group leader significantly shortens the duration of civil war. Conversely, he finds that civil wars are less likely to end when rebel groups are led by their founder for the entire duration of war. Collectively, these findings suggest that stable and effective leadership increases a rebel group's credibility and chance of success.

Another way that a rebel group might develop expectations regarding alliance credibility is to assess the organisational characteristics of a potential ally. Cohesive groups who have strong and stable leadership are likely to gain alliance credibility in the eyes of their peers because these features promote trust. Cohesive groups have, by virtue, achieved within-group cooperation regarding attainment of the group's goals (Kenny 2010). This ability to achieve within-group cooperation means that cohesive groups are less likely to disagree on the terms of an alliance, and in turn, they may be less likely to renege on an alliance deal made with another group. The longevity of rebel groups is also important for the same reason; *trust*. In order to gain alliance credibility, a group must be able to provide assistance over a period of time, or it must be around long enough to be at least of some assistance to its ally. Groups who have survived the test of time gain alliance credibility because other groups trust that they will be able to provide support over a period of time. Indeed, if there was some expectation that a group would disintegrate or get eliminated before it was able to provide support, then the rebel group's credibility regarding their commitment to an alliance would clearly be lost. Intuitively, if a group has ineffective leadership and/or internal divisions, it is less likely to gain trust or alliance credibility in the eyes of its peers. New groups are also likely to lack alliance credibility because they do not have enough previous history for trust to have developed. Fjelde and Nilsson (2012) point out that new entrants to a conflict are more likely to be viewed as competitors. By virtue, groups that are new entrants to a conflict have either opted to form a separate group, or they have splintered from an existing group and these features may give other groups the impression that the new group is self-interested and untrustworthy. These arguments suggest that efficiently organised rebel groups (i.e. those with strong and stable leadership, who are cohesive and who have achieved longevity) will be more likely to adopt a strategy of alliance formation, whereas rebel groups who are unable to manage their own internal affairs (i.e. those with unstable leadership and internal dispute) or new entrants to a conflict will be more likely to adopt a strategy of inter-rebel violence.

One notable example of the above occurred in the civil war in Algeria in the late 1980's. Two main groups were challenging the Algerian government and both were dedicated to implementing Islamic Sharia law. The first group, the *Armed Islamic Movement* (*MIA*) adopted a violent campaign but was not able to accomplish much militarily against the state. The second group, the *Islamic Salvation Front* (*FIS*), chose to pursue a political, rather than violent, strategy and competed in elections in 1991. The *FIS*, who had large support from the Algerian population, was set to win, but the government intervened militarily and cancelled the elections. Following this cancellation, armed conflict broke out. Initially, *FIS* stayed out of the conflict, but by 1992, *FIS* decided to endorse the armed struggle and it merged with the *MIA*. At this time, both the *FIS* and *MIA* were efficiently organised. This supports the arguments presented here, namely that well-organised groups are more likely to cooperate.

From the period of 1992 to 2001 the Algerian conflict became particularly bloody, resulting in approximately 100,000 deaths. During this period of high intensity conflict, *FIS* was weakened by state repression. First, the leaders, and then hundreds of *FIS* members, were targeted by the Algerian secret services, which left the group without directives and with no clear strategies (Lowri 2005). As a result, *FIS* lost control, both administratively and on the ground. This left a vacuum of governance in Algeria and in the absence of any political or moral authority, a number of poorly coordinated, uncontrollable, radical Islamic groups formed. The motivations of these groups, referred to collectively as the *Armed Islamic Groups* (or *GIA*), ranged from religious extremism to outright banditry (Lowri 2005). Since these newly formed groups lacked organisational integrity, the only way they could gain recognition was by demonstrating and exercising a capacity for disruptiveness, especially with respect to their rivals. As a result, maximalist strategies of targeting one another and outdoing one other through violence became the order of the day (Lowri 2005). All groups during this period lacked alliance credibility. They were poorly organised, with unstable and ineffective leadership and many of the groups were new entrants to the conflict. In this case, the groups were unable to trust one another and fighting inevitably erupted between them.

> *Hypothesis 6a: Rebel groups who share social ties with other groups are more likely to form alliances, conditional on the presence of those groups having stable leadership, cohesion and longevity.*
>
> *Hypothesis 6b: Rebel groups who share social ties with other groups are more likely to engage in inter-rebel violence, conditional on the presence of those groups having unstable leadership, poor cohesion or being a new entrant to the conflict.*

3.4 Research design

3.4.1 Dataset and dependent variables

The above conditional hypotheses are tested in a large-*N* framework using the dataset described in Chapter II. All multi-party civil wars listed in the dataset are analysed. The unit of analysis is the conflict-year. Two binary rebel group interaction outcomes are considered: cooperative alliances and inter-rebel violence. Categorical outcomes for the different interaction strategy types are also examined (see Chapter II for a detailed description of the coding of these). All dependent variables are coded as before (in Chapter II). These are:

Cooperation: a binary variable taking the value of *1* if the rebel group formed an alliance with one (or more) rebel group(s) in that conflict-year and *0* otherwise.

Fighting: a binary variable taking the value of *1* if the rebel group engaged in armed conflict with one (or more) rebel group(s) in that conflict-year and *0* otherwise.

Interaction strategy type: a categorical variable taking the value of *0* if the rebel group operated independently, *1* if the group formed an alliance only, *2* if the group engaged in inter-rebel violence only, *3* if the group cooperated with one group, whilst simultaneously fighting with another and *4* if the group fought with a previous ally.

3.4.2 Independent variables

A total of eight independent variables, described below, are used to test the hypotheses. Three independent variables from Chapter II are used in the present analysis. These are:

Ideological ties: a continuous variable signifying the degree of ideological similarity between groups. This variable has a range of *0* to *24* where *0* indicates that the group is ideologically dissimilar to its peers and *24* indicates that the group is heavily ideologically connected to its peers (see Chapter II for a detailed description of the derivation of this variable).

Strong rebels: a binary variable where *1* signifies that the group size was $\geq 75\%$ of the sum of all group sizes involved in the conflict and *0* signifies that the group size was $< 75\%$ of the sum of all group sizes involved in the conflict. Troop size data are used. These are taken from Cunningham *et al.* (2009).

Weak rebels: a binary variable where *1* signifies that the group size was $< 25\%$ of the sum of all group sizes in the conflict, and *0* signifies that the group size was $\geq 25\%$ of the sum of all group sizes. Troop size data are used. These are taken from Cunningham *et al.* (2009).

Two independent variables are used to test the hypotheses relating to the levels of external threat faced by rebel groups (hypotheses *5a* and *5b*). Both independent variables are proxies for state strength and are coded as follows:

State strength: a measure of the military capabilities of the state relative to the military capabilities of the rebel group. Troop size data are used. Data for rebel troop sizes are taken from Cunningham *et al.* (2009) and data for government troop sizes are taken from Lacina (2006). The relative power between the state and a single rebel group is calculated for each conflict-year using the expression, $(N_G - N_R) / (N_G + N_R)$, where N_G is the number of government troops and N_R is the number of rebel troops. This expression produces an index which ranges between *-1* and *1*, where a value of *0* signifies that the government forces and rebel group are at parity in terms of troop size, a positive value signifies that the government side is stronger (i.e. high levels of external threat) and a negative value signifies that the rebel side is stronger (i.e. low levels of external threat).

Polity: a measure of the administrative capabilities of the state. Polity scores are used and data are taken from the Polity IV Project, 1800-2009. The polity index ranges between *10* and *-10*, where positive values signify that a state is strong in terms of its administrative capabilities (i.e. high levels of external threat) and negative values signify that a state is weak in terms of its administrative capabilities (i.e. low levels of external threat).

Three independent variables are used to test the hypotheses relating to the organisational characteristics of rebel groups (hypotheses *6a* and *6b*). These are coded as follows:

Leadership turnover: a variable signifying the total number of leaders that the rebel group had since it was founded. High leadership turnovers are assumed to be associated with reduced alliance credibility, whereas low leadership turnovers are assumed to be associated with high alliance credibility. Data are taken from Tiernay (2013).[‡]

Fractionalisation: a binary variable where a value of *1* signifies that the rebel group experienced fractionalisation (i.e. group splintering) and *0* otherwise. Cohesive groups who do not experience fractionalisation are assumed to have high alliance credibility, whereas groups who do experience fractionalisation are assumed to have low alliance credibility. Data are taken from the UCDP Non-state Actor Dataset v.1 (2009).

New group: a binary variable where a value of *1* signifies that the rebel group is a new entrant to the conflict and *0* otherwise. Rebel groups are coded as being new entrants if they first crossed the UCDP defined threshold of *25* battle related deaths in a conflict-year that occurred after the conflict start date. (This includes splinter groups). New groups are assumed to be associated with low levels of alliance credibility, whereas rebel groups with longevity (i.e. those who have operated in the conflict since the start date) are assumed to have high levels of alliance credibility. Data for the coding of this variable are taken from Cunningham *et al.* (2009).

3.4.3 Control variables

To control for the lack of independence between the conflict-years for a single rebel group, additional variables are included, which control for time-dependence. These are:

Previous cooperation: a variable signifying the number of years elapsed since the rebel group cooperated with one or more other rebel group(s).

Previous fighting: a variable signifying the number of years elapsed since the rebel group engaged in inter-rebel violence with one or more other rebel group(s).

Following the proposal of Carter and Signorino (2010), the squared and cubed terms (and raw values) of the above variables are included instead of time dummies or splines.

[‡] The independent variable *leadership turnover* was not normalised by the number of conflict-years the rebel group existed. It was not viewed as being necessary because in the dataset analysed, *leadership turnover* was not found to vary as a function of the length of time a group existed. The mean survival of all rebel groups in the dataset = *8* conflict-years, the maximum survival = *59* conflict-years. Only one group in the dataset had the maximum leadership turnover of *4 leaders* (the *RCD* in Zaire) who were included in the dataset for a total of *4* conflict-years (1998 – 2001). This is below the mean value of survival. Four rebel groups in the dataset had a leadership turnover of *3leaders*. These were the *PLFP* in Israel who were included for a total of *2* conflict-years, the *PWG* in India for *4* conflict-years, the group *Hezbollah* in Israel for *8* conflict-years and the *GIA* in Algeria for *10* conflict-years. The majority of these cases were equal to, or below the mean value of survival.

3.4.4 Methods of estimation

Two different methodologies are used to test the conditional hypotheses described above; logistic regression modelling with the inclusion of moderating variables and classification and regression trees (CARTs). These are described below.

Logistic regression analysis

Firstly, logistic regression models are employed. The dependent variables, *cooperation* and *fighting* are examined separately. To investigate the possibility of a conditional relationship between social ties and alliance credibility, a set of moderating variables are constructed and these are included in the regression models. The independent variable, *ideological ties*, is multiplied by each of the independent variables relating to the alliance credibility of rebel groups; *state strength; polity; leadership turnover; fractionalised;* and; *new group*.

Classification and Regression Tree analysis

An alternative way to test for a moderating effect between independent variables is to use classification and regression trees (CART). The seminal work on CARTs was published by Breiman, Friedman, Olshen and Stone (1984). Tree models are used to predict continuous outcome variables and are called regression trees, whereas models used to predict binary or categorical outcomes are called classification trees. Since rebel group interaction outcomes may be either binary or categorical, only classification trees are utilised in this chapter.

To elaborate, CARTs are a type of decision tree derived by using a computer program based on a machine-learning methodology. CART analysis can be used as a tool for determining and ordering the relative importance or explanatory power of independent variables, determining the boundaries within which those independent variables have their strongest effect and assessing the possibility of moderating effects between variables. Instead of working deductively from starting hypotheses or theories, CARTs represent a machine-learning generative approach, which can be used to show how different combinations of variables can have different effects on an outcome. CARTs can also be used to show the ranges within which those particular variables have their strongest effect.

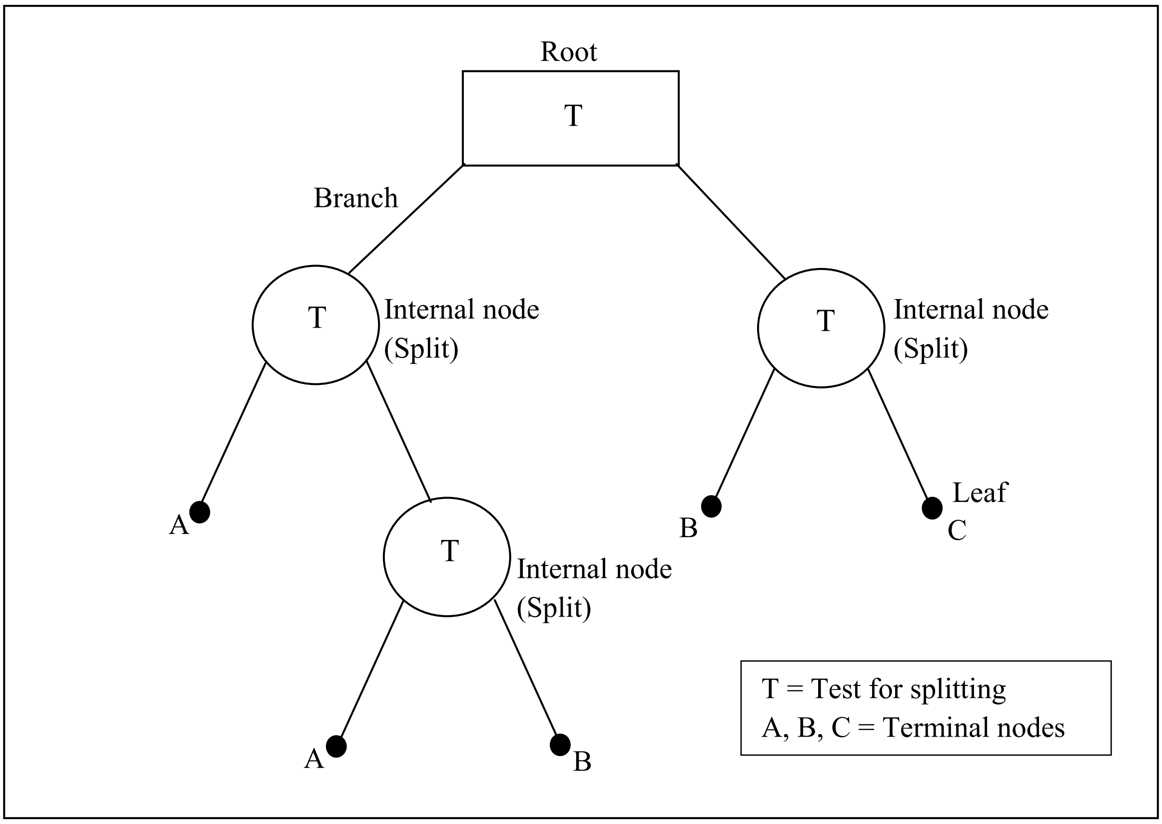
CARTs are performed using the same data used to fit statistical models (e.g. with the dependent and independent variables coded as separate vectors in a dataset). As with other statistical modelling methods, such as regression models or general linear models, CARTs seek to predict the dependent variable from a set of independent variables. The unique aspect of CARTs is that they use computer algorithms based on *recursive partitioning* to make predictions (instead using algorithms to find the *line of best fit*, which is the aim of regression methods). Recursive partitioning algorithms create a decision tree from the dataset by striving to correctly classify observations on the basis of several dichotomous independent variables. Put differently, CARTs search the parameter space for the best combination of variables (and their values) to classify particular outcomes. As such, CARTs are a more exhaustive approach than regression methods, which test only one combination of variables and the moderating effects (or variable interactions) where specified.

In classification tree models, *leaves* represent class labels and *branches* represent conjunctions of features that lead to those class labels. Classification trees *grow* from a *root* using an algorithm which splits the source set into subsets (at a node) based on an attribute value test. This process is repeated on each derived subset in a recursive manner called recursive partitioning. The recursion is completed when the subset at a node has the same value of the outcome variable (i.e. the node is *pure*), or when splitting no longer adds value to the predictions. At this point, the nodes become terminal and a *leaf* is created. A schematic visual representation of this process is shown in Figure 3.1.

In the analysis leading to the development of CARTs, it is required to predict an outcome of interest, Y, from the given factors $x_1, x_2, x_3, \ldots, x_n$ in the domain X. Then in Figure 3.1, the graphic is the domain of all factors associated with Y in descending order of importance. In traditional regression models, single models are used to represent the entire dataset. CARTs are an alternative approach where the data space is partitioned into smaller sections in which the interactions between variables are broken down in a clearer manner. Each node in the tree is derived from a splitting test algorithm which applies to that node only. In this way, CARTs are analogous to other conditional modelling methods (such as testing for moderating effects between independent variables in regression models), because as a route is followed down the nodes of the tree the conditioning occurs on a specific variable.

The above process is described in detail by Loh (2008). In essence, if it is required to find a function $d(x)$ to map domain X to the response variable, Y, the existence of a sample is assumed on n observations $L = \{(x_1, y_1), \ldots, (x_n, y_n)\}$. As in standard regression equations, the criterion for choosing $d(x)$ is the mean squared prediction error $E\{d(x) - E(y|x)\}^2$ for a regression tree, or the expected misclassification cost in the case of a classification tree. For a regression tree, each leaf-node *l* and training samples in the regression tree (i.e. samples of data used to grow each of part of the tree), the model is $\hat{y} = \frac{1}{c}\ {}_{c=1}^{c}\ y_1$, or the sample mean of the response variable at that node (Loh 2008). For a classification tree, each leaf-node *l,* training sample *c* and *p(c|l)*, the probability that an observation *l* belongs to class *c* (i.e. the node splits) are determined by the *Gini impurity criterion (1 -* ${}_{c=1}^{c}\ p^2(c|l)$*)*, where each split maximises the decrease in impurity. In the growth of both types of tree, reducing error is the primary driving force of tree growth.

Figure 3.1 Visualisation of a CART



In the present chapter, a classification tree is implemented using the statistical software programming language R. The tree is constructed using the **rpart** routines. The code listing is taken from Therneau and Atkinson (2014), which is based on the original programs of Breiman, Friedman and Olshen (1984). The dependent variable used for the CART analysis is *interaction strategy type*. All independent variables defined above are used, with the exception of the moderating variables (i.e. variable interaction terms), which are of course redundant in CART analysis. The time-dependent control variables (*previous coop* and *previous fight*) are also excluded from the CART analysis. Note again that the whole point of CART analysis is to assess moderating effects between independent variables by using an alternative and complementary methodology to regression analysis. In summary, regression analysis is limited to the model specified and is theoretically motivated. As such, regression analysis does not test all the moderating effects between variables that may be important. CARTs on the other hand are atheoretical. They test all possible moderating effects that might exist and as a result, CARTs are more exhaustive than regression analysis

Table 3.1 Descriptive statistics

Level	Variable	Obs.	Mean	SD	Min	Max
Dependent variables	Cooperation	*1126*	*0.67*	*0.47*	*0*	*1*
	Fighting	*1126*	*0.10*	*0.29*	*0*	*1*
	Strategy type	*1126*	*1.56*	*1.20*	*0*	*4*
Independent variables	Ideological ties	*1126*	*6.47*	*4.77*	*0*	*24*
	Strong rebels	*1126*	*0.14*	*0.34*	*0*	*1*
	Weak rebels	*1126*	*0.36*	*0.48*	*0*	*1*
External threat proxies	State strength	*1126*	*0.46*	*0.62*	*-0.99*	*0.99*
	Polity	*1126*	*-0.21*	*6.72*	*-9*	*10*
Organisational characteristics proxies	Leadership turnover	*1126*	*1.28*	*0.51*	*1*	*4*
	Fractionalised	*1126*	*0.15*	*0.36*	*0*	*1*
	New group	*1126*	*0.49*	*0.50*	*0*	*1*

3.5 Results and discussions

Descriptive statistics for all variables used in the analysis are shown in Table 3.1. The strongest state in the dataset had a relative strength of *0.99* (India outnumbered the *KCP* by *13,600:1* troops) and the weakest state had a relative strength of *-0.99* (Burma was outnumbered by the *CPB* by *1:15* troops). Governments involved in multi-party conflicts generally had poor administrative capabilities (the mean polity score = *-0.2*).

The maximum leadership turnover was *4* (the Congolese group, the *RCD*, who fought in Zaire) and the minimum leadership turnover was *1*. Three quarters of the groups in the dataset had only one leader for the entire duration of conflict. *15%* of the groups experienced fractionalisation, whereas about half the rebel groups (~ *49%*) were new entrants to their conflict. A matrix of correlation coefficients for the pairs of these independent variables is shown in Table 3.2. All variables used in the analysis are independent of one another.

Table 3.2 Correlation matrix (Spearman rank correlation)

	Ideol. ties	Strong rebels	Weak rebels	State strength	Polity	Leader turn.	Fract.	New group
Ideological ties	*1.0*							
Strong rebels	*-0.17*	*1.0*						
Weak rebels	*0.31*	*-0.30*	*1.0*					
State strength	*0.05*	*-0.10*	*-0.01*	*1.0*				
Polity	*-0.21*	*0.04*	*-0.15*	*-0.19*	*1.0*			
Lead. turnover	*0.06*	*-0.06*	*0.02*	*0.15*	*0.11*	*1.0*		
Fractionalised	*0.07*	*0.09*	*-0.02*	*-0.01*	*-0.15*	*-0.07*	*1.0*	
New group	*0.01*	*-0.13*	*0.09*	*0.08*	*-0.07*	*0.18*	*-0.22*	*1.0*

3.5.1 Results of logistic regression analysis

Table 3.3 shows logistic regression estimates for the effect of rebel group alliance credibility on the likelihood of cooperation. The coefficient for *state strength* is positive and significant (at the <*0.01* level), indicating that rebel groups are more likely to form alliances when they are at war with a militarily strong state. The coefficient for *fractionalisation* is also significant (at the <*0.01* level) but the coefficient is negative, indicating that rebel groups who experience fractionalisation are less likely to form alliances. The largest effect on cooperation is *state strength*, with an odds ratio = *2.03*, compared to an odds ratio = *0.49* for the variable *fractionalised*. Predicted probabilities showing the effects of *state strength* and *fractionalisation* on cooperation are shown in Figures 3.2 and 3.3 respectively.

Table 3.3 Logistic regression estimates showing the effect of rebel group credibility on the likelihood of alliance formation

Variable	Coefficient	Standard error
Ideological ties	0.132**	0.024
Strong rebels	-0.065	0.241
Weak rebels	0.341	0.196
State strength	0.710**	0.139
Polity	-0.001	0.013
Leadership turnover	0.112	0.165
Fractionalised	-0.712**	0.228
New group	-0.097	0.175
Previous coop	-1.779**	0.141
Previous coop^2	0.218**	0.024
Previous coop^3	-0.007**	0.001
Constant	0.488	0.274
Number of obs.	1126	
LR χ^2 (11)	501.82	
Log likelihood	-464.177	
Pseudo R^2	0.35	

Note: ** denotes significance at $p \leq 0.01$, * denotes significance at $p \leq 0.05$

Figure 3.2 Predicted probabilities of group cooperation for a range of assumed values of state strength (range = -1:1) generated from logistic regression estimates

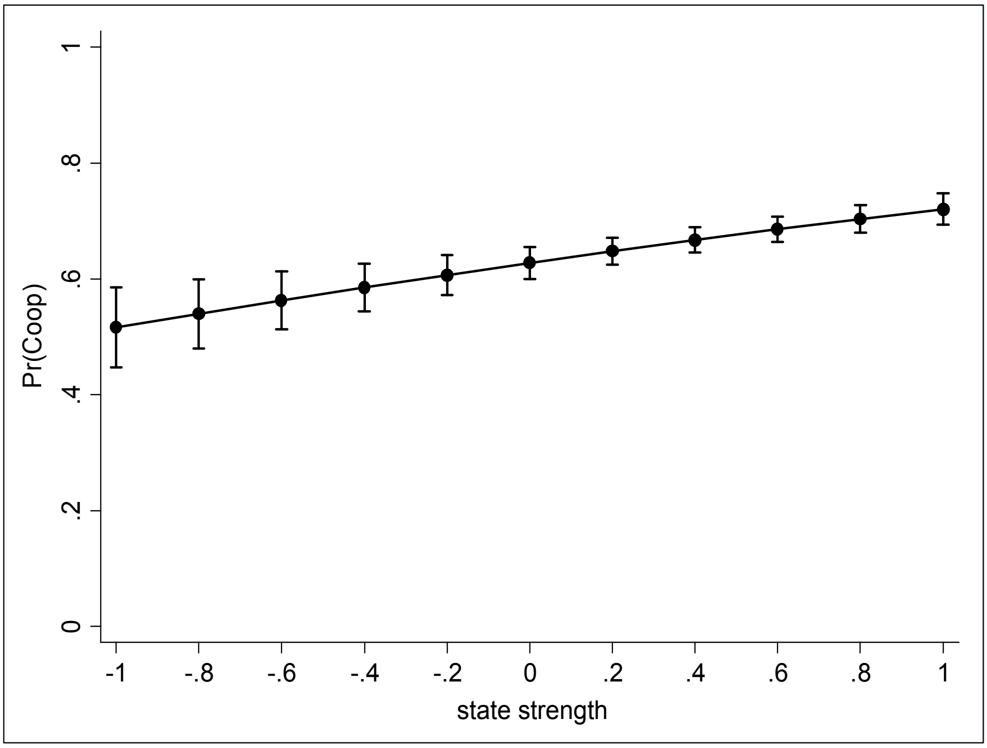


Figure 3.3 Predicted probabilities of group cooperation for a range of assumed values of rebel group fractionalisation (range = 0:1) generated from logistic regression estimates

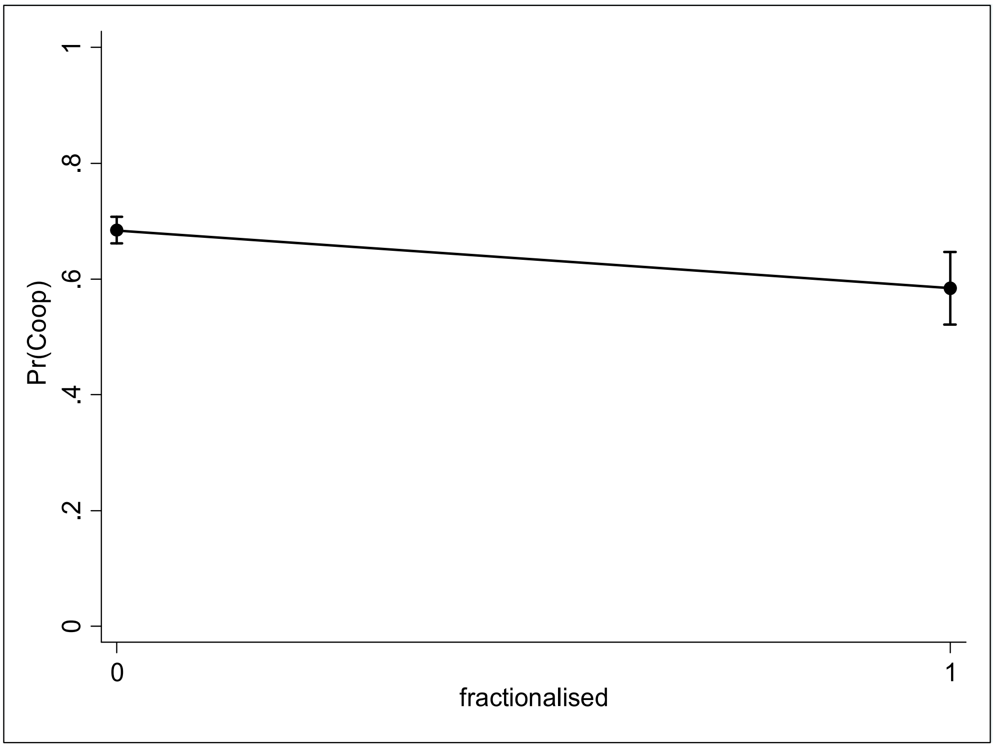


Table 3.4 shows logistic regression estimates for rebel group cooperation with the inclusion of the variable interaction terms to test for moderating effects. The results for *state strength* and *fractionalisation* are robust (both at the *<0.01* level). The size of the effect increases for *state strength* (as signified by an odds ratio *= 2.81* compared to *= 2.03* in the previous model), whereas the size of the effect for *fractionalisation* decreases (as signified by an odds ratio *= 0.53* compared to *= 0.49* in the previous model).

No evidence is found in support of hypotheses *5a*, but the variable, *ideology * new group*, is significant (at the *<0.01* level), which provides evidence in support of hypothesis *6a*, since it demonstrates a moderating effect between the variables *ideology* and *new group*. The coefficient is negative, indicating that rebel groups who are ideologically similar to their peers and who are also new entrants to the conflict are less likely to form alliances. Overall, the inclusion of the moderating variables improves the model fit (the pseudo R^2 has increased to *0.37* compared to *0.35* in the previous model).

Table 3.4 Logistic regression estimates showing the effect of rebel group credibility on the likelihood of alliance formation with the inclusion of moderating variables

Variable	Coefficient	Standard error
Ideological ties	0.178**	0.029
Strong rebels	-0.042	0.244
Weak rebels	0.306	0.200
State strength	1.032**	0.234
Polity	-0.004	0.024
Leadership turnover	0.088	0.171
Fractionalised	-0.633**	0.240
New group	0.069	0.188
Ideology * S. strength	-0.031	0.027
Ideology * Polity	-0.001	0.004
Ideology * L. turnover	-0.011	0.019
Ideology * Fracted.	-0.039	0.032
Ideology * New group	-0.087**	0.029
Previous coop	-1.769**	0.142
Previous coop^2	0.220**	0.025
Previous coop^3	-0.007**	0.001
Constant	0.492	0.284
Number of obs.	1126	
LR χ^2 (16)	526.75	
Log likelihood	-451.734	
Pseudo R^2	0.37	

Note: ** denotes significance at $p \leq 0.01$, * denotes significance at $p \leq 0.05$

Brambor *et al.* (2006) suggest that moderating effects between two independent variables are best analysed by plotting the marginal effect of the primary independent variable versus the conditional variable while holding all other variables constant. The findings for the conditional relationship between rebel group cooperation and *ideology * new group* are plotted this way in Figure 3.4 using Boehmke's (2006) **grinter** data utility in STATA. As is evident in Figure 3.4, the marginal effect of *ideology* on the probability of cooperation decreases as the variable *new group* increases, thus providing strong evidence in support of hypothesis *6a*. The *95%* confidence intervals (dashed lines) exclude zero at all values of *new group* indicating that this relationship is statistically significant across the entire range.

Figure 3.4 Marginal effect of ideology on the probability of cooperation versus the conditional variable, *new group* (range = 0:1), generated from logistic estimates

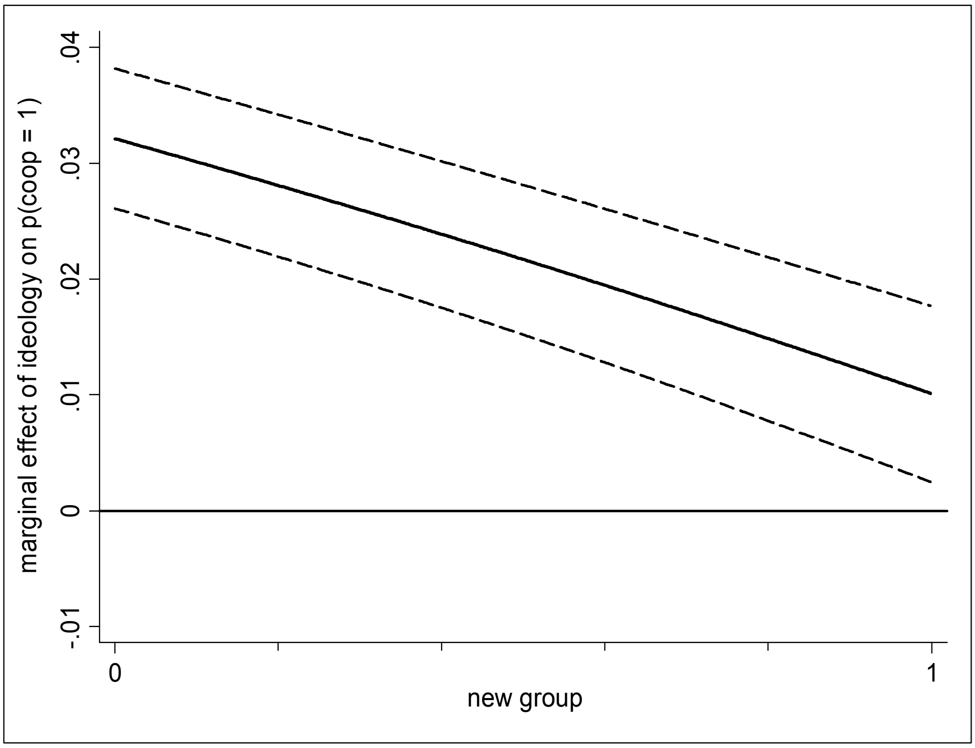


Table 3.5 shows logistic regression estimates for the effect of rebel group credibility on the likelihood of inter-rebel violence. The coefficients for *leadership turnover, fractionalisation* and *new group* are all positive and significant (at the *<0.01, <0.01* and *<0.05* levels respectively), indicating that rebel groups who have higher numbers of leaders, those who experience fractionalisation or those who are new entrants to a conflict are more likely to engage in inter-rebel violence. The odds ratio for *fractionalisation = 2.59*, *new group = 1.77* and *leadership turnover = 1.75*. Predicted probabilities for these effects are plotted in Figures 3.5 – 3.7. In Figure 3.5, the slope is steeper at higher values of *leadership turnover* indicting

that the probability of inter-rebel violence increases more markedly with higher numbers of leaders, whereas the slopes in Figures 3.6 and 3.7 are relatively flat, indicating that the probability of fighting is less sensitive to changes in *fractionalised* and *new group*.

Table 3.5 Logistic regression estimates showing the effect of rebel group credibility on the likelihood of inter-rebel violence

Variable	Coefficient	Standard error
Ideological ties	*0.045*	*0.026*
Strong rebels	***2.027****	*0.310*
Weak rebels	***0.668****	*0.290*
State strength	*0.091*	*0.178*
Polity	*-0.014*	*0.019*
Leadership turnover	***0.560****	*0.186*
Fractionalised	***0.952****	*0.274*
New group	***0.573****	*0.245*
Previous fight	***-0.537****	*0.106*
Previous fight^2	***0.029****	*0.010*
Previous fight^3	*-0.001*	*0.001*
Constant	***-3.601****	*0.427*
Number of obs.	*1126*	
LR χ^2 (11)	*162.57*	
Log likelihood	*-272.295*	
Pseudo R^2	*0.23*	

*Note: ** denotes significance at $p \leq 0.01$, * denotes significance at $p \leq 0.05$*

Figure 3.5 Predicted probabilities of group fighting for a range of assumed values of leadership turnover (range = 1:4) generated from logistic regression estimates

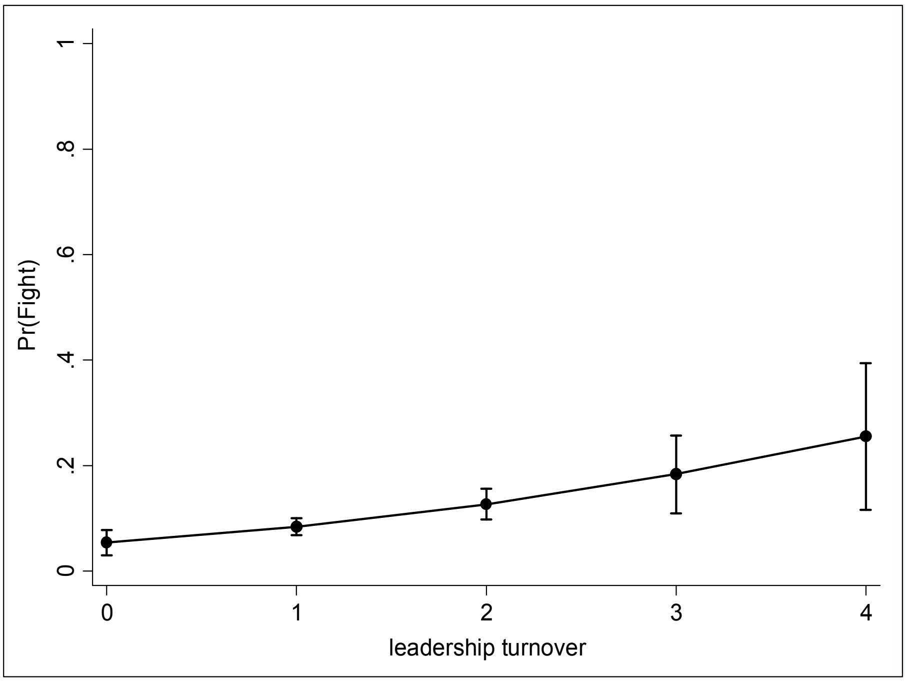


Figure 3.6 Predicted probabilities of group fighting for a range of assumed values of group fractionalisation (range = 0:1) generated from logistic regression estimates

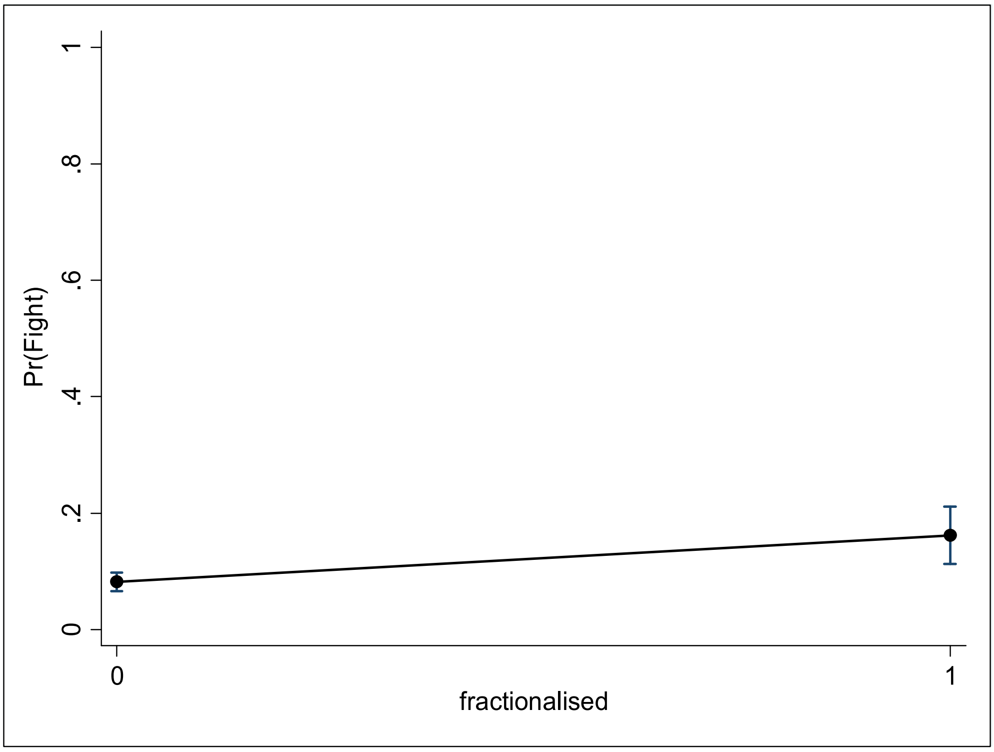


Figure 3.7 Predicted probabilities of group fighting for a range of assumed values of new group (range = 0:1) generated from logistic regression estimates

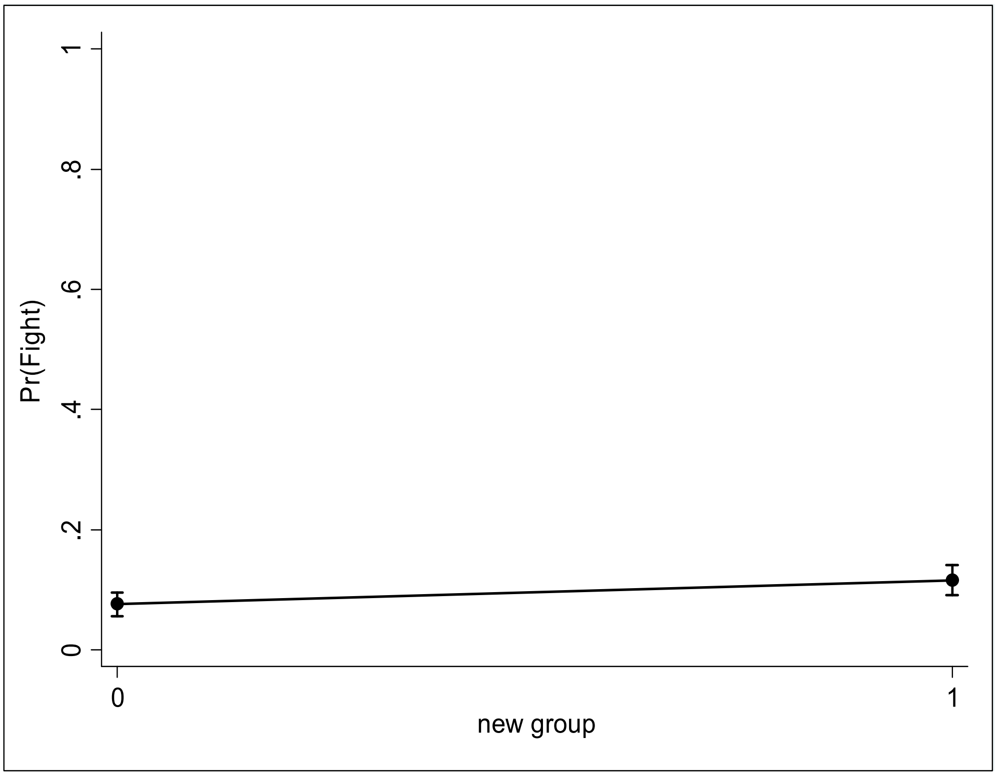


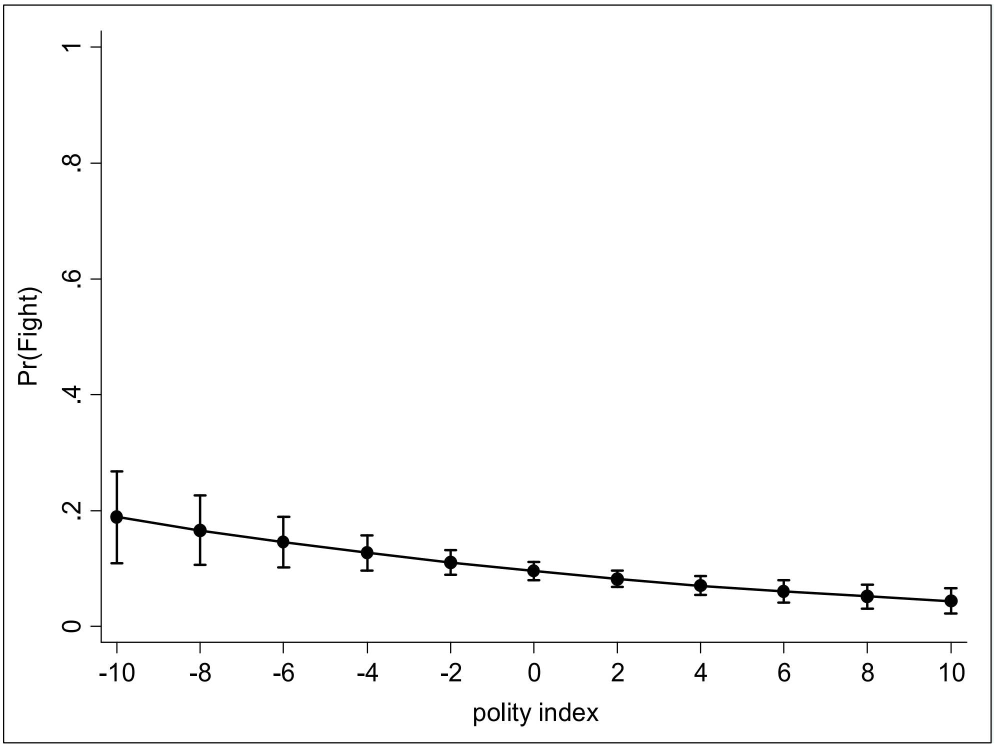
Table 3.6 shows logistic regression estimates for inter-rebel violence with the inclusion of the moderating variables. The results for *leadership turnover, fractionalisation* and *new group* are all robust. The coefficient for *polity* gains significance (at the *<0.01* level) with a negative coefficient, indicating that rebel groups are less likely to engage in inter-rebel violence when they are at war with an administratively strong state. Predicted probabilities for the effect of *polity* on inter-rebel violence are shown in Figure 3.8. The effect is moderate as signified by the small change in the probability of inter-rebel violence between the lower and upper values of *polity* (this moderate effect is also signified by an odds ratio for *polity = 0.89*). The result on *polity* replicates the findings of Fjelde and Nilsson (2012) who suggest that if the state authority is weak, rebel groups are more likely to be concerned about their position relative to the other rebel groups, since these are all vying for political influence. This competition over political influence is likely to motivate inter-rebel violence because groups seek to eliminate their competitors in anticipation of the state being overthrown.

Table 3.6 Logistic regression estimates showing the effect of rebel group credibility on the likelihood of inter-rebel violence with the inclusion of moderating variables

Variable	Coefficient	Standard error
Ideological ties	**_0.078*_**	_0.032_
Strong rebels	**_2.140**_**	_0.324_
Weak rebels	**_0.726**_**	_0.293_
State strength	_-0.416_	_0.290_
Polity	**_-0.108**_**	_0.035_
Leadership turnover	**_0.525**_**	_0.195_
Fractionalised	**_1.028**_**	_0.290_
New group	**_0.549*_**	_0.269_
Ideology * S. strength	**_0.061*_**	_0.031_
Ideology * Polity	**_0.016**_**	_0.005_
Ideology * L. turnover	_0.030_	_0.026_
Ideology * Fracted.	_-0.038_	_0.038_
Ideology * New group	_-0.019_	_0.037_
Previous fight	**_-0.558**_**	_0.107_
Previous fight^2	**_0.028**_**	_0.010_
Previous fight^3	_-0.001_	_0.001_
Constant	**_-3.939**_**	_0.461_
Number of obs.	_1126_	
LR χ^2 (16)	_180.03_	
Log likelihood	_-263.566_	
Pseudo R^2	_0.25_	

*Note: ** denotes significance at* $p = \leq 0.01$*, * denotes significance at* $p = \leq 0.05$

Figure 3.8 Predicted probabilities of fighting for a range of assumed values of polity (range = -10:10) generated from logistic estimates



The variable, *ideology * state strength*, is significant (at the *<0.05* level) but the coefficient is positive (contrary to the expectations of hypothesis *5b*), indicating that rebel groups who are ideologically similar to their peers and who are at war with a militarily strong state are more likely to engage in inter-rebel violence. The variable *ideology * polity* also yields an effect contrary to expectations with a positive coefficient (significant at the *<0.01* level). This suggests that groups who are ideologically similar to their peers and who are at war with an administratively strong state are also more likely to engage in inter-rebel violence.

Although the outcomes described above are contrary to expectations, the effects are small. Further investigation using Boehmke's (2006) **grinter** data utility in STATA, reveals the results plotted in Figures 3.9 and 3.10. In Figure 3.9 the slope showing the marginal effect of *ideology* on the probability of inter-rebel violence is essentially flat and the same is true in Figure 3.10, although in this latter figure there is a slight increase in the slope of the curve at higher values of *polity*. The confidence intervals in both figures exclude zero, indicating that the effects are statistically significant over the entire ranges of both *state strength* and *polity*, but since the curves are essentially flat, these results may be regarded as *no-effect*.

Figure 3.9 Marginal effect of ideology on the probability of inter-rebel violence versus the conditional variable, *state strength* (range = -1:1), generated from logistic estimates

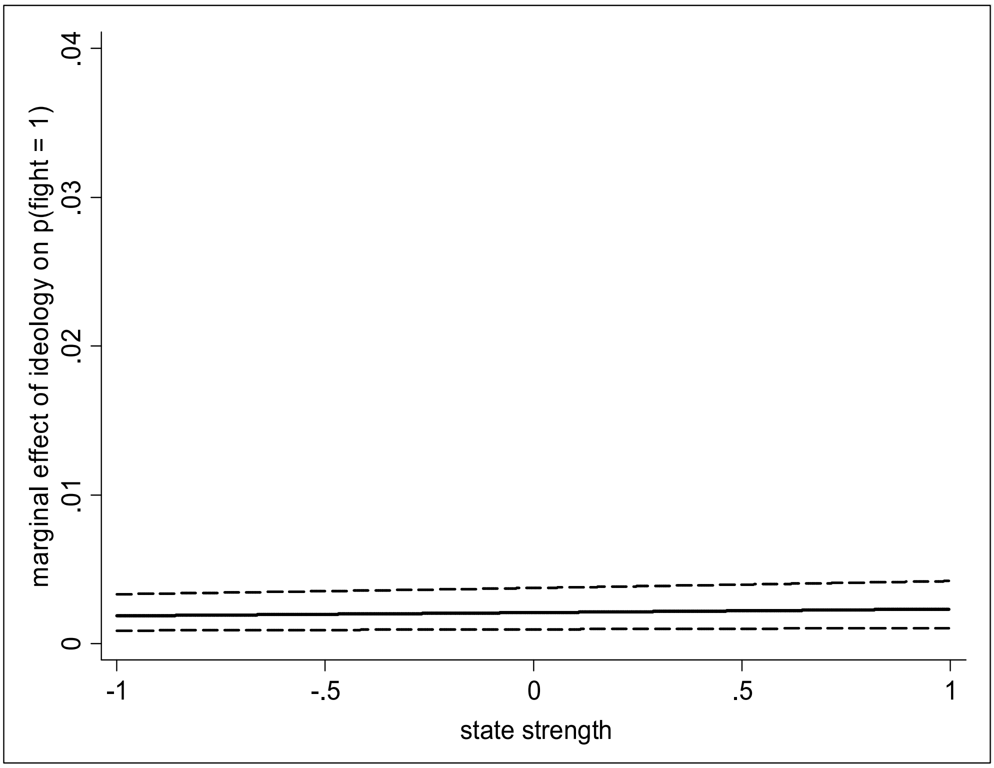
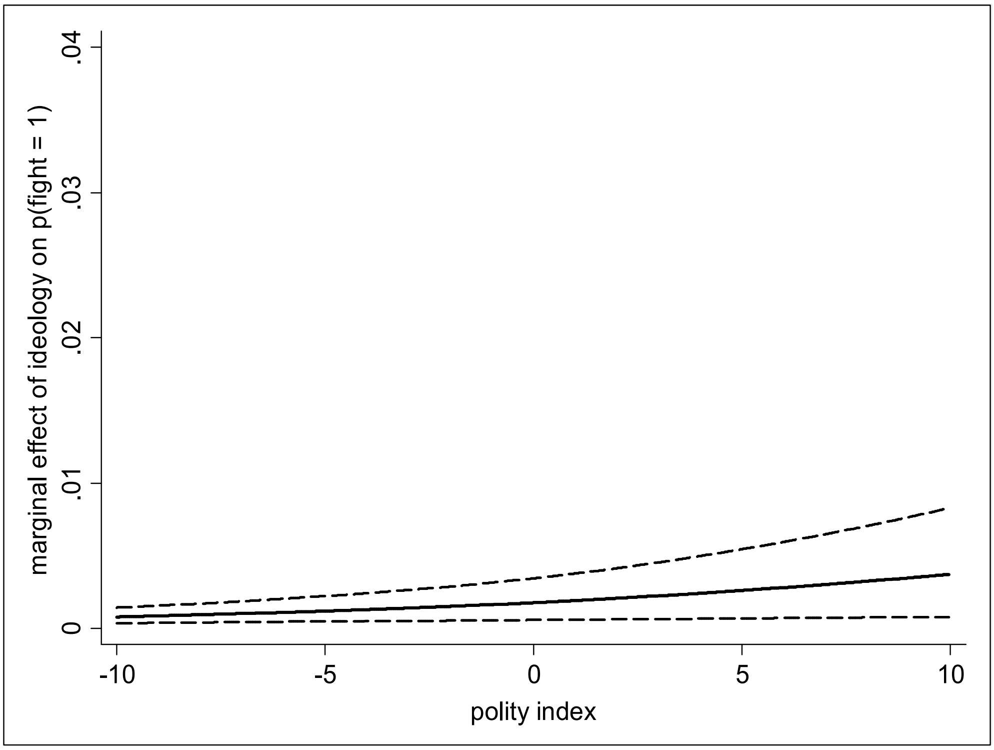


Figure 3.10 Marginal effect of ideology on the probability of inter-rebel violence versus the conditional variable, *polity* (range = -10:10), generated from logistic estimates



3.5.2 Results of CART analysis

Results of the classification tree analysis are shown in Figure 3.11. The dependent variable *interaction strategy type* was used. The interaction strategy types were; *operate independently, cooperate only, fight only, cooperate with one group and fight with another, fight with previous ally*. The classification tree reveals that the most important variables associated with *interaction strategy type* are *ideological ties, state strength, fractionalisation* and *leadership turnover.* Importantly, in the CART analysis, the independent variables for relative rebel group size, *strong rebels* and *weak rebels* are shown to be unimportant predictors of *interaction strategy type*. Note that this result is contrary to the findings reported in Chapter II, which suggested that relative rebel group size was an important predictor of rebel group interactions. Instead, the first node is ideology, which suggests that the variable, *ideological ties,* is the most powerful predictor of interaction strategy type.

At each node, the left branch is conditional on the node being true and the right branch is conditional on the node being false. In figure 3.11, the first left branch includes those observations where *ideological ties < 10.5* (the condition is true), whereas the right branch includes those observations where *ideological ties > 10.5* (the condition is false). Note again for reference; the range of the *ideological ties* variable is *0* to *24*. The values under each node correspond to the number of observations of each of the five interaction strategy types. At the root level (i.e. underneath the first node), the numbers *116/ 679/ 54/ 134/ 143*, signify the initial number of observations for each of the five interaction outcomes. Thus: *operate independently = 116, cooperate only = 679, fight only = 54, cooperate with one group, fight with another = 134* and *fight with previous ally =143*). As a check, these numbers sum to *1126*, which is equal to the total number of observations included in the analysis.

If a rebel group has an *ideological ties* value < *10.5*, the variable *state strength*, is the second most powerful predictor of interaction strategy type, whereas if a group has an *ideological ties* value of > *10.5*, then the variable *fractionalised*, is the second most powerful predictor of interaction strategy type. This provides evidence in support of hypotheses *6a* and *6b* as it implies that groups who are heavily ideologically tied to their peers are influenced by *fractionalisation*. The implication is that groups who are ideologically similar to their peers make interaction decisions on the basis of the organisational characteristics of other groups, whereas groups who are ideologically dissimilar to their peers make their interaction decisions on the basis of the level of external threat. *12%* of rebel groups who adopted a strategy of *cooperate only* had an *ideological ties* value > *10.5*, whereas *88%* of rebel groups who adopted a strategy of *cooperate only* had an *ideological ties* value < *10.5*. In total, *11%* of rebel groups who adopted a strategy of *fight only* had an *ideological ties* value > *10.5*, whereas *89%* of rebel groups who adopted a strategy of *fight only* had an *ideological ties* value < *10.5*. This reflects the fact that the majority of rebel groups in the dataset have a low ideological ties score (the mean value of *ideological ties* = *6.5*).

The third level of the classification tree indicates that rebel groups who are ideologically dissimilar to their peers (i.e. *ideological ties* < *10.5*) and who are engaged in conflict against relatively strong states (i.e. with a relative strength > *-0.38*, are most effected by *leadership turnover*, whereas groups who are ideologically dissimilar to their peers but who are engaged in conflict against weaker states (i.e. with a relative strength < *-0.381*) are most effected by *ideological ties*. Of those groups who are ideologically dissimilar to their peers, *92%* who adopted a strategy of *cooperate only* were engaged in conflict against a stronger state.

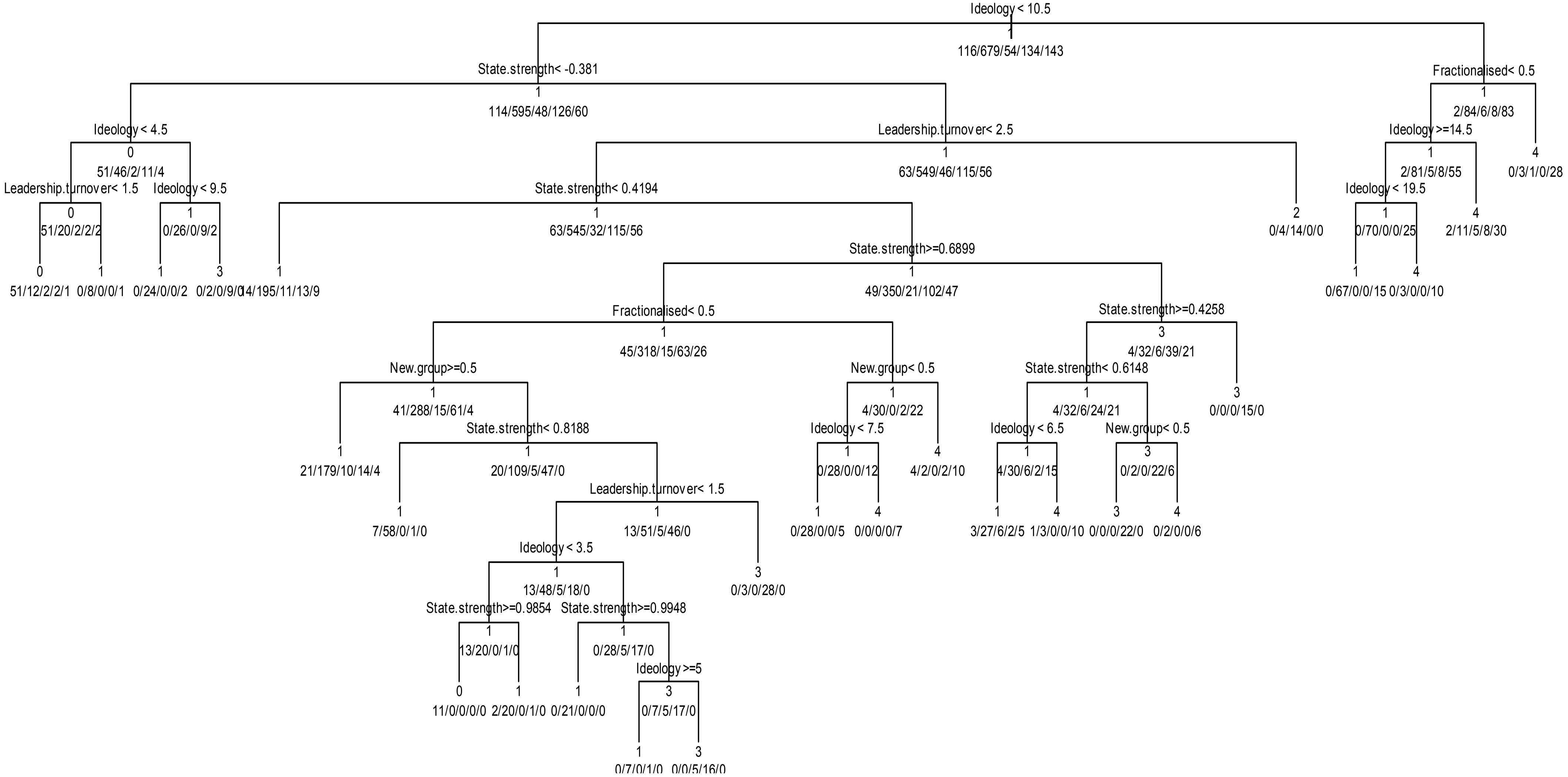
Table 3.7 shows summary results for the classification tree analysis. The first column shows the number of splits in the tree (= *25*). The second column shows the complexity parameter (*CP*), which signifies the *Gini impurity* measure at each split. Classification trees use *Gini impurity* to determine each split from the root of the tree (i.e. to *grow* the tree). Gini impurity is a measure of statistical inequality which measures how often a randomly chosen element from the set (in this case interaction strategy type) would be incorrectly labelled if it were randomly labelled according to the distribution of labels in the subset.

Table 3.7 Summary results for the interaction strategy type classification tree analysis shown in Figure 3.11

***N* splits**	**CP**	**Relative error**	**x error**	**SD**
0	*0.031*	*1.000*	*1.000*	*0.037*
5	*0.022*	*0.832*	*0.906*	*0.036*
6	*0.020*	*0.810*	*0.846*	*0.035*
10	*0.018*	*0.732*	*0.837*	*0.035*
11	*0.016*	*0.714*	*0.817*	*0.035*
14	*0.015*	*0.667*	*0.767*	*0.035*
22	*0.013*	*0.544*	*0.734*	*0.034*
25	*0.010*	*0.503*	*0.613*	*0.032*

Number of observations = *1126*
Root node error: *447/1126 = 0.397*

Figure 3.11 Classification tree for rebel group interaction strategy type



Gini impurity is computed by summing the probability of each item being chosen, multiplied by the probability of a mistake in categorising that item. It reaches its minimum (zero) when all cases in the node fall into a single target category. The classification tree algorithm selects the splits that result in the greatest decrease the Gini impurity measure. The minimum *CP* value (set at a default of = *0.01*) occurs at *25* splits, indicating that at *25* splits, all cases at each node fall into a single category.

On occasions the algorithms used to grow the trees in classification tree analysis can produce a large number of nodes and splits, such that certain variables, which are not very informative themselves, may lead to highly informative subsequent splits. This problem is known as *over-fitting* and to overcome this issue, a cross-validation method is used to *prune* the tree.

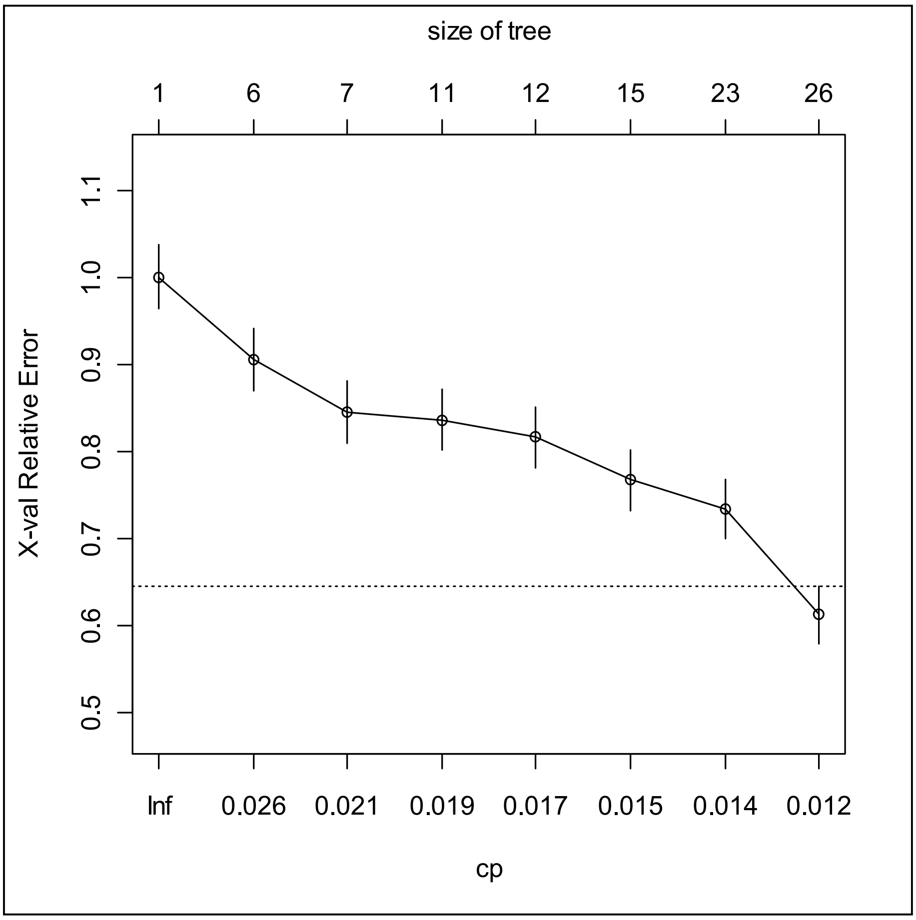
To achieve this, the data are randomly divided into two sets (‘training data’ *50%* and ‘testing data’ *50%*). The tree-growing algorithm described above is then applied to the training data only and the tree grown from the training data is then cross-validated using the testing data. The error rate for the training data and testing data is evaluated for each split at each node. For classification trees, the error rate refers to the misclassification rate (i.e. the fraction of cases assigned to the wrong class at each split). If the error rate of the testing data is decreased by removing a split at a node, the tree is pruned and the split is removed. This process is repeated until pruning no longer improves the error on the testing data.

In Table 3.7, the column, *relative error*, shows the error at each split for the tree grown by the training data and the column, *x error*, shows the error at each split when the testing data is fitted. It is evident that the error on the testing data (*x error*) is larger than the error on the training data (*relative error*) at all splits. Crucially, the fit improves at every split for both trees grown by the training and the test data, which confirms that the tree is not over-fitted and thus contains the optimum number of splits. Figure 3.12 shows a graphical depiction of this. If the classification tree was over-fitted, there would be an increase in the *x error* at larger tree sizes. Reassuringly, the graph shows a continuous decrease in the *x error* with increased numbers of splits.

The final column in Table 3.7 shows the standard deviation of the data at each split of the classification tree. At each branch of the tree, the data is partitioned into subsets that contain similar values and the standard deviation for all possible subsets is calculated. The subset that creates the highest reduction in the standard deviation is selected to form new branches of the tree and a split is formed on the basis of this calculation. This process is repeated at each branch. The resulting standard deviation is subtracted from the standard deviation before the split. Thus, CARTs seek to create the most homogenous branches by achieving the highest possible standard deviation reduction at each split.

The root node error shows the presences and absences (i.e. the frequency of each response class) at nodes for the entire tree. The root node error of the classification tree in this case is ~ *40%*, a value that signifies the number of presences in the data.

Figure 3.12 Plot showing cross-validation results for the interaction strategy type classification tree analysis shown in Figure 3.11



Robustness checks for CART analysis

Figure 3.13 shows a classification tree for the binary outcome, *cooperate*. The results obtained from this classification tree can be compared directly to the logistic regression results presented earlier in this chapter. Inspection of Figure 3.13 reveals that the most important variables associated with rebel group cooperation (in order of importance) are *ideological ties*, *state strength, fractionalised* and *leadership turnover.*

This confirms the robustness of results obtained from the logistic regression models, with the exception of the variable *new group*, which was found to be important in the logistic regression models but not in the CART analysis, and the variable *leadership turnover*, which has explanatory power in the CART analysis but was not found to be statistically significant in the logistic regression models. The main result obtained from Figure 3.13 is that groups who are ideologically similar to their peers (i.e. with *ideological ties* > *4.5*) are influenced by *fractionalisation.* This provides some further evidence in support of hypothesis *6a*.

Figure 3.13 Classification tree for rebel group cooperation

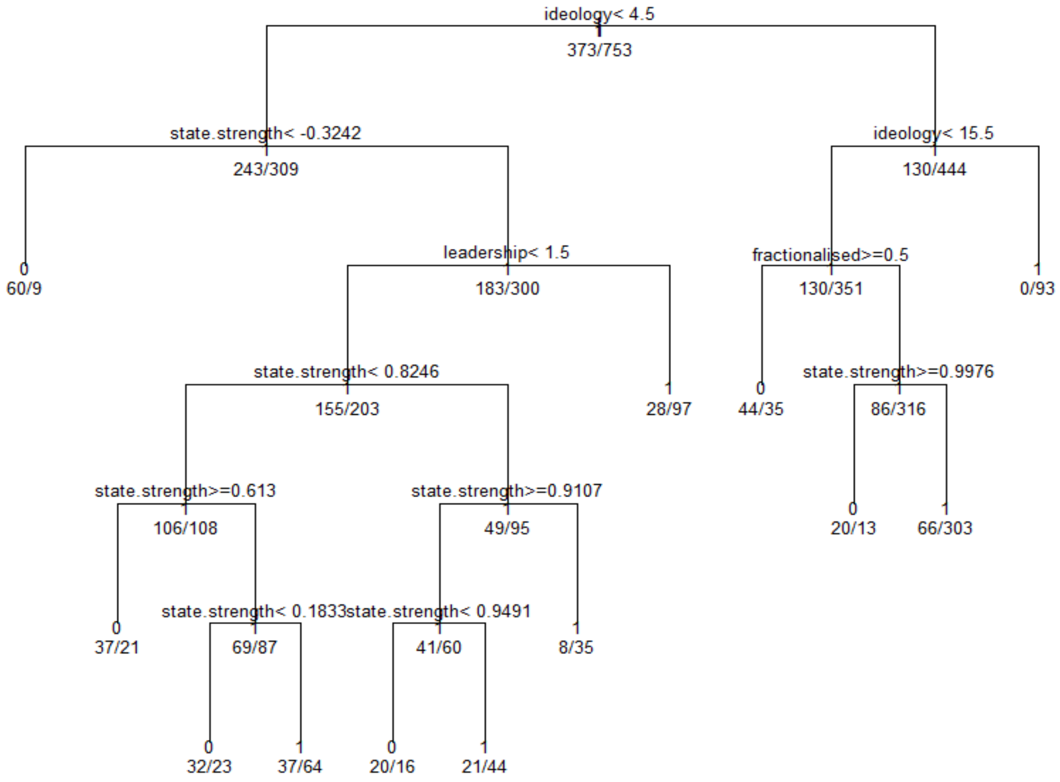


Table 3.8 shows the summary of cross-validation results obtained from the cooperation classification tree. The root node error is ~ *33%*. In this case, the *x error* and *SD* are not reduced between splits 2 and 9 and the complexity parameter is *<0.01* after 9 splits. This suggests that the tree is slightly over-fitted (as is evident by the fact that all branches after 5 splits are subsets of the *state strength* variable.

Table 3.8 Summary results for the cooperation classification tree analysis

N splits	CP	Relative error	x error	SD
0	*0.068*	*1.000*	*1.000*	*0.042*
2	*0.014*	*0.863*	*0.866*	*0.041*
6	*0.012*	*0.791*	*0.866*	*0.041*
9	*0.005*	*0.748*	*0.858*	*0.041*
12	*0.001*	*0.732*	*0.842*	*0.040*

Number of observations = *1126*
Root node error: *373/1126 = 0.331*

Figure 3.14 Plot showing cross-validation results for the cooperation classification tree analysis shown in Figure 3.13

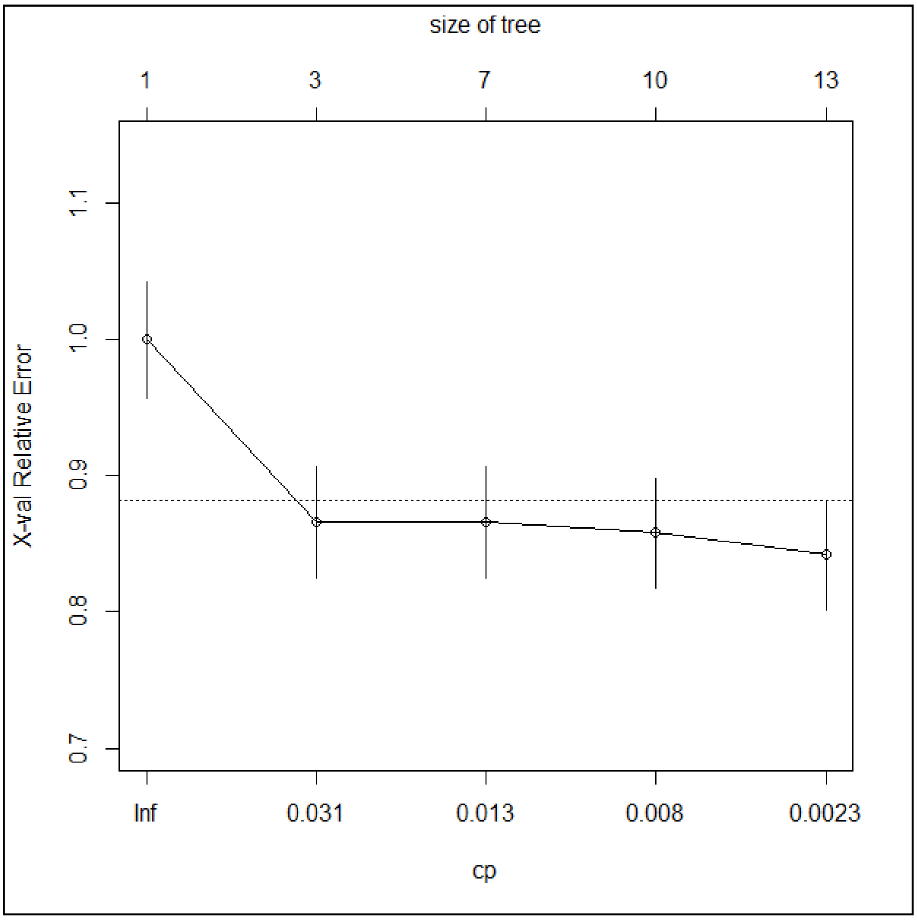


Figure 3.15 shows a classification tree for the binary outcome *fight*. The results obtained from this classification tree can be compared directly to the logistic regression results presented earlier in this chapter. Inspection of Figure 3.15 reveals that the most important variables associated with inter-rebel violence (in order of importance) are *strong rebels, ideological ties, leadership turnover* and *fractionalised*. This confirms the robustness of results obtained

from the logistic regression models, with the exception of the variables *weak rebels* and *new group* which were statistically significant in the logistic regression models but not in the CART analysis. The main result obtained from Figure 3.15 is that groups who are ideologically similar to their peers (i.e. with *ideological ties* > *7.5* and < *13.5*) are influenced by the variable *fractionalisation.*

But, inspection of the cross-validation results (shown in Table 3.9 and plotted in Figure 3.16) show that the *x error* and *SD* increases with increased numbers of splits in the tree. This indicates that the data do not fit the tree well. One possible reason could be the extent of absences in the data, shown via the root node error = ~ *10%.* As such, it is not possible to draw strong results from the classification tree in this instance.

Figure 3.15 Classification tree for inter-rebel violence

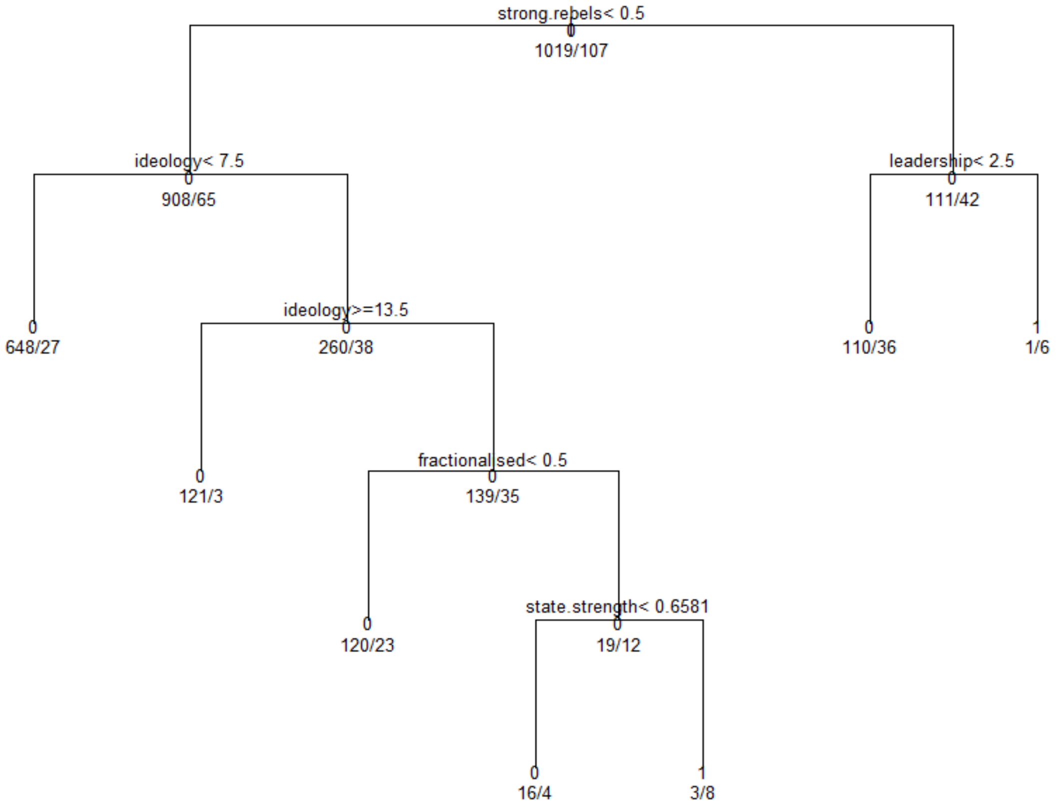
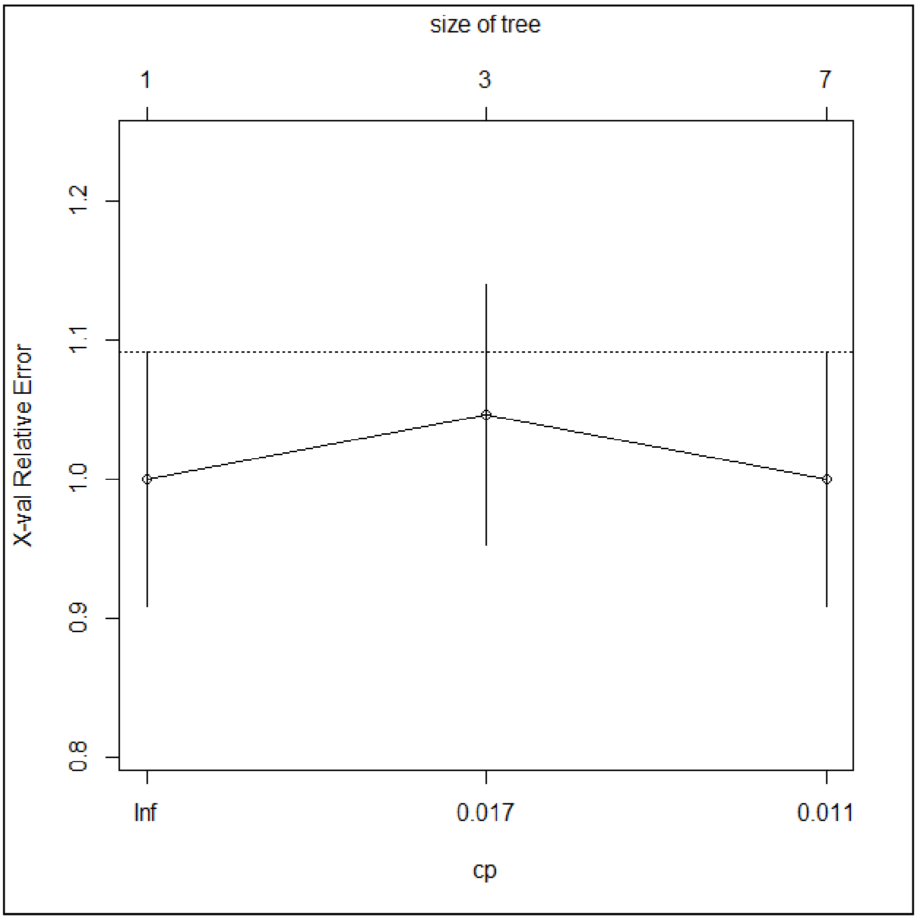


Table 3.9 Summary results for the inter-rebel violence classification tree analysis

N splits	CP	Relative error	x error	SD
0	*0.023*	*1.000*	*1.000*	*0.092*
2	*0.012*	*0.953*	*1.047*	*0.094*
6	*0.010*	*0.907*	*1.000*	*0.092*

Number of observations = ***1126***
Root node error: ***107/1126 = 0.095***

Figure 3.16 Plot showing cross-validation results for the inter-rebel violence classification tree shown in Figure 3.15



Advantages and limitations of CART analysis

The main advantage of CARTs is that they are self-explanatory and easy to follow. They can handle outcomes that are continuous or discrete, they are not affected by outliers and they can be adapted easily to deal with missing values. This makes them highly suitable for the analysis of cross-country conflict data, which indeed often has missing values. Since CARTs are a non-parametric method, they are not based on distributional assumptions, making them highly amenable to the study of a wide range of real-world situations. As such, they are especially useful for studying complex problems, such as rebel group interaction strategies, since they inherently measure the moderating effect of one independent variable on another.

A number of limitations do exist however and these can be divided into two categories, namely (*i*) algorithmic problems that complicate the goal of finding a small tree and (*ii*) problems inherent to the tree representations (Friedman *et al.* 1996). One of the algorithmic limitations is that CARTs represent a *divide-and-conquer* method. This means that they perform well if a few highly relevant attributes exist but perform badly if many complex interactions between variables are present (Pagallo and Huassler 1990). This limitation is perhaps applicable to the first classification tree presented in this chapter (Figure 3.11), which shows a large number of moderating effects between the independent variables over different ranges. A second algorithmic limitation is that CART algorithms are *greedy* (i.e. they make the locally optimum choice at each node of the tree, with the hope of finding a global optimum). This means that CARTs are over-sensitive to noisy data and might propagate this *noise* down the tree (Quinlan 1993).

One of the problems inherent with tree representation arises when the datasets contain large numbers of relevant features. The classification tree may then be too large and complex, making it hard to read and difficult to understand. Again, this limitation arguably applies to the classification tree shown in Figure 3.11, in which most of the independent variables are important. On the other hand, in some cases when there are too few relevant explanatory variables, a tree will not be grown beyond the root. Alternatively, if an outcome is under prevalent, it is likely that the tree will over-fit (as was the case for the classification tree shown in Figure 3.15).

3.6 Conclusions

The aim of this chapter has been to address the previously unanswered question of why some rebel groups form alliances with their peers while other groups, driven by apparently similar identity-based motives, engage in inter-rebel violence. The main contribution of the present work has been to propose novel theory relating to rebel group interactions, based on Walter's (1997) theory of *credible commitments*. On the basis of this theory, it was argued that rebel groups who are ideologically similar to their peers are more likely form alliances if they are perceived by other groups as being able to credibly commit to an alliance. If a group is ideologically similar to their peers but lacks alliance credibility however, it was argued that the group is more likely to engage in inter-rebel violence.

Alliance credibility was measured against two criteria: (*i*) the level of external threat faced by the rebel groups and (*ii*) the organisational characteristics of the groups themselves. External threat levels were proxied using two measures of state strength (the relative military capabilities of the state compared to the rebel group, *state strength*, and the administrative capabilities of the state, *polity*). The organisational characteristics of rebel groups, that were assumed to effect a group's perceived credibility, were leadership stability (proxied by *leadership turnover*), group cohesion (proxied by *fractionalisation*) and group longevity (proxied according to whether the group was a *new group* or new entrant to the conflict).

A set of conditional hypotheses were tested using two contrasting methodologies, namely logistic regression modelling with the inclusion of moderating variables (i.e. variable interaction terms) and classification and regression trees (CARTs). The application of CARTs in civil war research is novel. As such, the value of CARTs for testing moderating effects between variables has been highlighted. Unlike regression analysis that is theoretically motivated and limited to the model specified, CARTs are atheoretical. CARTs search the entire parameter space and test every combination of variables (and their values) to classify particular outcomes. The two methodologies are complimentary because CARTs can be used to validate the results obtained from regression models. If the conclusions drawn from both methods are the same then the results may be regarded as being more convincing.

3.6.1 Results of logistic regression analysis

Results of the logistic regression modelling suggest that rebel groups who are ideologically similar to their peers are less likely to form alliances if they are also a new entrant to a conflict. This provides evidence in support of the proposed conditional hypothesis that groups who lack alliance credibility in the eyes of their peers are less likely to form alliances with other groups. Results also suggest that rebel groups are less likely to form alliances if they are fractionalised (i.e. not cohesive), but are more likely to form alliances if they are engaged in conflict against a militarily strong state. Although these results support the theoretical arguments put forward in this chapter, no evidence is found in support of a moderating effect between the independent variable, *ideological ties*, and the two conditional variables, *fractionalised* and *state strength*.

With regards to the interaction outcome of inter-rebel violence, results of the logistic regression modelling show that rebel groups with high leadership turnovers are more likely to fight with other groups. Although this result supports the theoretical arguments put forward in this chapter, no evidence is found in support of a moderating effect between the independent variable, *ideological ties*, and the conditional variable, *leadership turnover*.

3.6.2 Results of CART analysis

Results of the CART analysis show that the most important variables associated with rebel group *interaction strategy type* (in order of importance) are *ideological ties, state strength, fractionalisation* and *leadership turnover.* Ideology is found to be the most important predictor of rebel group interactions. A moderating effect between the variables *ideological ties* and *fractionalisation* is found, which indicates that groups who are ideologically similar to their peers are most likely to base their interaction decisions on the cohesiveness (i.e. organisational characteristics) of their peers. This result provides additional evidence in support of the conditional hypotheses put forward in this chapter.

3.6.3 Comparison of results obtained from logistic regression versus CART analyses

The results obtained from the two methods are somewhat in agreement. The CART for alliance formation showed that the most important variables associated with cooperation (in order of importance) were *ideological ties*, *state strength, fractionalised* and *leadership turnover.* This confirmed the robustness of results obtained from the logistic regression models, with the exception of the variable *new group*, which was found to be important in the logistic regression models but not in the CART analysis, and the variable *leadership turnover*, which was found to have explanatory power in the CART analysis but was not found to be statistically significant in the logistic regression models. The main result obtained from the CART for alliance formation was that groups who are ideologically similar to their peers are most influenced by *fractionalisation.*

The CART for inter-rebel violence showed that the most important variables associated with fighting (in order of importance) were *strong rebels, ideological ties, leadership turnover* and *fractionalised*. This confirmed the robustness of results obtained from the logistic regression models, with the exception of the variables *weak rebels* and *new group* which were statistically significant in the logistic regression models but not in the CART analysis. The main result obtained from the CART for rebel group fighting was that groups who are ideologically similar to their peers are influenced by *fractionalisation.*

3.6.4 Additional lines of enquiry

Theories in the conflict literature assume that non-state actors adopt interaction strategies to increase their chance of military victory, to decrease their chance of being eliminated or to increase their bargaining power at the negotiating table with the aim of receiving concessions from the state. But few studies have examined the effects that alliance formation and inter-rebel violence have on rebel group credentials. Do rebel groups who adopt interaction strategies survive longer than those who operate independently? Do rebel groups who interact have an increased chance of attaining favourable conflict outcomes against the state? From the viewpoint of conflict resolution, gaining knowledge on the motivations and conditions responsible for rebel group interactions is only of value to policy-makers if we know how these interactions shape civil war dynamics. This aspect is considered next in Chapter IV.

Chapter IV

Rebel group interactions and civil war dynamics

Abstract

Theories regarding the motivations for rebel group interactions are based on the assumption that non-state actors interact to maximise their chance of military victory, to minimise their chance of being eliminated or to increase their bargaining power at the negotiating table with the aim of receiving concessions from the state. But these assumptions have not been tested empirically. Do rebel groups who interact survive longer than groups who operate independently? Do rebel groups who interact have an increased chance of attaining favourable conflict outcomes against the state? This chapter seeks to address these questions by exploring how alliance formation and inter-rebel violence influence the longevity and termination-type of rebel groups. Results show that groups who interact with their peers do not have increased longevity in comparison to groups who operate independently. Groups who engage in inter-rebel violence are more likely to concede to peace deals, whereas groups who align are less likely to concede to peace deals. Groups who form alliances are also less likely to suffer defeat and they are less likely to end up in a state of persistent war. The implications of these results are that states can maximise the chances of peaceful resolution by capitalising on moments that are opportune for offering peace deals.

4.1 Introduction

In multi-party conflicts, rebel groups coexist with others; some groups may have similar objectives or identities and others may not. Similarly, the state must account for the presence of multiple groups, some of which may pose a large threat because of their military capabilities, or the nature of their demands, whilst other groups may pose a lesser threat. In general, rebel groups start out weak, so the probability of their defeat is high in the initial stages of war. But if a rebel group is able to increase its military capabilities and reach a threshold where they are at parity with or stronger than the state, their chance of victory is clearly increased. These aspects pose the following fundamental questions. Why are states with substantial advantages in military capabilities and resources often unable to attain even limited objectives against much weaker insurgent groups? How do rebel groups starting out with weak capabilities and limited resources manage to avoid early elimination by stronger states? Unlike two-sided conflict, groups engaged in multi-party conflicts have the potential to gain strategic advantages by adopting interaction strategies. Weak rebels, who may be perceived as low-risk initially, might have the potential to pose a credible future threat if they interact with their peers in an advantageous way. Thus, rebel group interactions might explain why weak groups sometimes survive against low odds, or why strong states sometimes suffer defeat against seemingly less capable enemies (Akcinaroglu 2012).

The theories regarding the motivations for rebel group interactions discussed in the previous chapters are based on the assumption that non-state actors interact to increase their chance of military victory, to decrease their chance of being eliminated or to increase their bargaining power at the negotiating table with the aim of receiving concessions from the state. But few studies have examined the effects that interaction strategies have on rebel group survival and outcomes. Do rebel groups who adopt interaction strategies survive longer than those who operate independently? Do rebel groups who interact have an increased chance of attaining favourable conflict outcomes against the state? Answers to these questions are essential from the viewpoint of policy-makers concerned with conflict resolution. Gaining knowledge on the determinants of interactions is of value, only if we know how these interactions affect a rebel group’s chance of success. For example if groups who engage in inter-rebel violence get eliminated quickly or achieve less favourable outcomes, such as government defeat, policy-makers may be less concerned about the onset of conflict between rebel groups. But, if violence between non-state actors increases the chance of survival for some groups (who have survived at the expense of others), and if this results in favourable outcomes for the victorious group, such as rebel victory, then policy-makers might take the opposite view.

This aim of this chapter is to examine how alliance formation and inter-rebel violence alter the prospects of rebel groups in civil wars. The analyses presented in this chapter build on the insights gained from Akcinaroglu (2012) who has shown that the presence of multiple groups, alliances among rebel groups and the cumulative capabilities of those alliances, shape civil war outcomes. In the present work, survival models are employed so that the effect of rebel group interactions (alliance formation and inter-rebel violence) on group survival and conflict outcomes (i.e. termination-type) can be assessed. The next part of this chapter provides some further background and outlines the data, variables and modelling methods used. Results and discussions are provided. Conclusions are drawn and additional lines of inquiry intended for the final chapter of this thesis are discussed.

4.2 Background

Research on civil war dynamics has shown that if a government is unable to defeat rebels during the early stages of a conflict, the chances of a swift resolution are remote (Bapat 2005, Regan 2002). If a rebel group is able to avoid early elimination, it might then have the opportunity to replenish its resources via the assistance of external actors who could be strategically interested in prolonging the conflict (Balch-Lindsay and Enterline 2000; Akcinaroglu and Radziszewski 2005). This happened in the Sudanese and Ugandan conflicts, where both governments supported each others' rebel groups in an effort to weaken the other state (Prunier 2004). Rebels in Angola and Mozambique also received support from the government of South Africa who pursued a policy of external involvement in several civil wars (Minter 1994). External involvement also occurred in the Iranian and Iraqi conflicts, where both countries provided substantial support to one another's rebel organisations during the 1980's and 1990's as a result of their ongoing territorial dispute surrounding the Shatt Al-Arab waterway (Salehyan, Gleditsch and Cunningham 2011). The literature has shown that conflicts involving external actors last longer (Regan 2002), cause more fatalities (Heger and Salehyan 2007), and are more difficult to resolve through negotiations (Cunningham 2006).

By avoiding early defeat, a rebel group may also have the opportunity to gain control of natural resources and use the profits to assist recruitment (Olson 1965; Popkin 1979; Tullock 1971). Weinstein (2007) notes that resource constraints are often a major impediment against the formation and survival of rebel groups and Le Billon (2003) suggests that the extraction of natural resources provides one way for groups to overcome this constraint. Gates (2002) and Weinstein (2007) argue that groups with access to valuable resources can use profits, not only to mobilise troops, but also to supply weapons and other equipment. This occurred in Sierra Leone, when the two rebel groups, the *AFRC* and *RUF*, were able to build their military strength from international businessmen and arms suppliers who were willing to provide the groups with resources up-front, in exchange for mineral concessions (Humphreys and Weinstein 2008).

Swerving initial defeat might also boost a group's reputation, enabling them to establish themselves as a formidable force, giving them the opportunity to make use of repression as a mobilisation tool (Byman 1998; Kalyvas 2006; Wood *et al.* 2012). Insurgent groups in northern Uganda, Burma and Colombia all forcibly abducted children to fill their fighting ranks and the *Revolutionary United Front* (*RUF*) and *Lord's Resistance Army* (*LRA*) in Africa adopted recruitment strategies involving amputations and rape (Humphreys and Weinstein 2006). In a related matter, insurgents may also target civilians to emphasise the government's inability (or unwillingness) to protect vulnerable civilians. This occurred in Mozambique when the *Frente de Libertaçao de Moçambique* (*FRELIMO*) shelled villages to demonstrate that the Portuguese forces could not protect civilians (Henriksen 1983).

Despite these varied attempts to identify the mechanisms that enable rebel groups to avoid early defeat, few studies have considered the role of rebel group interaction strategies. A notable exception is the recent study by Akcinaroglu (2012) who has shown that alliances between non-state actors influence the dynamics of civil war. Akcinaroglu analyses civil conflict outcomes using competing-risks regression. She finds that rebels are more likely to avoid defeat if there are a large number of groups engaged in the conflict, or if the groups are able to form alliances against their common enemy. Akcinaroglu also finds that peace agreements are unlikely if rebel groups have access to high levels of ally capabilities and she finds that the chance of rebel victory is highest for groups who formally merge. Whilst this study represents an important contribution to the rebel group dynamics literature, its scope is limited, firstly because rebel group survival is not examined (the study considers civil war outcomes only), but also because the strategy, inter-rebel violence, is overlooked.

This chapter builds on the insights gained from Akcinaroglu (2012) by exploring how alliances and inter-rebel violence influence the conflict prospects of rebel groups. Theories regarding the motivations for rebel group interactions are based on rationalist explanations. They assume that rebel groups interact to maximise their chance of military victory, minimise their chance of being eliminated or to increase their bargaining power. On this premise, we should expect allied groups to have a higher chance of survival than non-allied groups. In-line with the findings of Akcinaroglu (2012) we should also expect allied rebels to terminate in favourable outcomes. This was the case for the *Tigrayan People's Liberation Front* (*TPLF*) in the Ethiopian civil war. In 1974 the emperor of Ethiopia, Haile Selassie, was overthrown in a military coup and his government was replaced with a Marxist-Leninist dictatorship. Almost immediately, the new regime faced armed insurgency from a number of groups who called for democracy and self-determination for all Ethiopian ethnic groups, many of whom (such as the Tigrayans), felt that they had been discriminated against under Haile Selassie and continued to be so under the new dictatorship. In the late 1970's and early 1980's the Mengistu government had the upper hand against the insurgents, far outnumbering them in military capacity. But by the late 1980's, the momentum had shifted, largely as a result of the political and military alliances that had been forged between the *TPLF* and a number of other rebel groups (now fighting under the banner *Ethiopian People's Revolutionary Democratic Front, EPRDF*).

In 1989, soon after the rebels had aligned, the government offered to conduct bilateral negotiations with the insurgent groups, but that offer was rejected and in 1991, the *TPLF* (with support from its allies) surrounded Addis Ababa and defeated the Ethiopian army, even though it was only one tenth the size. As a result, President Mengistu fled the country and the rebels took control of the capital. In this case, the *TPLF* was able to avoid early elimination by forming an alliance. The group increased its bargaining power, which meant that it refused to concede to the peace deal offered by the state. As a result of this alliance, the *TPLF* was subsequently able to defeat the much larger Ethiopian state; an outcome that would have been highly unlikely had the *TPLF* been operating on its own.

Devising possible expectations regarding the effect of inter-rebel violence on group survival is not a simple task, firstly, because the nature of the effect is likely to differ between the initiators and targets of violence (an aspect that is not coded in the available data), but also because the effect of inter-rebel violence on group survival will differ according to the outcome of the battle that takes place between the rebel groups. Clearly, if a rebel group is able to entirely defeat the other, then the victorious group might increase both its longevity and its chance of outright victory against the state by absorbing the resources of the defeated group and by eliminating competition over vital resources such as recruits or financial profit from natural resources (Fjelde and Nilsson 2012). That is of course assuming the victorious group did not encounter too heavy losses whilst engaging in inter-rebel violence. In this example the defeated group would inherently have decreased its longevity. On the other hand, if inter-rebel violence between two rebel groups does not result in an outright victory for either, then it might be expected that both groups would have decreased longevity as a result of eroding their capabilities by attempting to sustain conflict on multiple fronts. Under this condition, we might also expect rebel groups to be more likely to concede to peace deals in response to their diminishing capacity. This occurred in the conflict which took place in the Shan region of Burma (now Myanmar).

The Shan region was ruled separately during the British colonial period but was joined with Burma (as Shan State) upon independence in 1948. A provision was included in the constitution however, that Shan state could hold a referendum for independence after a period of ten years. In the early years after independence, Shan state experienced spill-overs from two neighbouring conflicts and these, combined with the government's move to centralise power, motivated the Shan population to start seeking independence. But when the time came for a referendum, the Myanmar government refused to give the Shan state an option to declare independence and in 1958, armed conflict erupted between the government and a number of Shan insurgent groups.

One group that emerged was the *Mong Tai Army* (*MTA*), which managed to gain control of a large amount of Shan territory along the border with Thailand by attacking other Shan insurgent groups in the region. By the late 1980's and 1990's, after a long period of conflict, the Myanmar government pursued a dual strategy of escalating the military conflict on the ground, at the same time as pursuing negotiations with the insurgent groups. In the face of increased intensity conflict from the state, combined with the losses being made a result of inter-rebel violence, several of the groups, including the *MTA*, agreed to ceasefire and they soon signed peace agreements with the Myanmar state.

These various dynamics are explored in more detail in this chapter using statistical models. Survival models are employed so that variations in rebel group survival (longevity) and conflict outcomes (termination-type) can be assessed according to the two rebel group interaction strategies discussed above; alliance formation and inter-rebel violence. The aim is to investigate whether rebel groups who interact have increased longevity compared to groups who operate independently and/or if groups who interact have a higher chance of attaining favourable outcomes against the state. The next part of this chapter describes the research design. Results and discussions are provided, limitations are discussed and conclusions are drawn. Additional lines of enquiry intended for Chapter V are outlined.

4.3 Research design

This section describes the dataset, variables and methods used to assess how rebel group interactions shape civil war dynamics.

4.3.1 Dataset and dependent variables

A sample containing all two-sided and multi-party conflicts is analysed using the dataset described in Chapter II. The unit of analysis is conflict-year. The total sample consists of *373* rebel groups, operating in *90* conflicts for *2,361* conflict-years. The outcomes of interest are rebel group *longevity* and *termination-type*. The dependent variable, *longevity*, is simply coded as the number of years the rebel group survived before termination. The dependent variable, *termination-type*, is coded at the rebel group level using the Cunningham *et al.* (2009) Dyadic Dataset. Table 4.1 shows the distribution of rebel group termination-types.

Table 4.1 Distribution of rebel group termination-types

Outcome	***N***	**%**
Peace agreement	*106*	*31.27*
Government victory	*69*	*20.35*
Rebel victory	*41*	*12.09*
Ongoing conflict	*123*	*36.28*
Total	*339*	*100*

The majority of rebel groups in the sample were engaged in ongoing conflict (*36%*). This outcome refers to conflicts that were still active at the end of the dataset but also, for some cases, this outcome refers to *attrition*. A state of attrition is assumed to occur when all sides are equally matched and have adequate resources to continue fighting (usually at diminishing intensity), but no side is able to achieve a decisive victory, nor are they prepared to negotiate a peace deal. Approximately one third of groups accepted a negotiated peace settlement (*31%*). One fifth suffered defeat, which resulted in government victory (*20%*) and a small minority (*12%*) of groups achieved an outright military victory against the state.

4.3.2 Independent variables

Two interaction strategies are examined; alliance formation and inter-rebel violence. These are coded in two different ways. Firstly, they are coded as binary variables as in Chapter II, but also as continuous variables indicating the number of consecutive years the group interacted with another group. This continuous variable was constructed because it might be the case that rebel groups are able to achieve favourable conflict outcomes only when they interact with other groups over a sustained period of time.

Coop: a binary variable taking the value of *1* if the rebel group cooperated with one or more other rebel groups in that year and *0* otherwise.

Coop duration: a continuous variable indicating the number of consecutive years the group cooperated with one or more other rebel groups.

Fight: a binary variable taking the value of *1* if the rebel group fought with one or more other rebel groups in that year and *0* otherwise.

Fight duration: a continuous variable indicating the number of consecutive years the group fought with one or more other rebel groups.

4.3.3 Control variables

Rebel strength: a variable for rebel group size, expressed as thousands of troops. This is included because groups with higher military capabilities are likely to be able to survive longer than militarily weak groups. Strong rebels are also expected to have increased chances of achieving a decisive victory (Cunningham *et al.* 2009).

Rebel support, government support: two binary variables, taking the value of *1* if the rebels or government received external support from a foreign actor and *0* otherwise. These are included because foreign support has been shown to increase the duration of war (Regan 2000; 2002). Foreign support is also likely to increase the chances of decisive victory for the recipient (Cunningham *et al.* 2009).

Number of groups: a variable corresponding to the number of overlapping rebel groups in any single conflict-year. This is coded according to the definition provided earlier in Chapter II. It is included as a control because multi-party conflicts have been shown to last longer than two-sided civil wars (Cunningham 2006).

Polity: a variable representing the administrative capabilities of the government and political freedom within a state. Polity scores are used (data are taken from the Polity IV Project, 1800-2009). This is included as a control because in a politically free atmosphere negotiated peace settlements might more likely because rebels have increased incentives to return to civilian life and states may be more accommodating of rebels as a result of the potential positive dividends associated with peace (Collier 1995).

Intensity: a variable corresponding to the intensity of conflict. A value of *1* signifies low intensity conflict (*25 - 999* battle related deaths) and a value of *2* signifies high intensity conflict (*1000* battle related deaths or more). Data are taken from the UCDP Dyadic Dataset (Harbom, Melander and Wallensteen 2008). This is used as a control because heavy losses on all sides are likely to affect rebel group survival and termination-type.

GDP (*ln*)*:* a variable equal to the gross domestic product of a state, transformed by taking the natural log. This variable is associated with the duration of civil war. Higher GDP indicates larger state capacity, but also lower opportunity costs for rebellion (Fearon and Laitin 2003; Collier and Hoeffler 2004).

Data are taken from the Cunningham *et al*. (2009) Dyadic Dataset, except where stated.

4.3.4 Methods of estimation

The effects of the covariates on rebel group *longevity* are tested using the semi-parametric Cox proportional hazards model, or CPH model (1972). This type of model deals with censored data, where the likelihood of observing an outcome differs across subjects (in this case rebel groups) due to each subject having different entry dates in the dataset (in this case when the rebel group first became active) and due to each subject surviving for different periods of time (in this case how long the rebel group participated in the conflict before termination). The CPH model estimates the effect of covariates on the cause-specific hazard function. The hazard rate for an observation *i* at a specific point in time *t*, is given by;

$$\lambda_i(t|X) = \lambda_{i,0}(t)\exp(\beta_i X') \qquad (4.1)$$

where $\lambda_{i,0}(t)$ is the baseline hazard of the event and *X'* is a matrix of covariates. The CPH model is particularly useful because hazard rates refer to cessation, i.e. termination of a rebel group. Unlike parametric models, which assume a particular form of the hazard function (thus making them sensitive to distributional assumptions), the CPH baseline hazard function is flexible and unspecified. Note that the CPH model does not require estimating the baseline hazard $\lambda_{i,0}(t)$ because the term cancels out when the hazard rates are calculated at cessation. The coefficients, β_i indicate the impact of each covariate on the hazard function. A positive coefficient indicates that the hazard of termination in a given time period is increased, whereas a negative coefficient indicates that the hazard of termination is decreased.

The effect of rebel group interactions on *termination-type* is tested using the competing-risks regression model described in detail by Fine and Gray (1999). This is similar to the CPH model, except that sub-distributional hazard rates are computed for categorical outcomes, which in this case are (*i*) *peace agreement*, (*ii*) *government victory*, (*iii*) *rebel victory* and (*iv*) *ongoing conflict*. Crucially the competing risks model relies on the assumption that all possible outcomes are modelled (i.e. rebel groups can only terminate by one of these four outcomes). The appropriate equation detailed by Haller *et al.* (2012) is:

$$\lambda_i^*(t|X) = \lambda_{i,0}^*(t)\exp(\beta_i^* X') \qquad (4.2)$$

where $\lambda_{i,0}^*(t)$ denotes the sub-distribution baseline hazard function. In this model, the sub-distribution hazard is linked directly to the cumulative incidence function (CIF) making the interpretation of the effect straightforward (Fine and Gray 1999; Gutierrez 2010). A sub-distributional hazard rate (SHR) >*1* indicates that the covariate increases the hazard of termination by that outcome, while a SHR <*1* indicates that the hazard of termination by that outcome is decreased. In both types of model (i.e. the CPH model and the competing risks model), robust standard error estimates are reported, which take into account the nesting of observations within conflicts. Summary statistics of all variables used in the analysis are shown in Table 4.2. A matrix of Spearman correlations is shown in Table 4.3.

Table 4.2 Summary statistics

Variable	Obs.	Mean	SD	Min	Max
Longevity	*2361*	*7.616*	*8.631*	*1*	*59.178*
Coop	*2361*	*0.496*	*0.500*	*0*	*1*
Coop duration	*2361*	*3.200*	*5.773*	*0*	*41*
Fight	*2361*	*0.073*	*0.260*	*0*	*1*
Fight duration	*2361*	*0.207*	*0.989*	*0*	*12*
Rebel strength	*2347*	*12.488*	*43.717*	*0.05*	*1000*
Rebel support	*2361*	*0.598*	*0.490*	*0*	*1*
Government support	*2361*	*0.565*	*0.496*	*0*	*1*
Number of groups	*2361*	*3.031*	*2.204*	*1*	*8*
Polity	*2361*	*-0.263*	*6.706*	*-10*	*10*
Intensity	*2356*	*1.233*	*0.423*	*1*	*2*
GDP (*ln*)	*2352*	*4.937*	*4.883*	*0.153*	*42.887*

4.4 Results and discussions

Table 4.2 shows that groups in the dataset survive for an average of ~*8* conflict-years. The longest surviving group was the *Karen National Union* (*KNU*) in Myanmar, who survived for *59* conflict-years. The most durable alliance lasted *41* conflict-years, between the *Arakan Insurgents* and the *Communist Party of Burma* in Myanmar. The most durable bout of inter-rebel violence lasted *12* conflict-years, again in Myanmar by the *KNU*. Table 4.3 shows that there is little association between the variables used in the analyses, with the exception of positive correlations between three pairs, *coop* and *coop duration* (*0.56*), *fight* and *fight duration* (*0.74*) and *coop* and *N groups* (*0.55*). The variables *coop duration* and *fight duration* are not included in the CPH model (which examines rebel group longevity) since it is implicit that durable interactions can only occur if a group survives for long time periods. The variables for durable interaction strategies are included the Competing-risks regression analysis (which examines termination-type) but, because of the high levels of association observed, *coop duration* and *fight duration* are examined separately from *coop* and *fight*.

Table 4.3 Spearman correlation matrix

	Coop	**Coop duration**	**Fight**	**Fight duration**	**Rebel strength**	**Rebel support**	**Gov. Support**	***N* groups**	**Polity**	**Intensity**	**GDP (*ln*)**
Coop	*1.00*										
Coop duration	*0.56*	*1.00*									
Fight	*-0.03*	*-0.03*	*1.00*								
Fight duration	*0.01*	*0.03*	*0.74*	*1.00*							
Rebel strength	*-0.05*	*-0.04*	*0.01*	*0.01*	*1.00*						
Rebel support	*-0.08*	*-0.04*	*0.04*	*0.07*	*0.07*	*1.00*					
Gov. support	*-0.06*	*-0.12*	*0.12*	*0.13*	*-0.01*	*0.01*	*1.00*				
***N* groups**	*0.54*	*0.39*	*-0.09*	*-0.08*	*-0.07*	*-0.02*	*-0.22*	*1.00*			
Polity	*-0.08*	*-0.09*	*-0.01*	*0.01*	*-0.12*	*-0.12*	*-0.05*	*0.05*	*1.00*		
Intensity	*-0.01*	*-0.02*	*0.03*	*0.02*	*0.17*	*0.12*	*0.05*	*0.01*	*-0.18*	*1.00*	
GDP (*ln*)	*0.01*	*0.10*	*-0.01*	*0.07*	*-0.01*	*0.03*	*-0.11*	*-0.04*	*0.27*	*-0.13*	*1.00*

4.4.1 Results for rebel group longevity

Results for rebel group longevity are shown in Table 4.4.

Table 4.4 Cox proportional hazard estimates showing the effect of alliances and inter-rebel violence on the hazard of rebel group termination (SE's clustered by country)

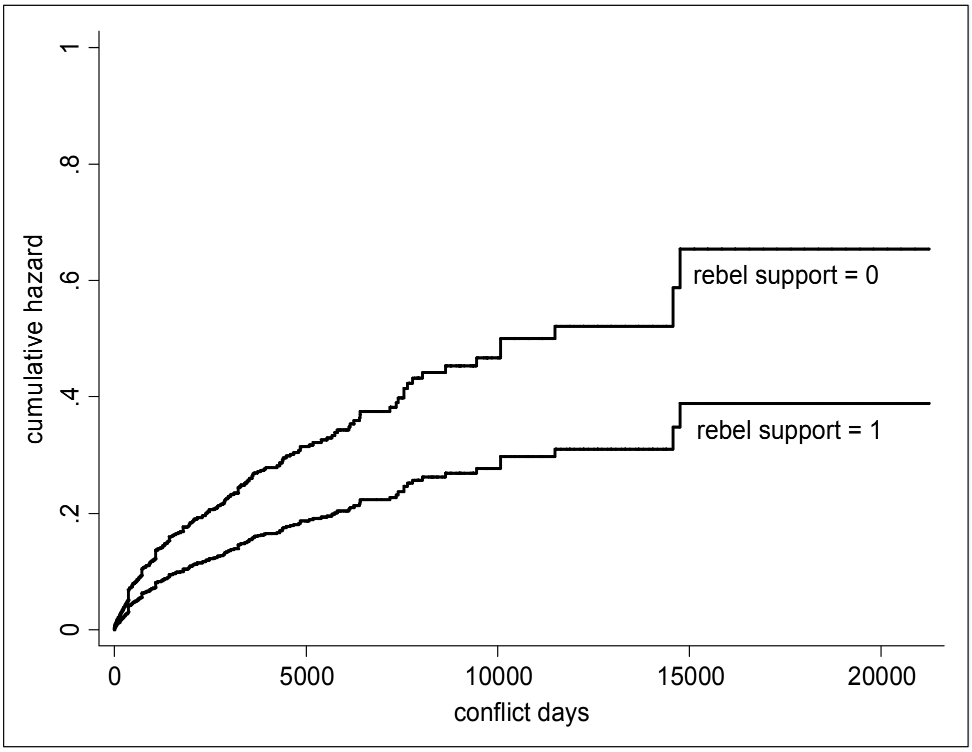
	Coefficient	SE
Coop	*-0.430*	*0.310*
Fight	*0.269*	*0.219*
Rebel strength	*0.001*	*0.001*
Rebel support	***-0.521****	*0.230*
Government support	*-0.395*	*0.227*
***N* groups**	*-0.079*	*0.047*
Polity	*-0.025*	*0.014*
Intensity	*-0.340*	*0.193*
GDP (ln)	*-0.025*	*0.028*
Number of obs.	*2333*	
Wald χ^2 (9)	*54.19*	
Log pseudo likelihood	*-2444.77*	

*Note: ** denotes significance at $p \leq 0.01$, * denotes significance at $p \leq 0.05$*

Only the variable, *rebel support*, is statistically significant (at the *0.05* level) with a negative coefficient, indicating that support from external actors increases the longevity of rebel groups. This result is plotted in Figure 4.1, which shows the cumulative hazard of termination for rebel groups who received foreign support compared to the cumulative hazard of termination for rebel groups who did not receive support. The cumulative hazard of termination for groups who received support is approximately *39%*, a value much lower than the hazard of termination for groups who did not receive support (~ *68%*).

The coefficient for *coop* is negative, suggesting that rebels who form alliances have increased longevity and the coefficient for *fight* is positive, suggesting that rebels who engage in inter-rebel violence have decreased longevity. These correlations lack statistical significance however and although they are indicative, it must be concluded that interaction strategies have little or no effect on rebel group longevity. This result is intriguing given the above discussions, which argue that groups might adopt interaction strategies to gain military advantages against the state. One possible explanation for this result is that groups with strong credentials, or those who have high expectations about their longevity, might be unwilling to interact. This might be reflected by the fact that about a third of rebel groups in the dataset, operate independently for the entire duration of war. This implies that groups might only adopt interaction strategies out of desperation when their expectations of survival are poor. These interactions may not be sufficient, or might have occurred too late in the conflict to increase the rebel group's longevity. An alternative explanation might be that groups with larger capabilities are attacked by the state more often and on a wider scale than smaller groups because they pose a larger threat. If a rebel group increases its military capabilities via an alliance, it would be more heavily targeted as a result of its increased size and status. This mechanism might also explain why *rebel strength* is not statistically significant - a result that is also intriguing given the intuition that larger groups ought to have a lower hazard of termination in comparison to their smaller peers.

Figure 4.1 Cumulative hazard rates versus conflict days for rebel groups who received support from external actors compared to groups who did not receive external support



4.4.2 Results for rebel group termination-type

Results for rebel group termination-type are shown in Table 4.5. For the first outcome, *peace agreement*, results show that groups who engage in inter-rebel violence have an increased hazard of termination by peace agreement, whereas groups who form durable alliances have a decreased hazard of termination by peace agreement (both significant at the < *0.05* level). This suggests that alliances between groups decrease the likelihood of peace settlements, whereas violence between rebel groups increases the likelihood of peace settlements.

The cumulative incidence functions (*CIFs*) for these statistically significant effects are plotted in Figures 4.2 and 4.3. Figure 4.2 shows that the incidence of termination by peace agreement for groups who engaged in inter-rebel violence is *~0.2*, much higher than the incidence of peace agreements for groups who did not (*~0.1*). In Figure 4.3, the incidence of peace agreements for the maximum alliance duration of 41 years is *~0.02*, much lower than the incidence of peace agreements for alliances that lasted 21 years (*~0.05*) and lower still compared to groups who did not form an alliance at all (*~0.16*).

These results are potentially explained by bargaining power. On the one hand, weak groups who are the targets of violence might be keen to terminate by peace agreement out of the fear of elimination. On the other hand, strong groups who have the capacity to engage in inter-rebel violence might be offered more favourable deals by the state. Indeed, when faced with a strong group, a weak state might be willing to concede to the demands of a strong group, rather than risk suffering defeat. This effect is highlighted by the significant result obtained for state capacity (proxied by *GDP*), which indicates that conflicts involving weak states are more likely to end in peace deals (significant at the *<0.01* level).

Groups that are able to strike durable alliances also have increased bargaining power against the state. In this instance, weak states have an incentive to offer peace deals, but rebel groups have an incentive to reject them on the basis of their capabilities, which are increased as a result of alliance formation. This effect is highlighted by results obtained for the second outcome, *government victory*, which show that groups who form durable alliances are more likely to avoid suffering defeat (this effect is significant the *0.01* level). The cumulative incidence function for this effect is plotted in Figure 4.4.

In Figure 4.4 the incidence of termination by government victory for groups who did not form an alliance is *~0.04* compared to an incidence of *~0.002* for groups who formed a durable alliance of 20 consecutive years. The incidence of government victory for the maximum alliance duration of 41 years (not shown in Figure 4.4) is *0*. These incidence rates are much lower than the incidence rates observed in Figures 4.2 and 4.3 for the termination-type, *peace agreement*. This reflects the fact that *government victory* occurs less frequently (*20%* of groups suffer government defeat compared to *31%* of groups who terminate by peace agreement). Inter-rebel violence is found not to have a statistically significant effect on the hazard of termination by government victory. For the third outcome *rebel victory*, alliance formation and inter-rebel violence are found to have no effect on the hazard of termination.

Instead, militarily strong rebels, or those who face weak governments are more likely to emerge victorious (the result for *rebel strength* is *>1* at the *<0.01* significance level, *GDP* is *<1* at the *<0.01* level). These results replicate the findings of Cunningham *et al.* (2009), who obtained similar results, but using multinomial logistic regression analysis, to predict rebel group termination-type.

Results obtained on the final outcome *ongoing conflict* show that rebel groups who form durable alliances are less likely to terminate by this outcome (the effect is significant at the *<0.01* level). In other words, rebels who strike durable alliances with their peers are more able to sustain conflict against the state. This result relates to the point made earlier, that durable alliances increase the conflict prospects of the groups involved.

The effect of durable alliances on the incidence of the outcome, *ongoing conflict*, is plotted in Figure 4.5. For groups who did not form an alliance, the incidence of termination by *ongoing conflict* is *~0.15*, a value much higher than the incidence for groups who formed durable alliances (of 20 years) where the cumulative incidence is *~0.001*. Inter-rebel violence is found not to have a statistically significant effect on the outcome, *ongoing conflict*.

Table 4.5 Competing risks regression estimates showing the effect of cooperation and fighting on rebel group termination-type (SE's clustered by country)

	Peace agreement				*Government victory*			
	Model 1		**Model 2**		**Model 1**		**Model 2**	
	SHR	**SE**	**SHR**	**SE**	**SHR**	**SE**	**SHR**	**SE**
Coop	0.707	0.221	-	-	0.960	0.517	-	-
Coop duration	-	-	0.943*	0.028	-	-	0.845**	0.058
Fight	2.049*	0.696	-	-	0.387	0.266	-	-
Fight duration	-	-	1.001	0.085	-	-	0.713	0.196
Rebel strength	0.991	0.016	0.992	0.015	1.000	0.001	1.000	0.001
Polity	1.015	0.021	1.012	0.020	0.916**	0.026	0.918**	0.026
Rebel support	0.948	0.295	0.921	0.279	0.325**	0.119	0.341**	0.122
Gov. support	0.951	0.253	1.001	0.270	0.685	0.255	0.678	0.260
***N* groups**	0.844**	0.055	0.854*	0.058	0.570**	0.106	0.715**	0.112
Intensity	0.430*	0.170	0.437*	0.174	0.794	0.254	0.785	0.255
GDP (ln)	0.886**	0.041	0.896**	0.040	1.036	0.030	1.039	0.030
***N* obs.**	2333		2333		2333		2333	
Wald χ^2 (9)	50.01		45.62		69.50		66.05	
Log pseudo likelihood	-688.04		-688.69		-453.71		-448.89	

Note: ** denotes significance at p = ≤ 0.01, * denotes significance at p = ≤ 0.05

	Rebel victory				*Ongoing conflict*			
	Model 1		**Model 2**		**Model 1**		**Model 2**	
	SHR	**SE**	**SHR**	**SE**	**SHR**	**SE**	**SHR**	**SE**
Coop	*1.579*	*0.647*	-	-	*0.657*	*0.288*	-	-
Coop duration	-	-	*0.980*	*0.038*	-	-	***0.850*****	*0.027*
Fight	*0.611*	*0.318*	-	-	*1.220*	*0.358*	-	-
Fight duration	-	-	*0.856*	*0.145*	-	-	*1.038*	*0.087*
Rebel strength	***1.004*****	*0.001*	***1.004*****	*0.001*	***0.953****	*0.019*	***0.949*****	*0.019*
Polity	*1.027*	*0.054*	*1.016*	*0.056*	*0.973*	*0.016*	***0.953*****	*0.015*
Rebel support	*1.454*	*0.744*	*1.458*	*0.728*	*0.645*	*0.174*	*0.583*	*0.163*
Gov. support	*0.455*	*0.190*	*0.488*	*0.199*	*0.589*	*0.170*	***0.588****	*0.138*
***N* groups**	*0.832*	*0.090*	*0.905*	*0.090*	*1.033*	*0.075*	***1.148****	*0.080*
Intensity	***6.049*****	*2.072*	***5.603*****	*1.896*	***0.287*****	*0.026*	***0.267*****	*0.117*
GDP (ln)	***0.655*****	*0.096*	***0.668*****	*0.103*	*1.021*	*0.03*	*1.033*	*0.027*
***N* obs.**	*2333*		*2333*		*2333*		*2333*	
Wald χ^2 (9)	*124.55*		*182.66*		*78.70*		*122.56*	
Log pseudo likelihood	*-248.89*		*-249.45*		*-842.31*		*-816.03*	

*Note: ** denotes significance at $p \leq 0.01$, * denotes significance at $p \leq 0.05$*

Figure 4.2 Cumulative incidence functions versus conflict days showing the effect of inter-rebel violence on the incidence of termination by peace agreement

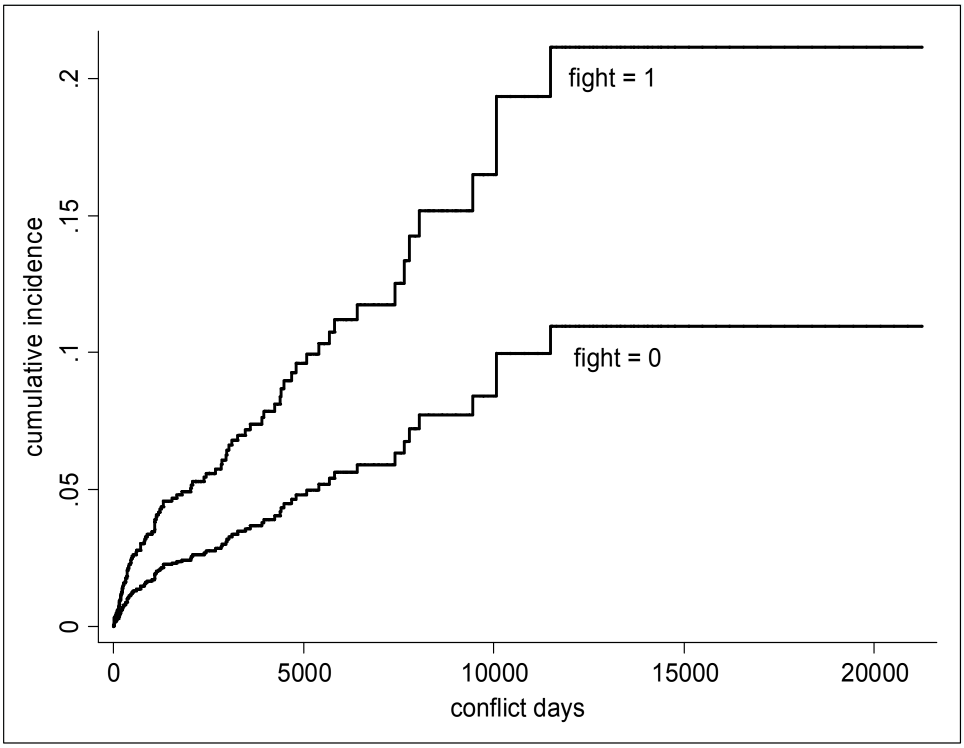


Figure 4.3 Cumulative incidence functions versus conflict days showing the effect of durable alliances on the incidence of termination by peace agreement

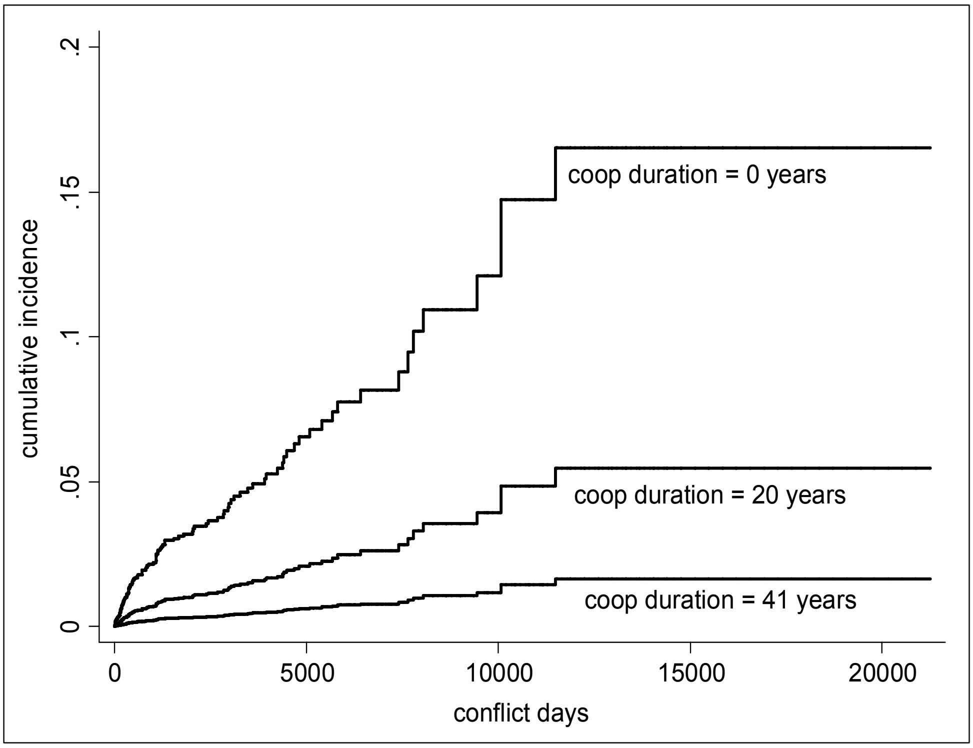


Figure 4.4 Cumulative incidence functions versus conflict days showing the effect of durable alliances on the incidence of termination by government victory

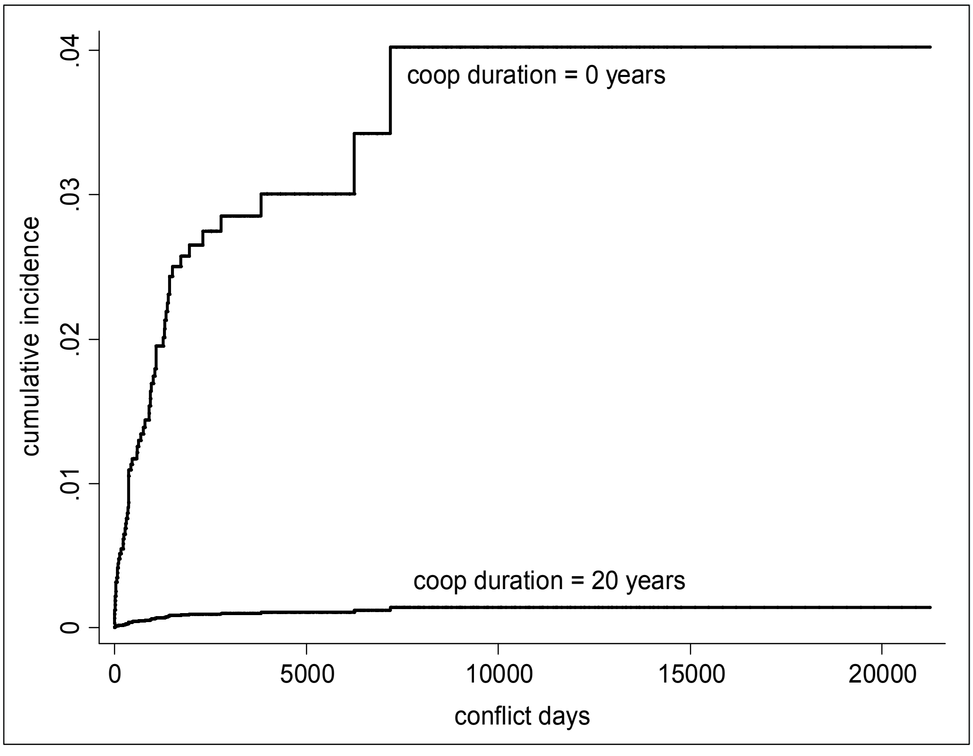
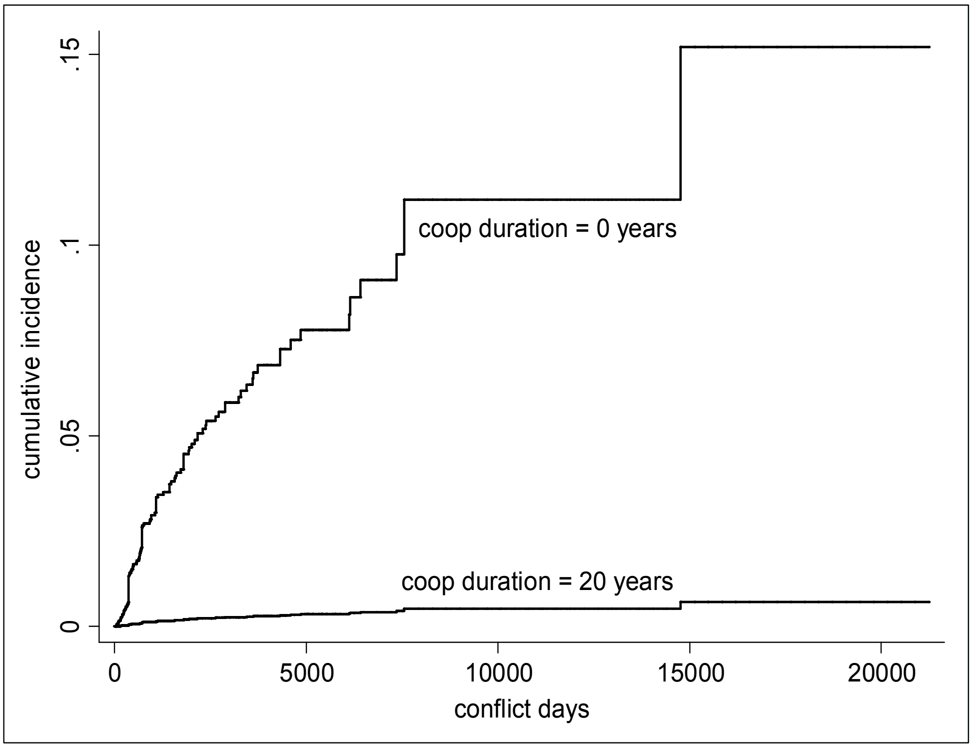


Figure 4.5 Cumulative incidence functions versus conflict days showing the effect of durable alliances on the incidence of termination by government victory



4.5 Limitations

A few limitations of the present work exist. Firstly, results from the Cox Proportional Hazards model that suggest that groups who receive foreign support survive longer than groups who do not receive support. But the direction of this effect is ambiguous. It could be the case that rebel groups who receive foreign support survive longer as a direct result of receiving the external aid (as was proposed in this chapter). Alternatively, the rebel group might receive foreign support in the first place, only because they are perceived by others as being able to survive for a long period of time. After all, it is unlikely that an external patron would be willing to provide financial or military support to a group whose elimination was imminent. A second limitation is that the data analysed are correlational and not experimental. As such, it is not possible to know what the specific mechanisms underlying the statistically significant effects are. Results obtained from the competing risks regression analyses suggest that allied groups are less likely to terminate by peace agreement, whereas groups that engage in inter-rebel violence are more likely to terminate by peace agreement. But, some of these effects could have emerged simply because states are more likely to offer peace when violence breaks out than at other times.

4.6 Conclusions

These results suggest that rebel groups who adopt interaction strategies do not increase their survival (i.e. decrease their chance of being eliminated) compared to groups who operate independently. This might occur because rebel groups adopt interaction strategies in desperation, as a matter of last resort. In these instances, gaining strategic advantages may not be possible if the interactions were not initiated early enough to ensure survival. An alternative explanation for this effect might be that rebel groups who increase their capacity as a result of interacting with their peers may simply become more heavily targeted by the state as a result of their increased size.

But, if rebels are able to strike alliances early on, so that cooperation is maintained over a number of years, groups are more likely to achieve favourable conflict outcomes. Rebel groups who form durable alliances are less likely to suffer defeat, they are less likely to concede to peace settlements and they are more likely to achieve decisive war outcomes (i.e. avoid the outcome of ongoing conflict). Other results show that rebel groups who engage in inter-rebel violence are more likely to sign peace deals. This might occur because the targets of non-state violence become pressured into accepting peace deals out of fear of being eliminated by another group, whereas the initiators of non-state violence may be offered sweeter deals by the state as a result of their large capacity.

The main implications of these results are that states could maximise the likelihood of peaceful resolution by capitalising on opportune moments for offering peace deals. If there is some expectation that rebel groups might form alliances, then states have a higher chance achieving peaceful resolution if negotiations take place before a group is able to increase its bargaining power by aligning with its peers. If violent conflict breaks out between rebel groups, the state may also benefit from offering peace deals instead of waiting for the groups to eliminate one another, especially in light of the finding that groups who engage in inter-rebel violence do not have a higher hazard of termination than groups who operate alone.

4.6.1 Additional lines of enquiry

In this chapter, survival models were used to explore whether groups who adopt interaction strategies survive longer, or terminate in more advantageous conflict outcomes, than groups who operate independently for the entire duration of war. An advantage of survival-analysis models is that they capture the dynamic reality of civil war more effectively than other types of statistical modelling, such as the regression models used in the previous chapters. Survival models however, are not able to fully capture the strategic actions and reactions taken by the actors involved. For example, in Burma the *MTA* opted into a ceasefire and a subsequent peace agreement with the state as a result of encountering heavy losses from inter-rebel violence. The survival models allow us to draw conclusions regarding the macro-level effect of inter-rebel violence on the likelihood of termination by peace agreement, but they cannot provide information regarding the underlying mechanisms responsible for these effects (as alluded to in the previous section of this chapter). Statistical modelling alone cannot inform on whether the *MTA* opted for a peace agreement as a direct result of encountering losses from engaging in inter-rebel violence or if other mechanisms were operating.

The present results show that allied groups do not have an increased longevity compared to groups who operate alone. Two possible explanations for this effect were proposed. The first was that rebel groups might form alliances in desperation as a matter of last resort and these take place too late in the conflict for the group to reap the benefits. The second explanation was that rebel groups might become more heavily targeted by the state after forming an alliance as a result of their increased size. Once again, by using statistical modelling methods alone, it is not possible to test these mechanisms.

The two aspects described above, illustrate some of the limitations of statistical modelling of civil conflict. These are that statistical correlations can be determined by these methods and these assist in the construction of physical models. The final chapter of the thesis examines how the underlying generative mechanisms of civil war dynamics can be investigated by the use of computer simulation techniques.

Chapter V

Potential uses of numerical and agent-based simulation for the modelling of rebel group interactions

Abstract

This chapter explores ways in which civil conflict can be simulated using numerical methods and agent-based computer models. A general two-party model of the dynamics of conflict is developed by extending an approach suggested by Christia (2012), which is based on the metric of relative power. This is defined as the relative military capabilities between a rebel group and the state and the evolution of a conflict is reflected by changes in this metric. Various definitions of relative power are evaluated and the optimal choice is used to illustrate different types of two-sided armed conflict, namely direct-fire, guerrilla and asymmetric warfare. The inclusion of stochastic effects (which models random or unexpected events) and the inclusion of terms for rebel group recruitment of civilians and for state deployment of troops is described. The model of two-sided conflict is extended so that multi-party conflicts can also be simulated. Various model parameters are implemented in this multi-party model and the ways in which the model can be used to simulate rebel group interaction strategies is explored. Examples are given for some simple cases. These studies illustrate that numerical and agent-based simulation techniques have great potential for modelling rebel group interactions in multi-party civil wars. It is shown that the Christia (2012) approach provides an excellent basis from which conflict models can be built and can be used to great visual effect in illustrating the dynamics of civil conflict.

5.1 Introduction

Computer-generated modelling techniques are a useful alternative approach for studying complex problems, in addition to statistical methods (Gilbert and Terna 1999; Ostrom 1988). Statistical methods (such as those used in the studies described in Chapter I and employed in Chapters II – IV) involve the analysis of empirical data with the aim of uncovering correlations that are consistent with particular theories or mechanisms. But, since statistical approaches are correlational and not experimental, they cannot be used to demonstrate causality (i.e. there are issues with internal validity). Moreover, since many variables and constructs in civil war research are measured using proxy variables, it is difficult to isolate the role of particular mechanisms (i.e. there are issues with construct validity). Experimental approaches allow for more control and reduce issues associated with validity, but they are often costly and in many cases are unethical (such as in conflict research). Simulation modelling is an alternative, generative approach, which aims to uncover the underlying mechanisms that generate an observed, macro-level phenomenon (Smith and Conrey 2007). Unlike statistical modelling, where empirical data are processed via a statistical program and results produced that describe the relationships that exist within the data, simulation models are themselves computer programs that incorporate the critical aspects of the phenomenon being modelled (Groff 2007). As Doreian (2001) points out, simulation modelling tries to capture the generative mechanisms underlying the social phenomena under study, whereas statistical modelling seeks a numerical summary of relationships between variables. Computer simulations may therefore be regarded as simple representations of real-world systems (Gilbert and Troitzsch 2005) and a platform to test hypotheses and predict real-world outcomes in cases where data are non-existent.

The first computational models of armed conflict appeared during the Cold war era (Cioffi-Revilla and Rouleau 2010). These early models were implemented using a system dynamics approach and utilised ordinary differential equations (ODEs) to model two-sided conflicts between a state and a rebel group (Forrester 1968; Hanneman 1988). ODEs arise in many contexts throughout mathematics and science. They are equations containing a function of one independent variable and its derivatives and as such, are used to describe dynamic phenomena, evolution and variation. Quantities are defined as the rate of change of other quantities. In the context of civil war, these rates of changes are often in the form of time derivatives. For example, ODE models have been used to model the progression of different types of two-sided conflict over time, including; *direct-fire* warfare (a type of battle in which each side shoots directly at the other), *guerrilla* warfare (where each side has to search for their enemy before making a kill) and *asymmetric* warfare (where one side adopts a *direct-fire* approach while the other adopts a *guerrilla* approach). See Lanchester (1956) for an early overview of these types of conflict. ODE models were often empirically informed by prominent insurgencies of the time, such as the Vietnamese War or the Soviet invasion of Afghanistan (Milstein and Mitchell 1969; Ruloff 1975; Allan and Stahel 1985) and they attained their greatest success in representing asymmetric two-sided conflict at a national level (Gilbert and Troitzsch 2005). Mathematical and numerical modelling has been extensively used over a long period and these types of systems dynamics models remained the dominant approach to computational modelling of armed conflict until the more recent introduction of *object-oriented* approaches such as agent-based models (ABM).

Agent based models have proved to be a particularly useful method for representing real-world systems. ABM involves the simulation of automated *agents* in the context of an artificial *environment* and the analysis of macro-level patterns emerging from these micro-level agent behaviours and interactions (Epstein and Axtell 1996; Gilbert and Troitzsch 1999). Agents are 'autonomous, goal-directed software entities' that engage in behaviours described as *condition-action-rules* (O'Sullivan and Haklay 2000). Agents commonly represent people, but they can also represent groups, organisations or governments for example. The characteristics and behavioural rules of agents can be assigned according to agent-type (i.e. government agents, civilian agents), or they can be assigned according to a known distribution observed in the population, or at random, so that specific societal averages can be modelled. Thus, ABM allows for heterogeneity among individuals that more closely approximates the empirical reality than many other computational modelling methods (Groff 2007).

Agents interact with each other on the basis of their condition-action-rules and their characteristics can be dynamically changed as a result of those interactions. In effect, agents are able to pass information to each other and react to that information on the basis of their programmed preferences, which may be fixed or acquired. This allows an examination of the evolution and history of the process under study, since information on the dynamics of the system can be collected as the ABM computer model runs (Axtell 2000). As such, ABM is a bottom-up approach that models global behaviour as emergent properties of local interactions between agents. It is thus well suited for studying complex and non-linear social processes that can produce cumulative effects over a protracted time scale (Keller e*t al.* 2010). For example, ABM can be used to elucidate the process of, and conditions for, certain outcomes. Sometimes the process itself can be more important than the outcomes (e.g. a knowledge of the way in which an infection spreads may ultimately be more important than a knowledge of the number of deaths in a specific epidemic). In other cases, the macro-level outcomes of agent-based models can be counter-intuitive despite complete initial knowledge of the micro properties of individual agents (Epstein 1999).

The condition-action-rules assigned to agents may be based on a rational choice framework with agents programmed for example, to consider the costs and benefits of a given decision. In the real world however, rationality is bounded (or imperfect), in that individuals lack complete information or the cognitive ability to make purely rational decisions when faced with multiple choices (Simon 1997). ABM is able to accommodate this feature through the incorporation of stochastic processes. This is achieved by building randomness into an agent-based model by assigning different probabilities to the range of actions from which an agent can choose. Thus, rather than agents making purely deterministic choices by always selecting the optimal choice, agents may programmed to act in random or unexpected ways (Grimm and Railsback 2005). This sets ABM apart from other modelling methods such as ODEs, which are generally based on deterministic mechanisms.

In ABM, agents interact in a virtual environment. They are placed on an artificial landscape upon which they move and interact with each other and their environment (Gilbert and Troitzsch 2005). The agent environment may include *patches* which represent some physical aspect of the virtual world (i.e. a patch of grass in an ecological model, or the presence of some natural resource in economic or conflict models). Agents have the ability to recognise and react to their environment, make decisions and undertake goal-directed behaviour to meet objectives (Gilbert 2007). For example, an agent may be given the ability to detect whether another agent or a patch is nearby. The agent may then assess the characteristics of these entities and execute actions according to their condition-action rules. ABM also allows the use of Geographic Information Systems (GIS) data to provide 'real' landscapes, a feature that can provide an advantage over artificially created environments, when the impact of the landscape on agent behaviours is likely to be significant (Brown *et al.* 2005; Groff 2007; O'Sullivan and Haklay 2000).

Numerical models (i.e. ODEs and ABM) are generally used for two purposes; (*i*) to test or falsify a theory or hypothesis and (*ii*) to answer "what if" questions (Gilbert 2007). They can be used to test whether a theory is *sufficient* to generate an expected outcome, or if other processes are necessary for that outcome to be generated (Eck and Lui 2008). In this case, a researcher formalises a theory by identifying the relevant parameters of the system, establishing their properties and interactions and articulating the mechanisms underpinning these interactions in the form of agent condition-action rules (Gilbert 2008). The model can then be validated by comparing generated outcomes to theoretical expectations or empirical data. Numerical models can also be used for prediction. In this case a *facsimile* model can be constructed which seeks to replicate the social system under study as accurately as possible (Gilbert 2007). Different parameters within the model can then be manipulated so that their impact on model outcomes can be evaluated (Gilbert 2007).

The accuracy of numerical modelling methods in general, is of course a function of the validity of the assumptions on which the model is based and just like statistical models, they therefore reflect the quality of the theoretical ideas or empirical data available (Groff 2007).

All numerical models remain approximations of the complexity of their real world counterpart, since certain features of human actors (such as irrationality, preoccupation and other psychological or emotional factors) are difficult to quantify and incorporate into a model (Keller *et al.* 2010). This means that care must be taken when analysing the findings from purely numerical models. The results obtained do not represent either an absolute empirical test of a theory nor produce guaranteed predictions of future events. Instead, the findings from numerical models should be used to indicate the plausibility of a theory or to highlight a range of potential outcomes (Groff 2007) given a certain set of assumptions and conditions.

ABM has become increasingly favoured over ODE models as a method of modelling armed conflict (Choucri *et al.* 2007), the main reason being the recognition of the importance of the bottom-up causal processes in civil war (Fearon and Laitin 2003; de Rouen and Sobek 2004; Kalyvas 2006; Cederman and Girardin 2007). In addition, ABM allows for the influence of stochastic processes that are often less easily accounted for in ODE models. The SUGARSCAPE model of Epstein and Axtell (1996) was one of the first ABM simulations of social unrest. By formalising a few simple rules, SUGARSCAPE allowed for the experimental investigation of some of the theorised micro-level mechanisms responsible for the dynamics of civil war. Subsequently, Epstein (2002) produced the first ABM simulations of armed conflict. These simulations modelled the emergence of rebellion and ethnic cleansing behaviour as a product of the rebel agent's perception of the police force numbers (i.e. the size of government forces) and intervention tactics at individual (civilian) level. This research was pioneering in that it examined the citizen-based impetus for rebellion and the model was *generative*, analysing civil conflict from an individual level up, as opposed to simply identifying those variables at the state level that increased the likelihood of civil war.

Since then a number of researchers have extended Epstein's model of civil conflict. The ISAAC and EINSTEIN models (Ilachinski 2004) use a similar technique to model combat at the level of individual soldiers. Doran (2005) has constructed the IRUBA model which represents a meso-scale replication of Epstein's model. The IRUBA model uses simple geographic features, such as terrain and the spatial distribution of rebel resources and troops, to test the impacts on model outcomes of various insurgency and counterinsurgency tactics. Bennett (2008) omits variations in terrain but instead includes social emotions in the civilian population such as fear and anger felt against the state (the aim was to model the US military's strategy of appealing to the *'hearts and minds'* of the US population). Bhavnani *et al.* (2008) have created the first simulations of civil war involving state repression and Cioffi-Revilla and Rouleau (2010) have devised the MASON model which considers how the administrative strength, or *polity*, of the state results in different emergent conflict outcomes. All of these computer simulations examine the macro-level conflict dynamics emerging from rebel agent and civilian agent behaviours in two-sided conflicts.

The models developed in this chapter build on these previous models using both ODE and ABM methods. The main contributions made are as follows (*i*) extending previous two-sided models of conflicts to include multi-party conflicts and (*ii*) proposing ways in which computer based simulation techniques could be used to model rebel group interactions. The next section describes the aims and objectives of this chapter. This is followed by a section describing general models of two-sided armed conflict. Finally models of multi-party conflict are presented, which are used to illustrate the influences of rebel group interactions such as alliance formation and inter-rebel violence.

5.2 Aims and objectives

The aim of this chapter is to assess the potential of numerical simulation techniques (namely ODEs and ABM) for the modelling of rebel group interactions. The previous chapters have used statistical modelling methods (i.e. top-down methods) to examine the motivations for rebel group interactions (Chapter II), the conditions that influence interaction decisions (Chapter III) and the effect of interactions on rebel group survival and termination, and subsequent conflict dynamics (Chapter IV). In this chapter, ways are proposed in which these statistical findings and other empirical findings could be implemented into numerical models. As described in the section above, ABM has certain features that are attractive for civil conflict modelling. ABM allows not only the elucidation of the relevant dynamic processes, but also the modelling of stochastic processes. One purpose of this chapter is to assess the utility of various options and to propose ways in which ODEs and ABMs of conflicts can be developed. One approach is examined in particular; that proposed by Christia (2012), who suggests that a two-sided conflict might be modelled by using the concept of the *relative power* that exists between the two sides. This concept is developed in the present chapter and used in simulations of two-sided conflict. The model is extended to include rebel group recruitment, government deployment of troops and the influence of stochastic processes is investigated. The relative power concept is extended to describe multi-party conflicts and a numerical model of these conflicts is developed. Possible ways to model rebel group interactions are then proposed and some are tested in the current model. Finally, general conclusions are drawn regarding the potential uses of computer-based simulation for the modelling of rebel group interactions. It is important to note that the aim of this chapter is to provide examples that demonstrate the scope and utility of ODE and ABM approaches for the modelling of rebel group interactions. These examples are based on assumptions and parameter estimates and are not intended to provide evidence of real effects. The example models can be used to provide evidence of real effects (by tuning model inputs and outcomes to match empirical data) but this was not within the scope of the present work.

5.3 A general model of two-sided armed conflict

5.3.1 Modelling relative power between the state and a rebel group

Christia (2012) has proposed that the progress and outcome of a civil war can be modelled using a metric p, which relates to the *relative power* between the groups involved. In Christia's model it is assumed that there are two sides at war; the government (side A) and a rebel group (side B). Rebel groups are assumed to have two objectives: (*i*) to win the war (or at least sustain conflict against the state) and (*ii*) to maximise their returns. The metric of interest is relative, rather than overall, power and the basis of the model is that the evolution of relative power over time defines the progress of a conflict. The conflict between the government and a rebel group starts at $t = 0$, when the relative power of the government is p_0 and the relative power of the rebel group is $1 - p_0$. Christia proposes that the change in the value of p throughout a conflict can be described by an expression that contains the sum of a deterministic component $f(p)dt$ and a stochastic component $\Psi(p,t)$. Thus;

$$dp = f(p)\,dt + \Psi(p,t) \tag{5.1}$$

where dp is the change in p over a time increment dt and $f(p)$ is a drift term that depends on the current level of p, which in the absence of the stochastic term, is simply the derivative of

p with respect to time dp/dt. Based on this deterministic component in equation (5.1) alone, if the level of p at time t_0 were known, it would be possible in principle to ascertain how p would evolve over time. In the model, a rebel group with an initial value $p > 0.5$, would eventually be expected to win because it would keep increasing its relative power over time eventually reaching $p = 1$. Conversely, if a rebel group were to start with $p < 0.5$, the rebels would eventually lose with the relative power reaching a value $p = 0$. Evidently, the rebel group would prefer to have a higher p at the start of the conflict because that would ensure a quicker victory. The deterministic function proposed by Christia (2012) must be continuously increasing and symmetric about $p = ½$ such that $f(p) > 0$ for $p > ½$, $f(p) < 0$ for $p < ½$ and $f(p) = 0$ for $p = ½$.

An important aspect of the concept is that the evolution of p over time is not just deterministic. If it were (assuming complete and symmetric information), then rational parties would never go to war simply because they would be able to predict the outcome of the conflict in advance and act accordingly. But, as represented by the second term in equation (5.1), there must also a stochastic component. This is intended to capture the inevitable randomness that arises in conflicts and might include battlefield mistakes, or other exogenous factors such as changes in external support, unexpected weather conditions, disease or other factors beyond the control of the actors involved. The random change in p over some time interval, dt, is represented by the term $\Psi(p,t)$, where Ψ determines the amount of randomness in the relative power change dp. Lower values of Ψ correspond to a lower random component, with no randomness if $\Psi = 0$. Thus, for the rebel side with $p > 1/2$ at t_0 with the deterministic component only, rebel victory would always be expected. But, if a stochastic component is included, victory need not necessarily occur. If victory does occur, it may be either quicker, or slower to attain than in the deterministic case, or indeed it is possible for the side that starts out weaker to emerge victorious. Christia (2012) suggests that the trajectory of a conflict resembles one of biased random walk, where at each time interval, there is a step in a direction of increased or decreased relative power that is random in part, but also influenced by the initial value of the relative power.

It is thus clear that equation (5.1) has attractive general features that make it suitable for modelling conflict, namely (*i*) it can be used to model a range of different scenarios relating to power-based theories of conflict, (*ii*) it models civil war as a dynamic process, (*iii*) it allows randomness to be implemented in the simulation of conflict and (*iv*) the expression is highly amenable to graphical representation which means that simulated conflict processes can be visualised to great effect. As such, the expression represents a promising basis from which simulations of multi-party conflict and rebel group interactions might be developed. If the expression is to be used effectively, the general concept proposed by Christia (2012) needs to be extended to include more specific aspects as follows (*i*) the development of mathematical descriptions of the deterministic function and the consideration of alternative possibilities, (*ii*) defining relative power in terms of actual parameters that could be used in a numerical model and that might also be amenable to statistical analysis of actual conflict data, (*iii*) exploring the ability and utility of the expression to illuminate different types of warfare and (*iv*) investigate how terms might be included in the expression that account for other conflict characteristics such as government troop deployment and rebel group growth. These aspects and their implications for modelling conflict are examined in the following sections. The efficacy of equation (5.1) as a graphical means of visualising conflict progression is also addressed in detail. Because the dynamics of conflict are complex (and often contain randomness), the appropriate differential equations are often not easily amenable to analytical methods. Thus in the following, attention is paid to determining the most suitable modelling methods for specific types, namely, ODE's or ABM.

5.3.2 Mathematical descriptions of the deterministic function

A specific mathematical description of the deterministic function is not given by Christia (2012) but various functions can be chosen that satisfy the required properties of the deterministic component $f(p)$. One obvious possibility is the relationship:

$$f(p) = \frac{dp}{dt} = \beta(2p - 1) \tag{5.2}$$

where β is a constant having units $time^{-1}$. The function $(2p - 1)$ has the properties required by Christia (2012), namely that it is zero at $p = ½$, positive when $p > ½$ and negative when $p < ½$. For victory to occur when $p = 1$ and defeat when $p = 0$, the function takes the values $+ 1$ and $- 1$ respectively. It is required dimensionally to insert the term β into equation (5.2). This gives equivalent values of dp/dt of $+ \beta$ and $- \beta$ respectively. Victory or defeat then corresponds to the situation where the critical rates of change $\pm \beta$ are reached. Although the inclusion of the function $(2p - 1)$ into the expression is in accord with the proposal of Christia (2012) and provides a promising way forward, the symmetry of the function about the value $p = ½$ is somewhat arbitrary. An alternative and simpler representation may be useful as described by the relationship:

$$f(p) = \beta' p \tag{5.3}$$

Unlike equation (5.2), which is symmetrical about $p = ½$, this function is symmetrical about $p = 0$, such that $dp/dt = 0$ when $p = 0$ with $dp/dt > 0$ for $p > 0$ and $dp/dt < 0$ for $p < 0$.

5.3.3 Physical interpretations of 'relative power'

The general concept of relative power is not defined by Christia (2012) in terms of actual parameters that could be used in conflict modelling, but an obvious first approach is to assume that relative power is related simply to the numbers of group members. Thus if there are N_1 and N_2 members in group-1 and group-2 respectively, the relative power may then be defined in several ways, such as the fractional values $f_1 = N_1/(N_1 + N_2)$ and $f_2 = N_2/(N_1 + N_2)$, the differences $\Delta_1 = N_1 - N_2$ and $\Delta_2 = N_2 - N_1$, or the ratios $R_1 = N_1/N_2$ and $R_2 = N_2/N_1$. It may also be useful to normalise the Δ terms as follows: $(N_1 - N_2)/(N_1 + N_2)$ and $(N_2 - N_1)/(N_1 + N_2)$, where the reference value is $N_1 + N_2$. The implications of these various definitions of p are as follows. If p is defined as the number of group members represented as a fraction of the total number of troops in the conflict, then:

$$p_1 = \frac{N_1}{N_1 + N_2}, \quad p_2 = \frac{N_2}{N_1 + N_2} \tag{5.4}$$

These definitions have the properties required by Christia, namely that $p_2 = 1 - p_1$, there is symmetry about $p = ½$ (when $N_1 = N_2$ then $p_1 = p_2 = ½$). The victory/defeat criteria are also identical. Thus, when $N_2 << N_1$ then $p_1 \to 1, p_2 \to 0$ and group-1 wins. On the other hand if $N_1 << N_2$ then $p_2 \to 0, p_2 \to 1$ and group-2 wins.

The second representation of the relative power is in terms of the (normalised) difference:

$$p_1 = \frac{N_1 - N_2}{N_2}, \quad p_2 = \frac{N_2 - N_1}{N_1} \tag{5.5}$$

In this case, $p_2 \neq 1 - p_1$ and there is symmetry about $p = 0$ (when $N_1 = N_2$ then $p_1 = p_2 = 0$). When $N_2 << N_1$ then $p_1 \to \infty$ and $p_2 \to -1$ and group-1 wins. When $N_1 << N_2$ then $p_1 \to -1$ and $p_2 \to \infty$ and group-2 wins.

The third representation of the relative power is in terms of the difference $(N_1 - N_2)$, normalised instead by the total number $(N_1 + N_2)$. Thus:

$$p_1 = \left(\frac{N_1 - N_2}{N_1 + N_2} \right), \quad p_2 = \left(\frac{N_2 - N_1}{N_1 + N_2} \right) \tag{5.6}$$

In this case, $p_1 + p_2 = 0$ and there is symmetry about $p = 0$ (when $N_1 = N_2$ then $p_1 = p_2 = 0$). When $N_2 << N_1$ then $p_1 \to +1$ and $p_2 \to -1$ and group-1 wins. When $N_1 << N_2$ then $p_1 \to -1$ and $p_2 \to +1$ and group-2 wins.

Finally, a simple ratio may be used to represent the relative power between groups. Thus:

$$p_1 = \frac{N_1}{N_2}, \quad p_2 = \frac{N_2}{N_1} \tag{5.7}$$

In this case, $p_2 \neq 1 - p_1$ and there is symmetry about $p = 1$ (when $N_1 = N_2$ then $p_1 = p_2 = 1$). When $N_2 << N_1$ then $p_1 \to \infty$ and $p_2 \to 0$ and group-1 wins. When $N_1 << N_2$ then $p_1 \to 0$ and $p_2 \to \infty$ and group-2 wins.

5.3.4 Use of ‘relative power’ in the theoretical analysis of conflict

In a two-party conflict, fatalities are incurred by both sides and if there is no concurrent replenishment of forces, each side must suffer a decrease in their number of troops over time. If the attrition rate of one group depends only on the size of the other, this is known as a *‘direct-fire’* conflict. In its simplest form this involves each side firing directly at its adversary, for example in a long-bow type of battle with lines of opposing archers, or a modern direct-fire tank battle (Lanchester 1956). Direct-fire conflict is governed by the coupled solution of the two differential equations:

$$\frac{dN_1}{dt} = -B_2 N_2 \tag{5.8}$$

$$\frac{dN_2}{dt} = -B_1 N_1 \tag{5.9}$$

where (dN_1/dt) and (dN_2/dt) are the rates of change in numbers in groups 1 and 2 respectively. The killing rate experienced by one group depends on the number in the opposing group. The proportionality constants B_1 and B_2 relate to the respective killing effectiveness of each side. Coupled differential equations are often difficult to solve analytically and commonly require numerical methods of solution. (For this specific case however, the analytical solution of a similar system of differential equations does exist[§]). A numerical solution of equations (5.8 and 5.9) can be achieved by using the following computational scheme. Values of the constants B_1 and B_2 and the initial numbers in both groups $(N_1)_0$ and $(N_2)_0$ are user-defined and the numbers in each group can be set to these values. Using a small time increment Δt, the incremental changes in the numbers in each group during this interval can be computed as follows:

$$(N_1)_{t+\Delta t} = (N_1)_t - B_2 (N_2)_t \, \Delta t \tag{5.10}$$

$$(N_2)_{t+\Delta t} = (N_2)_t - B_1 (N_1)_t \, \Delta t \tag{5.11}$$

These expressions are iterated repeatedly in the computer program and the elapsed time calculated by summation of the values of Δt. The program output gives the time-dependence of N_1 and N_2 and the computation is terminated when either N_1 or N_2 reaches zero. The summed time then represents the duration of the conflict. A flow diagram detailing the computational method shown in equations (5.10 and 5.11) is provided in Appendix II (a).

The numerical solution obtained by the iterative method described above, was compared to those predicted by using the analytical solution shown in the previous footnote. The curves showing the variation of numbers of troops versus time were in excellent agreement, thus validating the numerical method. For the case of the modelling of a direct-fire conflict, it is regarded that this numerical scheme is preferable to the analytical solution because it is more amenable to modifications such as the inclusion of stochastic terms and the inclusion of other terms describing government troop deployment and rebel group recruitment. Both of these features are considered later in this chapter.

To investigate the utility of the various definitions of relative power given by equations (5.4, 5.5, 5.6 and 5.7), the time dependence of N_1 and N_2 determined from either the analytical or numerical method described above can be used to calculate the values and time dependences of p_1 and p_2 as follows:

$$p_1(t) = \left(\frac{N_1(t) - N_2(t)}{N_1(t) + N_2(t)} \right), \qquad p_2(t) = \left(\frac{N_2(t) - N_1(t)}{N_1(t) + N_2(t)} \right) \tag{5.12}$$

[§] The solutions adapted from Kreysig (1983) are: $N_1(t) = m(\dot{N}_1)_0 \left[\sinh(mt) + (N_1)_0 \cosh(mt)\right]$ and $N_2(t) = m(\dot{N}_2)_0 \left[\sinh(mt) + (N_2)_0 \cosh(mt)\right]$, where $m = (B_1 B_2)^{-1/2}$ and $(N_1)_0$, $(N_2)_0$ are the initial values of group size and $(\dot{N}_1)_0$, $(\dot{N}_2)_0$ are the initial rates.

$$p_1(t) = \frac{N_1(t)}{N_1(t)+N_2(t)}, \qquad p_2(t) = \frac{N_2(t)}{N_1(t)+N_2(t)} \tag{5.13}$$

$$p_1(t) = \frac{N_1(t)-N_2(t)}{N_2(t)}, \qquad p_2(t) = \frac{N_2(t)-N_1(t)}{N_1(t)} \tag{5.14}$$

$$p_1(t) = \frac{N_1(t)}{N_2(t)}, \qquad p_2(t) = \frac{N_2(t)}{N_1(t)} \tag{5.15}$$

For the first illustration of the model outcome, the values of $p_1(t)$ and $p_2(t)$ for these above four definitions, were generated to simulate a direct-fire conflict using the computational method described above. The initial size of the government side was taken to be $N_2 = 1000$ in all four cases and the initial size of the rebel side (N_1) was varied for each computation. The progress of each hypothetical conflict is shown in Figures 5.1 – 5.4, using the four definitions of $p(t)$ from equations (5.12 – 5.15). For convenience it was assumed that $B_1 = B_2 = 0.01$ and time is represented in the normalised form (mt), where $m = (B_1B_2)^{-1/2}$. This normalisation was chosen for consistency with the analytical solution in the previous footnote.

Figure 5.1 Representation of a direct-fire conflict using the variation of $p_1(t)$ and $p_2(t)$ with time from equation (5.12). Time is expressed in the normalised form (mt). Values for initial group sizes are $N_2 = 1000$ and $N_1 = 800, 600, 400$ & 200 respectively and the curves are labelled as values of N_1/N_2

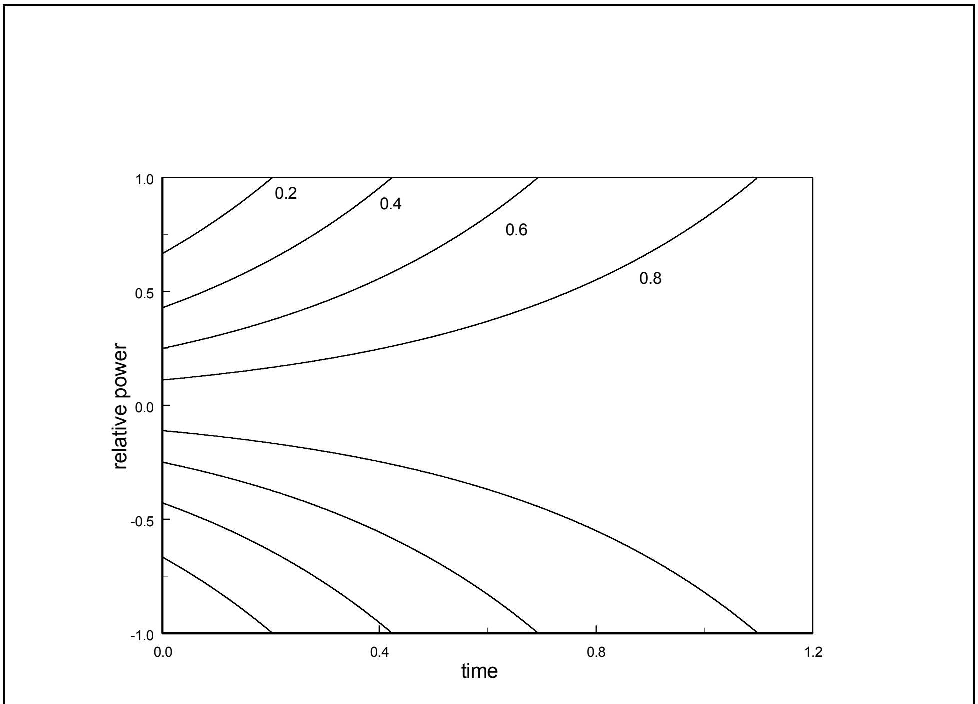


Figure 5.2 As for the previous figure but using $p_1(t)$ and $p_2(t)$ values given by equation (5.13)

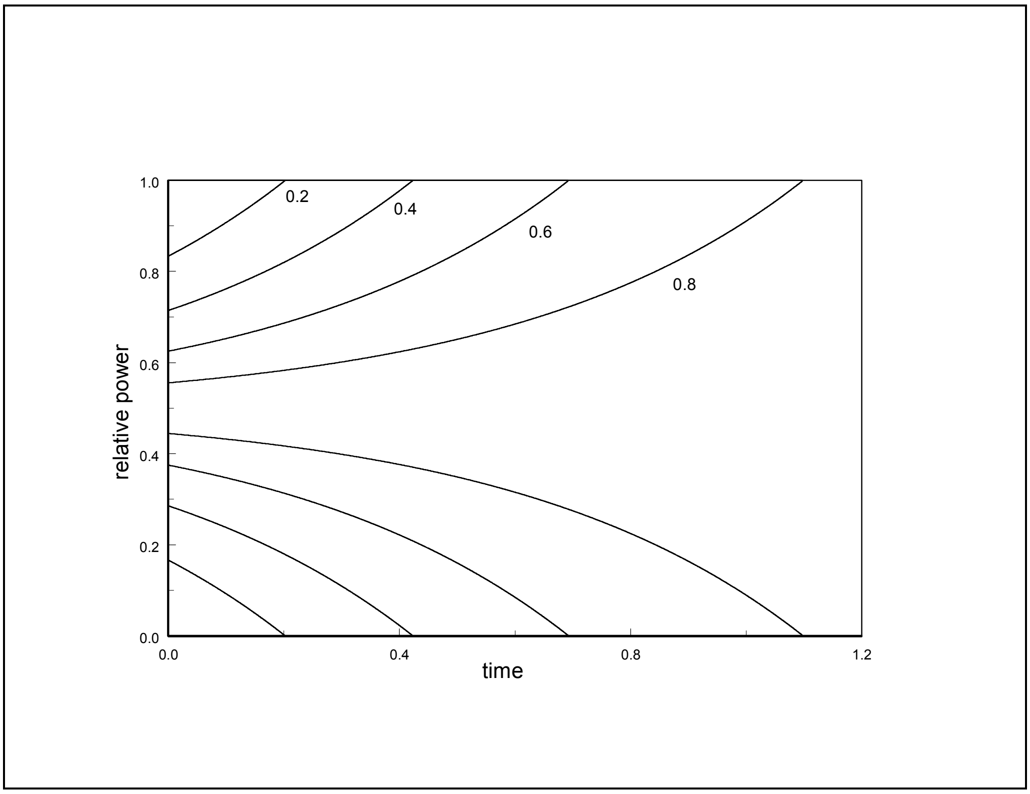


Figure 5.3 As for the previous figure but using $p_1(t)$ and $p_2(t)$ values given by equation (5.14)

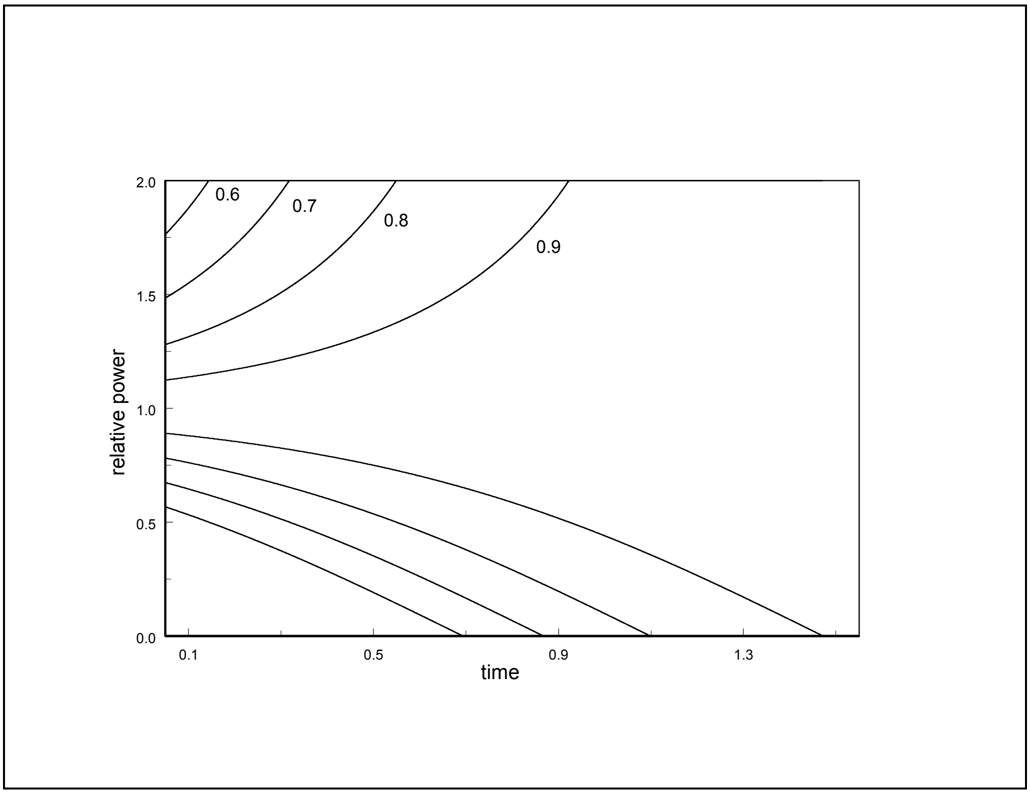
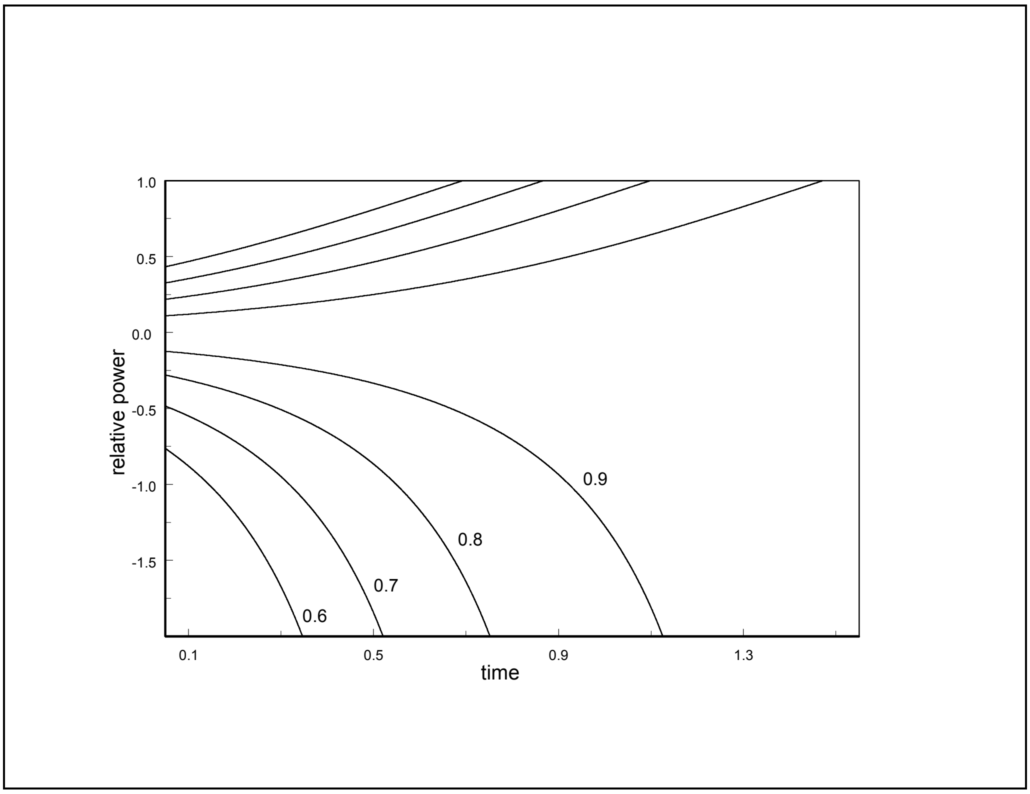


Figure 5.4 As for the previous figure but using $p_1(t)$ and $p_2(t)$ values given by equation (5.15)



Figures 5.1 and 5.2 are similar in shape, but differ in the range and symmetry of *p*. The range is between *+1* and *-1* with symmetry about the value $p = 0$ in Figure 5.1, but the range is between *0* and *1* with symmetry about the value $p = \frac{1}{2}$ in Figure 5.2. Both figures show that rebel groups with a large initial starting size (e.g. troop ratio *0.8*) are able to sustain conflict longer than rebel groups with a small initial starting size (e.g. troop ratio *0.2*). The rebels suffer a defeat in all cases because they start the conflict weaker than the government. Figures 5.3 and 5.4 show illustrations of the same conflict but with *p* values defined by equations 5.14 and 5.15 respectively. Inspection of the graphs suggests that these are less satisfactory for illustrating conflicts. In Figure 5.3, *p* ranges between *0* and *2*, but the curves are asymmetric around the value *1*. In Figure 5.4, *p* ranges between *1* and *-2*, again with the curves being asymmetric about the value *0*. These curves are arguably less desirable because they do not convey the progress of relative power during a conflict in an intuitive or aesthetic manner. Since one of the potential strengths of the current extension of the method proposed by Christia (2012) is to provide a way of visualising conflict, it is reasoned that the definitions shown in equations (5.12 and 5.13) are those most suitable for modelling relative power. As such, the definition shown in equation (5.13) and plotted in Figure 5.2 is used as the template for all subsequent simulations performed in this chapter.

5.3.5 Interpretation of the rate constants B_1 and B_2

The constants B_1 and B_2 in equations (5.8 and 5.9) relate to the fighting capabilities (expressed in terms of the killing 'effectiveness') of each side in a direct-fire conflict. The products B_1N_1 and B_2N_2 may thus be regarded as *weighted* parameters. Thus for the example given by equations (5.8 and 5.9), the rates of loss dN_1/dt and dN_2/dt are equal, not when $N_1 = N_2$, but rather when $B_1N_1 = B_2N_2$. The implication of this is that a small group with a high B-value can emerge victorious over a larger group with a low B-value. In the initial proposal by Christia (2012), war is assumed to be equally costly for both sides and indeed in the above initial numerical 'experiments', this was implicit, in that the same killing effectiveness was used for both sides in all calculations ($B_1 = B_2 = 0.01$). In general this will not be the case in real conflicts and in this respect the present approach extends that of Christia (2012).

In cases where $B_1 \neq B_2$, it is clear that the relative power may be represented in a modified form of equation (5.6) as follows:

$$p_1 = \left(\frac{B_1N_1 - B_2N_2}{B_1N_1 + B_2N_2} \right), \quad p_2 = \left(\frac{B_2N_2 - B_1N_1}{B_1N_1 + B_2N_2} \right) \tag{5.16}$$

The other definition of relative power given by equations (5.4, 5.5 and 5.7) can also be modified in a similar way.

Note that for simplicity in all subsequent simulations reported, the values are kept constant at $B_1 = B_2 = 0.01$ and the definition of normalised time is mt, where $m = (B_1B_2)^{-1/2}$.

The next section considers how the relative power concept developed so far may be utilised for illustrating other types of conflict, namely '*guerrilla'* and *'asymmetric'* warfare.

5.3.6 Modelling other types of two-sided armed conflict

A second type of conflict is '*guerrilla*' warfare (Lanchester 1956; Deitchman 1962). This differs from direct-fire warfare in that each opposing side has to 'search' for their opponent before firing (e.g. in jungle warfare). This means that the overall killing rate must contain a term similar to that in a direct-fire type of conflict, but also reflect the fact that it must be moderated as the number of opponents decrease and therefore become progressively more difficult to find. This type of conflict is described by the following coupled equations:

$$\frac{dN_1}{dt} = -C_2 N_2 (D_1 N_1) \tag{5.17}$$

$$\frac{dN_2}{dt} = -C_1 N_1 (D_2 N_2) \tag{5.18}$$

These equations are similar to equations (5.8 and 5.9) where the terms C_1N_1 and C_2N_2 are equivalent to B_1N_1 and B_2N_2. However, the equations contain the additional terms D_1N_1 and D_2N_2 to describe the decrease in killing rate as the remaining number decreases. The corresponding constants are D_1 and D_2 and may be regarded as 'search' probabilities. The analytical solution of these coupled equations is complex and to the author's knowledge no solution is available. However, numerical analysis can be performed relatively easily by using a method similar to that described earlier for the direct-fire conflict, but using modified forms of equations (5.10 and 5.11) shown below:

$$(N_1)_{t+\Delta t} = (N_1)_t - C_2 D_1 (N_2)_t (N_1)_t \Delta t \tag{5.19}$$

$$(N_2)_{t+\Delta t} = (N_2)_t - C_1 D_2 (N_1)_t (N_2)_t \Delta t \tag{5.20}$$

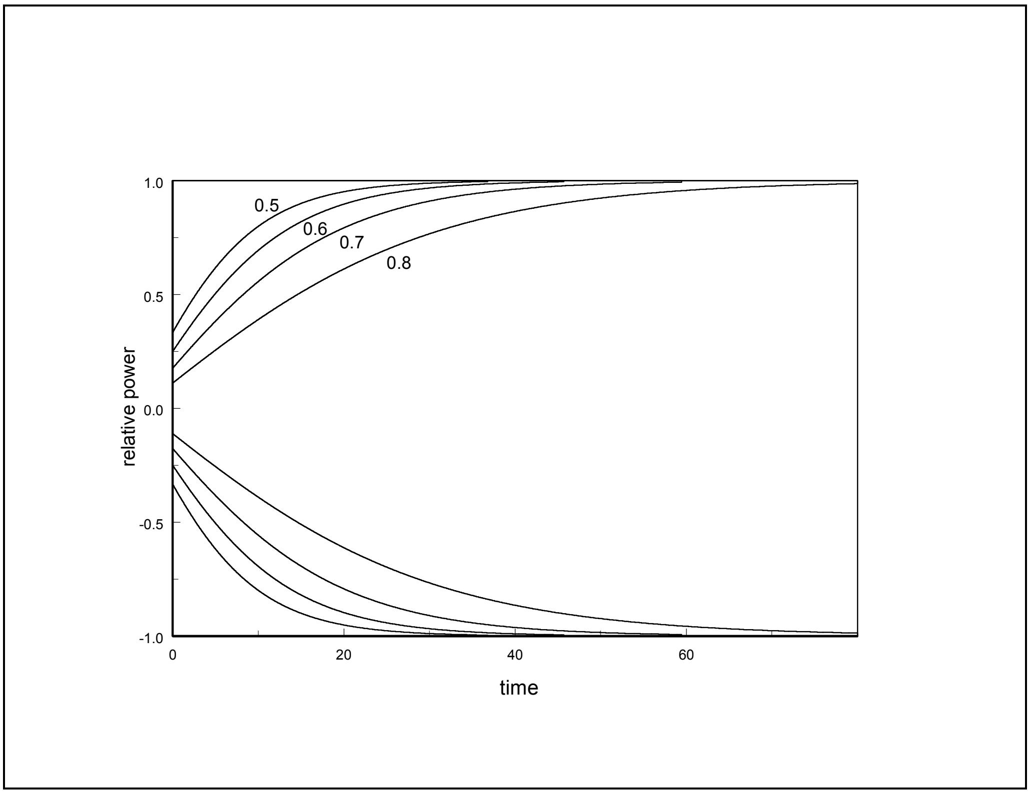
In the previous case of direct-fire war, agent-based models have little advantage over numerical computational methods. In the case of guerrilla warfare however, agent-based modelling methods can be more suitable. One facility of ABM is that virtual agents can be created and instructed to move around their environment randomly. They can then be instructed to engage in certain behaviours when they interact (or collide) with other (specified) agents. Thus for a conflict involving two groups, government agents and rebel agents may be instructed to move randomly and on interaction, prescribed killing probabilities for both types of agent can be enabled, so that each side experiences a decrease in numbers of troops over time. ABM is an ideal method for modelling guerrilla conflict because the random motion of the agents in two-dimensional space can be used as an analogue of the *search-and-kill* sequence that characterises this type of conflict.

Both the numerical computational method and the ABM method were used to model guerrilla conflict. The results of the numerical method based on equations (5.19 and 5.20) are shown in Figure 5.5, using an assumed initial size of the government forces $N_2 = 1000$, with four different initial rebel sizes; $N_1 = 800, 700, 600$ & 500. For illustration purposes, the *killing probability* constants C_1 and C_2 were taken to be the same as the constants B_1 and B_2 used earlier for direct-fire example. In the numerical models the *search* parameter values $D_1 = D_2$

= *0.0003* were used. These were selected by performing sensitivity analyses until the numerical computational method and ABM were calibrated.

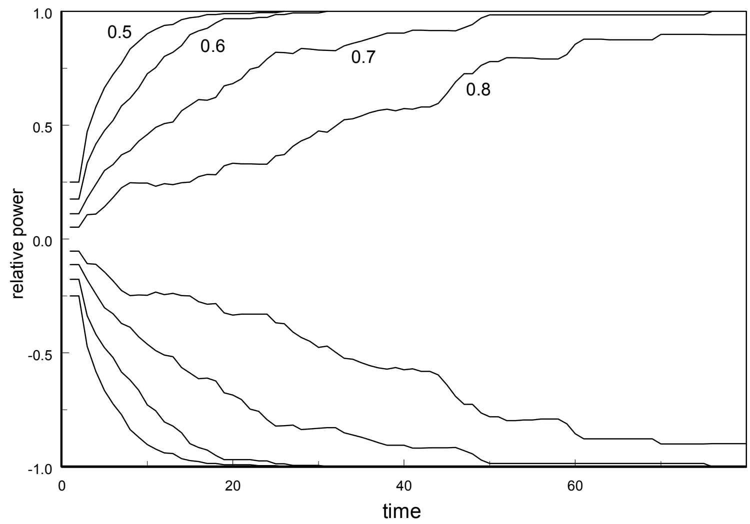
The variation of the relative power with normalised time is shown in Figure 5.5 and the corresponding flow diagram is given in Appendix II (b). Note the distinct difference in shape between Figure 5.5 for guerrilla conflict and Figure 5.2 for direct-fire conflict. The curvatures of the lines are of opposite sign for these two cases and this characteristic emphasises the utility of the current approach in the visual representation of conflict type. The 'long-tailed' curves for guerrilla conflicts reflect the increasing difficulty of eliminating the last few rebels in this type of conflict and demonstrate clearly why such conflicts are protracted.

Figure 5.5 Variation of $p_1(t)$ and $p_2(t)$ with normalised time for $N_2 = 1000$ and $N_1 = 800, 700, 600$ & 500 respectively during a guerrilla-conflict. Values were generated using the numerical algorithms described by equations (5.19 and 5.20)



Values of $p_1(t)$ and $p_2(t)$ were also generated assuming the same parameters as described in the above numerical model, but using an agent-based model. The flow diagram corresponding to the ABM of a guerrilla conflict is shown in Appendix II (c) and the variation of relative power with time for the rebel groups and the government is plotted in Figure 5.6. Although the characteristic curvatures of these curves are similar to those derived from the numerical model, a significant difference is that the curves derived from the ABM are ‘noisy’, a feature that relates to the inherent stochastic nature of ABM. This arises because the agents are programmed to move randomly in two dimensions and the random collisions between agents from each side is a proxy for killing, which then occurs according to an input value of probability. Because the government agents have to randomly ‘search’ for rebel agents before killing them, this effect naturally reflects guerrilla conflict. This ‘noisy’ nature of the curves illustrates this effect. Thus, the ‘built-in’ stochastic effects of ABM modelling illustrate how the progress of conflicts with the same starting conditions can have different trajectories. Towards the end of the conflict when the numbers of troops are small, the level of noise increases. Hypothetically, with smaller assumed initial values for the state and rebel groups, it is clear that in some circumstances, the relative power curves for the state and rebel group could cross over, so that the weaker side emerges victorious.

Figure 5.6 Results generated from an Agent-Based Model for the variation of $p_1(t)$ and $p_2(t)$ with normalised time for $N_2 = 1000$ and $N_1 = 800, 700, 600$ & 500 respectively during a guerrilla conflict. Note that one run for each rebel size (N_1) is shown.



A third type of conflict is ‘a*symmetric’* conflict (Lanchester 1956; Schaffer 1968). Typically this might occur when a large force, such as the government, is matched against a smaller force such as a rebel group, with the latter employing guerrilla tactics and the former employing direct-fire tactics. In asymmetric conflict, the rebel side can have an advantage over the government, in spite of their smaller size, because the government must search for their opponents before they can make a kill. The extent of this rebel advantage depends on how difficult it is for the government to locate the rebels. The corresponding differential equations describing an asymmetric conflict are as follows:

$$\frac{dN_1}{dt} = -C_2 N_2 (D_1 N_1) \tag{5.21}$$

$$\frac{dN_2}{dt} = -C_1 N_1 \tag{5.22}$$

Once again, a numerical solution can be achieved by using a method similar to the ones used previously. The finite difference equations corresponding to equations (5.21 and 5.22) are given by:

$$(N_1)_{t+\Delta t} = (N_1)_t - C_2 (N_2)_t \{D_1 (N_1)_t\} \Delta t \tag{5.23}$$

$$(N_2)_{t+\Delta t} = (N_2)_t - C_1 (N_1)_t \Delta t \tag{5.24}$$

Values of relative power, $p_1(t)$ and $p_2(t)$, were generated to simulate asymmetric warfare using equations (5.23 and 5.24). In this evaluation, the government side was assumed to adopt a *search-then-kill* strategy (with a trial search probability $D_1 = 0.0003$) and the rebels a direct-fire approach. The initial size of the government side was $N_2 = 1000$ and four different initial rebel sizes were assumed; $N_1 = 800, 600, 400, 200$. The flow diagram for the computation is shown in Appendix II (d) and the results are plotted in Figure 5.7. An important feature of asymmetric warfare (which is illustrated in Figure 5.7) compared to direct-fire (illustrated in Figure 5.1) and guerrilla warfare (illustrated in Figure 5.5), is that the rebels can emerge victorious despite starting out weaker than the government. Figure 5.7 shows, for the present choice of parameters, that rebel victory ensues in all cases, even when they start the conflict with a troop size ratio of *0.2*. The victory of the initially weaker side manifests itself in Figure 5.7 by the curves intersecting and crossing. This figure again illustrates the use of the present relative-power approach in producing highly visually-effective representations of conflict progress.

The classic empirical case of asymmetric conflict is the Vietnamese-US war (Mack 1975; Paul 1994; Arreguin-Toft 2001). The present analysis produces a new representation of asymmetric concept based on the relative-power approach proposed by Christia (2012).

Figure 5.7 Variation of $p_1(t)$ and $p_2(t)$ for $N_2 = 1000$ and $N_1 = 800, 600, 400$ & 200 during an asymmetric conflict with a 'search' probability $D_1 = 0.0003$. Each pair of lines cross in this example, indicating that rebel victory occurs in all cases

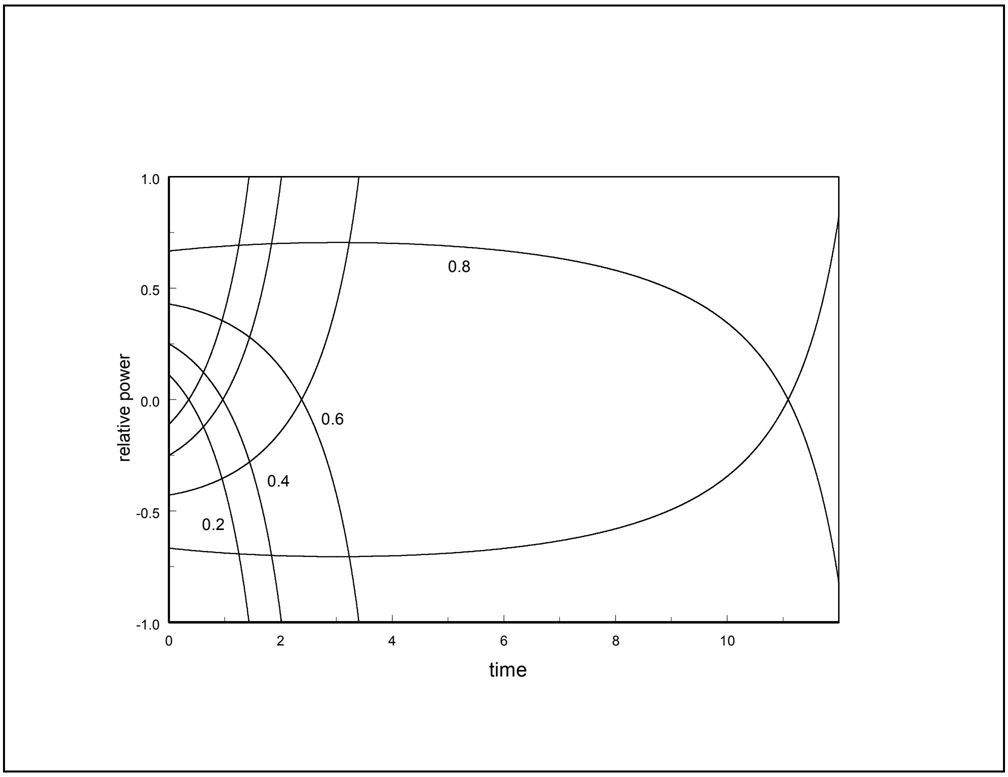


Figure 5.8 As for the previous figure but with D_1 increased by a factor of 5. This means that the state forces can find rebels more easily and in this case, rebel victory now occurs only for the largest rebel group size

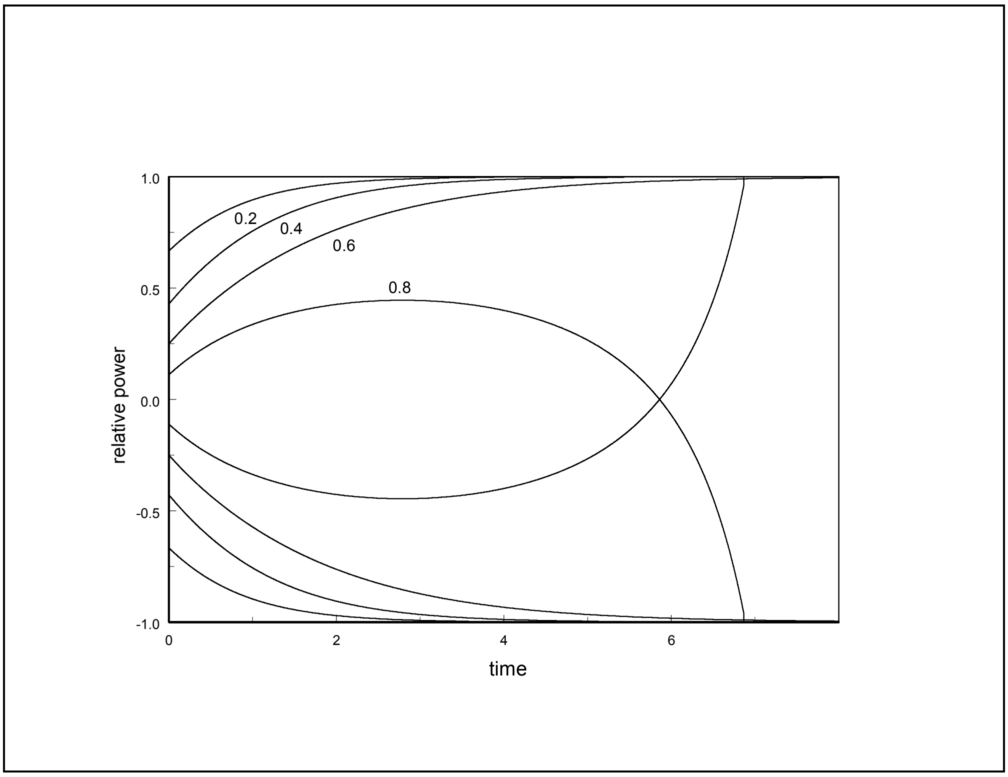


Figure 5.8 illustrates the results of a repeat evaluation of that shown in Figure 5.7 using the same parameters, except that D_1 is increased by a factor of *5*. This causes a major change of conflict outcome compared to that illustrated in Figure 5.7. Only the case where $N_1 = 800$ now results in a rebel victory. These curves clearly illustrate the expectation that when rebels are easier to find, their advantage is diminished. A further important point, is that the curves in Figure 5.8 for cases where rebels suffer defeat have the same sign for their curvature as those for guerrilla warfare (see Figure 5.5). Thus for cases where rebel defeat ensues, the curves for asymmetric warfare and guerrilla warfare are similar.

5.3.7 Inclusion of stochastic effects

Christia (2012) suggests that the variation of the relative power p during a conflict is unlikely to be smooth, but may be likened to a biased random walk, where random steps occur in the direction of increased or decreased relative power. The general ‘drift’ direction is driven at the onset by the initial values of p, but random influences are likely to occur over time. The agent-based model for guerrilla conflict illustrated in Figure 5.6 clearly shows the importance of such stochastic effects, but the numerical evaluations performed so far have not included any attempts to model stochastic terms.

It is important to re-emphasize the importance of the stochastic term in equation (5.1). In its absence, conflict outcomes would always be predictable if the initial conditions were known. In principle, there would be no need for a conflict. Christia (2012) does not describe ways in which the stochastic term could be implemented practically for the purposes of illustrating conflict progress. This section of the chapter examines specific ways in which such a term might be applied to deterministic models of two-sided conflict. These are not intended to model actual physical processes that might occur, but are simply used to illustrate the above important point, namely that random events can produce unexpected outcomes.

The next section will consider how randomness might be introduced into the value of the probability parameters (B_1 and B_2 or C_1 and C_2), then the following section will consider how it could be introduced via sudden random changes that might occur in the number of troops (N_1 or N_2).

In the first instance, random changes were incorporated into the term describing the ‘killing’ probability (i.e. incorporate randomness to the constants B_1 or B_2 that feature in equations (5.8 and 5.9). Since these are related to the fighting capability of a group, the real-life interpretation of this might be the unexpected acquisition of military equipment and arms from an external source, or indeed the unexpected loss of equipment and arms as a result of bad weather, illness, bombardment or looting. One way in which the randomness can be incorporated is by changing the values of B_1 and B_2 after each time step Δt in the computation, using the uniform distributions defined by the the relationships:

$$B_1 = (B_1)_{lower} + U\left[(B_1)_{upper} - (B_1)_{lower}\right] \tag{5.25}$$

$$B_2 = (B_2)_{lower} + U\left[(B_2)_{upper} - (B_2)_{lower}\right] \tag{5.26}$$

where $0 \leq U \leq 1$ is a random number and $(B_1)_{lower}$, $(B_2)_{lower}$ and $(B_1)_{upper}$ and $(B_2)_{upper}$ are the lower and lower limits for the chosen range of values for any chosen illustration.

Figures 5.9, 5.10 and 5.11 show the effect of applying the above stochastic variation to the killing probability of *just the rebel side*, for the cases of direct-fire, guerrilla and asymmetric warfare respectively.

A random increase or decrease in the killing probability of the rebels was introduced after each time step of the computation according to equation (5.25). In the previous simulations constant values $B_1 = B_2 = 0.01$ were assumed. In this simulation it was assumed that the lower limits were zero in all cases i.e. $(B_1)_{lower} = 0$, with an upper limit $(B_1)_{upper} = 0.05$ for the direct-fire conflict (Figure 5.9) and $(B_1)_{upper} = 0.04$ for the guerrilla and asymmetric conflicts (Figures 5.10 and 5.11). Once again $N_2 = 1000$ and $N_1 = 800, 600, 400$ & 200. The flow diagrams corresponding to these experiments are shown in Appendices II (e) and (f).

Inspection of the results obtained for one specific run, are shown in Figure 5.9. Comparing this to the equivalent case with no stochastic component (Figure 5.1), shows that the above stochastic contribution does not change the rebel outcome for $N_1 = 600, 400$ & 200, but slightly increases the timescale over which the conflict is sustained. For the largest rebel group ($N_1 = 800$), inclusion of the stochastic term has resulted in rebel victory. Inspection of Figures 5.10 and 5.11 (compared with Figures 5.5 and 5.8) reveals a similar effect. For the case of guerrilla warfare shown in Figure 5.10, the rebels have emerged victorious for $N_1 = 800$ & 600, unlike the outcome illustrated in Figure 5.5, where all rebel groups suffered defeat. In Figure 5.11, for the case of asymmetric conflict, the rebels achieve victory for $N_1 = 800, 600$ & 400, unlike the outcome in Figure 5.8, where rebel victory occurred only for the largest rebel group, $N_1 = 800$.

Figure 5.9 Variation of *$p_1(t)$* and *$p_2(t)$* for *$N_2 = 1000$* and *$N_1 = 800, 600, 400$ and 200* during a direct-fire conflict with a stochastic element applied to killing probability (B_1) of the rebel side. This leads to rebel victory for the largest group

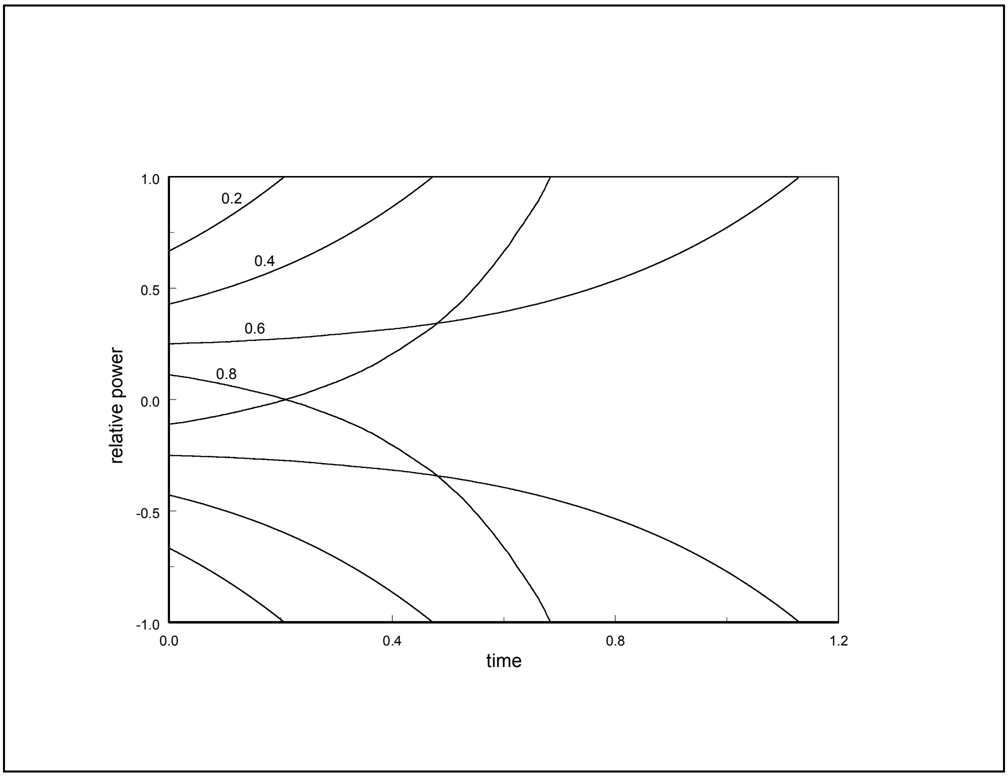


Figure 5.10 Variation of *$p_1(t)$* and *$p_2(t)$* for *$N_2 = 1000$* and *$N_1 = 800, 600, 400$ & 200* during a guerrilla conflict with a stochastic element applied to killing probability *(C_1)* of the rebel side only. Rebel victory occurs for the two largest groups

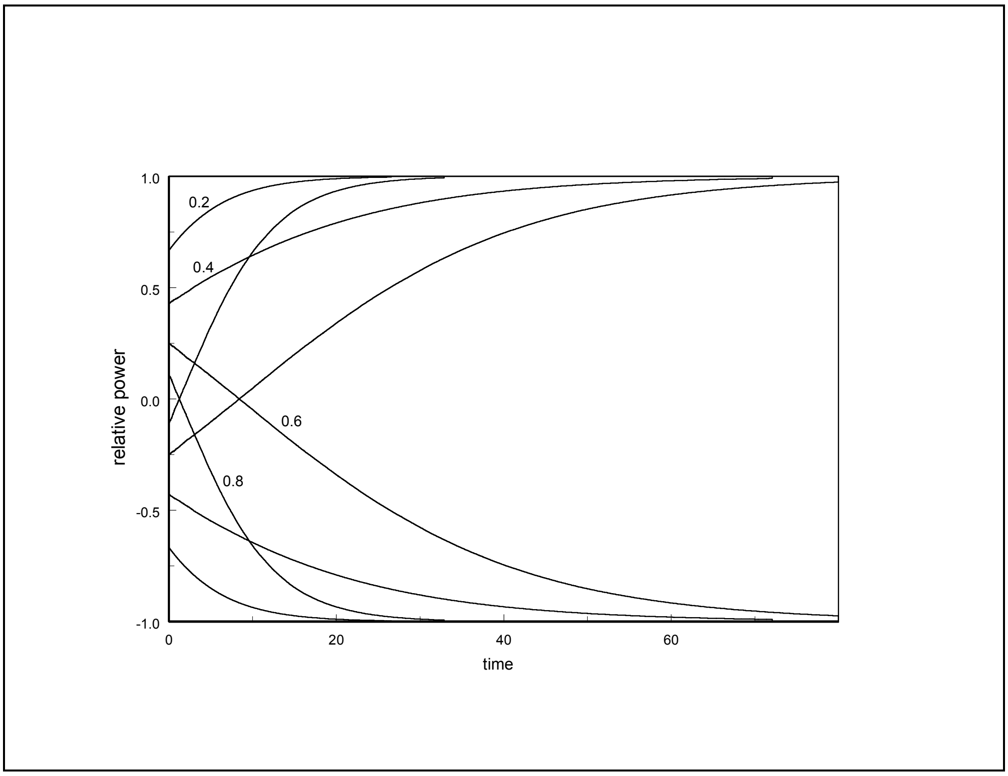
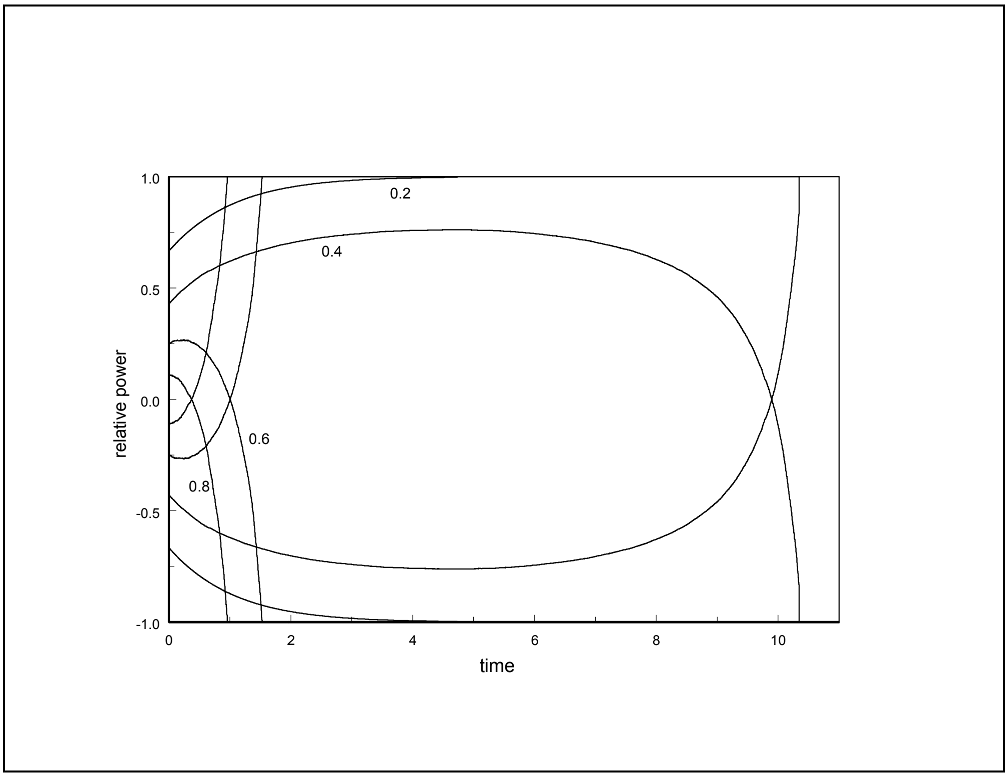


Figure 5.11 Variation of $p_1(t)$ and $p_2(t)$ for $N_2 = 1000$ and $N_1 = 800, 600, 400$ & 200 during an asymmetric conflict with a stochastic element applied to killing probability (C_1) of the rebel groups only. A search probability is applied to just the government side with the value 1.5×10^{-3}. Rebel victory occurs in three cases



An alternative approach to implementing stochastic effects is to introduce random changes to the number of troops of one or both sides (i.e. add randomness to either N_1 or N_2). The real-world interpretation of this might be an increase in troops as a result of access to mercenaries, or a decrease in troops as a result of disease. Unlike the previous case, where randomness was applied to the search probability, a different strategy is necessary in the case of adding stochastic changes to group numbers. An obvious possibility is to simply add or subtract a fixed random component $\pm\Delta N$ to the troop and/or rebel group size after each time increment Δt of the computation. It is unlikely however that this Brownian-type of randomness would occur in the real-world situation and a power-law relationship is perhaps more likely. A power law distribution is described by the function:

$$f(x) = \frac{\kappa}{x^{\alpha}} \tag{5.27}$$

where κ is a constant and α is the power law exponent.

This type of distribution is common in nature and is characterised by a high frequency of small values, an intermediate frequency of medium-sized values, with large values occurring more rarely. Power-law distributed random values of a variable z in the range $z_{min} \leq z \leq z_{max}$ can be generated from the standard relationship:

$$z = \left(\frac{z_{\min}^{\alpha} z_{\max}^{\alpha}}{U z_{\min}^{\alpha} + (1-U) z_{\max}^{\alpha}} \right)^{\frac{1}{\alpha}} \qquad (5.28)$$

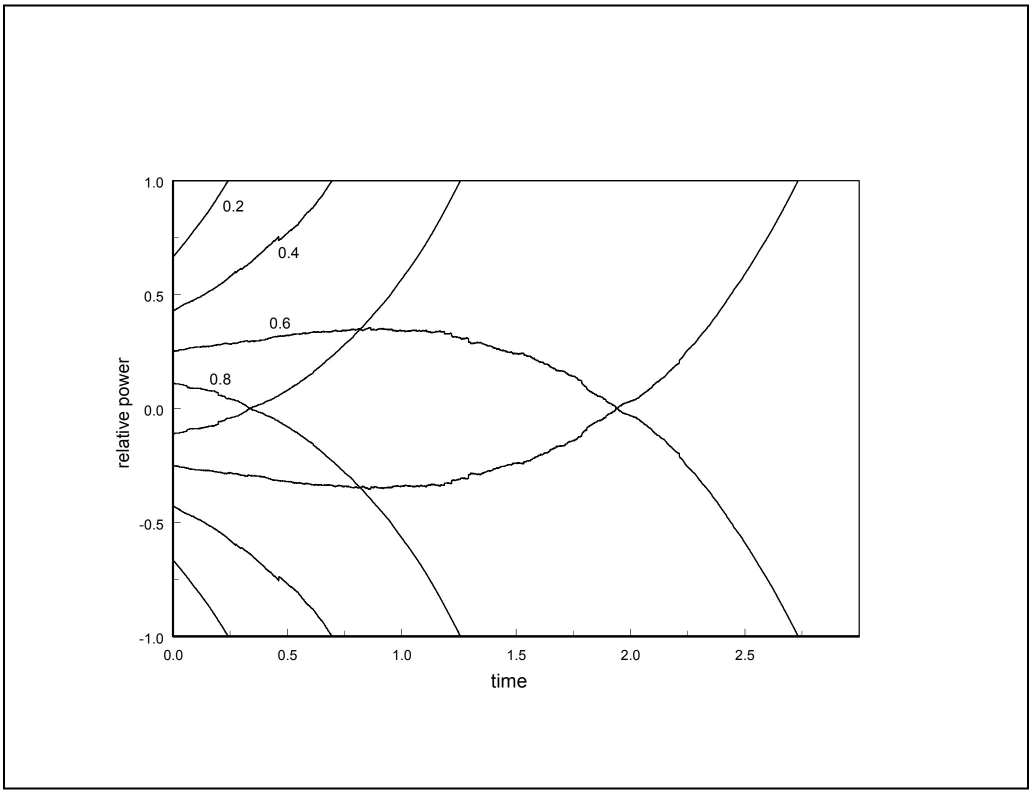
where $0 \leq U \leq 1$ is a uniformly distributed random number.

In the present case, to obtain the stochastic contribution for incorporation into the model, values of z were calculated from equation (5.28) after each time step (Δt) in the computation. The random value $\Delta N = z(N_1)_{init}$ was then determined, where $(N_1)_{init}$ is the initial number in the rebel group. A second (uniformly distributed) random number in the range $0 \leq U \leq 1$ was then used such that if $U \geq 0.5$, then ΔN was added to N_1 or was subtracted otherwise. An exponent $\alpha = 2$ was assumed and $z_{min} = 0.0001$ and $z_{max} = 1$ were taken as the lower and upper limits of possible values.

Once again, it was assumed that the group sizes were $N_2 = 1000$ and $N_1 = 800, 600, 400$ & 200. A direct-fire conflict was assumed, the corresponding flow diagram is shown in Appendix II (g) and results are shown for one example run in Figure 5.12. By comparison with the direct-fire conflict with no stochastic term illustrated in Figure 5.1, it is clear that inclusion of the stochastic term can lead to rebel victories (intersecting curves are observed for two cases) that would not be expected from predictions based on deterministic reasoning alone. No equivalent illustrations are given here for guerrilla and asymmetric conflict. The message is sufficiently clear from the above examples, namely that stochastic effects can give rise to radically different conflict outcomes.

It is important to reiterate here that the examples shown are driven by parameter values, which were selected by performing sensitivity studies. The purpose of these examples is to demonstrate the scope of the various models, not to demonstrate what might be typical over a number of experimental runs. That is, with the parameter values selected for the experiment shown in Figure 5.12, it is possible to observe a cross-over effect, where the group who starts off weaker (in this case, the rebels) may emerge victorious as a result of stochastic effects.

Figure 5.12 Variation of $p_1(t)$ and $p_2(t)$ for $N_2 = 1000$ and $N_1 = 800, 600, 400$ & 200 during a direct-fire conflict with a stochastic element applied to the rebel groups only (N_1). Rebel victory ensues for the two largest rebel groups



5.3.8 Inclusion of rebel recruitment and government deployment

The types of conflict described above, involve only the mutual attrition of two opposing groups and in the absence of stochastic events, it is assumed that there is no replenishment of state or rebel group members during the conflict. In most real-world cases however, numbers are likely to be replenished. This can be modelled in various ways, including one or more of the following possibilities: *i)* instantaneous increments of troop numbers occur, *ii)* time-dependent increases of troop numbers occur *iii)* increases of troop numbers occur in response to the size of the opposing group and *iv)* time-dependent increases of troop numbers occur either in response to (or independent of) the size of the opposing group, but with a time-lag.

In either ODE models or in an ABM, items *i)* and *ii)* can be modelled simply by allowing either an instantaneous step increase in numbers at a specific time, or enabling a time-dependent increase as the computation progresses. Items *iii)* and *iv)* can be modelled by incorporating a term that allows for a rate of increase in group numbers that depends on the number in the opposing group. Note that the inclusion of troop replenishment in conflict models represents an important novel contribution of the present work.

Consider first the growth of a rebel group with no attrition by an opposing force, whose growth follows the 'limited growth equation' described in detail in Appendix III. This takes the form:

$$\frac{dN_1}{dt} = A_1 N_1 (N_{\max} - N_1) \qquad (5.29)$$

where N_{max} is the maximum number of potential rebel recruits in the population and A_1 is a recruitment rate constant. To model an asymmetric conflict with concurrent rebel recruitment, the above growth term can be incorporated into equation (5.21) to give the expression for the overall rate of change of rebel group numbers as follows:

$$\frac{dN_1}{dt} = A_1 N_1 (N_{\max} - N_1) - (C_2 N_2) D_1 N_1 \qquad (5.30)$$

During a conflict it is likely that the state will respond to increases in the rebel threat by increasing its own strength. One of the strategies listed at the beginning of this section is that the state increases its troop numbers at a rate proportional to the current number of rebels (i.e. A_2N_1, where A_2 is a constant). This response term can then be incorporated into equation (5.22) to give the overall rate of change of state troop numbers as follows:

$$\frac{dN_2}{dt} = A_2 N_1 - C_1 N_1 \qquad (5.31)$$

Note that the 'loss' terms $(C_2N_2)D_1N_1$ and C_1N_1 in equations (5.30 and 5.31) are those for an asymmetric conflict. That is, the state troops are killed by a direct-fire process and the rebels by a search-and-kill, guerrilla strategy. This type of warfare is used for all subsequent numerical experiments because asymmetric fighting is common to most civil wars.

The progress of a hypothetical conflict with concurrent recruitment of the rebel group and deployment of state troop numbers in response is shown in Figure 5.13. The various constants were chosen to illustrate the important case that even if the state initially outnumbers the rebels (in this case by a ratio $20{:}1$), the rebels can emerge victorious because of their high rate of concurrent recruitment. The following values were used: $N_{max} = 2000$, $N_1 = 100$, $N_2 = 2000$, $A_1 = 10^{-5}$, $A_2 = 5 \times 10^{-2}$, $C_1 = C_2 = 1 \times 10^{-2}$ and $D_1 = 3 \times 10^{-4}$. In Figure 5.14, the time-dependence of the state and rebel numbers during the course of the above conflict are shown represented as a fraction of their initial numbers.

Figure 5.13 Variation of relative power with normalised time for the state and a rebel group in an asymmetric conflict with concurrent rebel recruitment and state deployment. In this example the rebel group gains victory even though it is outnumbered initially in the ratio *20:1*

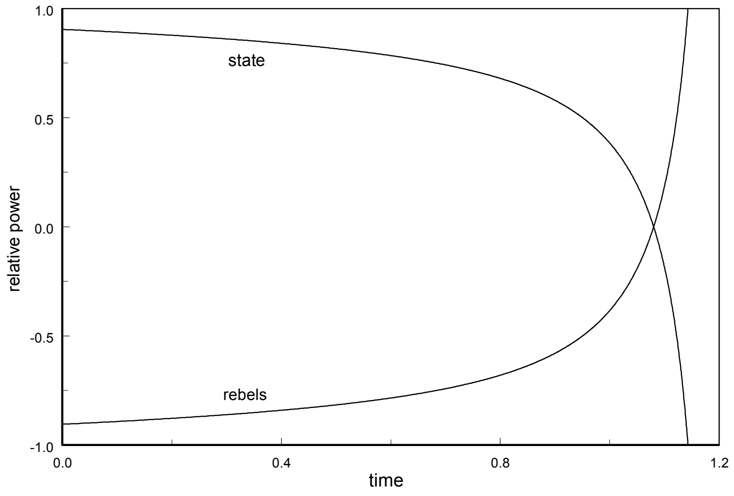
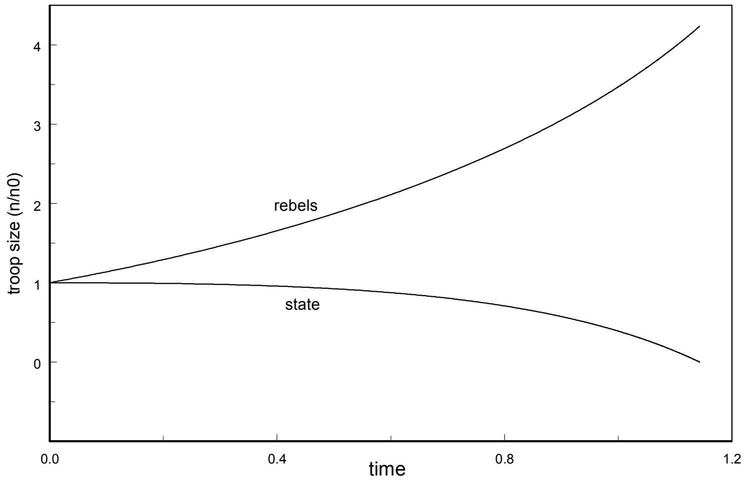


Figure 5.14 Time-dependence of the state and rebel numbers during the course of the conflict illustrated in the previous figure. Numbers are represented in terms of the fractions of their initial values



A further numerical investigation was performed by using the same values for the constants as those used for the previous hypothetical conflict, except that D_1 was increased by a factor of ten. The results are plotted in Figure 5.15. This illustrates that the outcome changes from a rebel victory to a state victory, since changing D_1 means that rebels are easier to locate by the state troops. In Figure 5.16, results are re-plotted in terms of the variation of troop numbers with time. In this particular case, state troop numbers remained almost unchanged throughout the conflict.

The influence of reducing the initial state strength on the outcome of a conflict otherwise similar to that described above is illustrated in Figure 5.17, where the ratio of rebels to state was changed from *1:20* to *1:6*. The state still emerges victorious, but the conflict lasts longer. Figure 5.18 shows the variation of troop numbers, normalised in terms of the initial number, as a function of the normalised time.

Figure 5.15 As for the hypothetical conflict illustrated in the previous two figures, except that the constant D_1 was increased by a factor of ten. This results in state, rather than rebel, victory since rebel agents are now easier to find

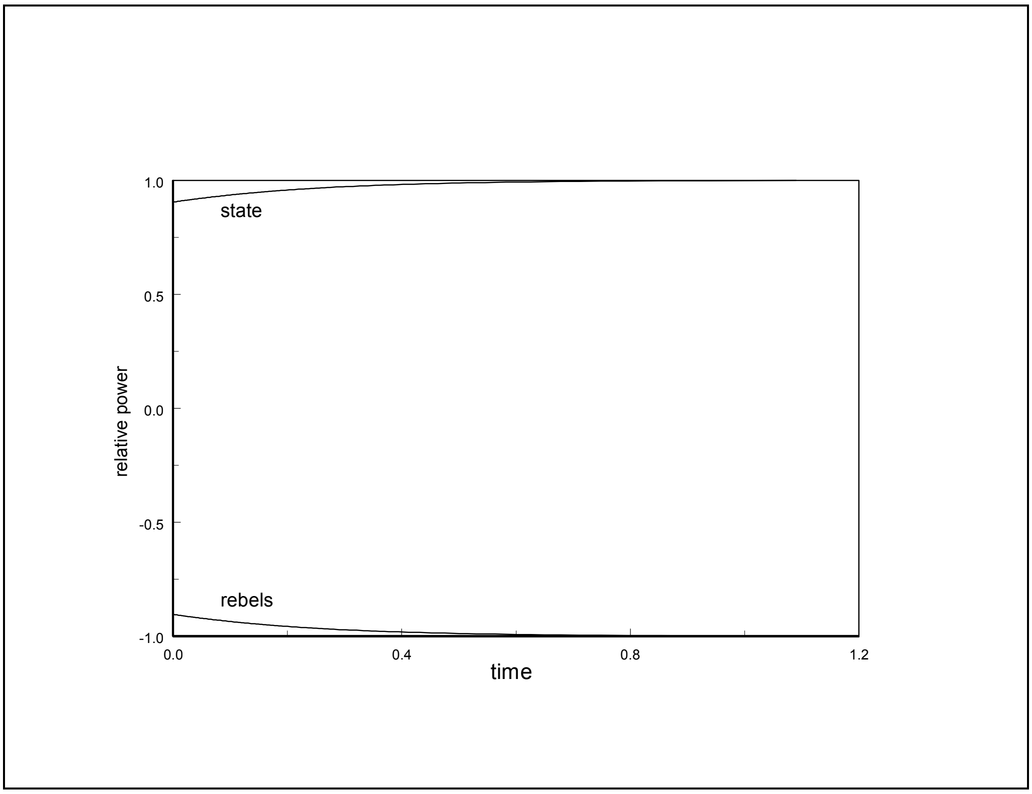


Figure 5.16 Results for the hypothetical conflict illustrated in the previous figure, plotted as the variation of troop numbers, normalised in terms of the initial number, as a function of time

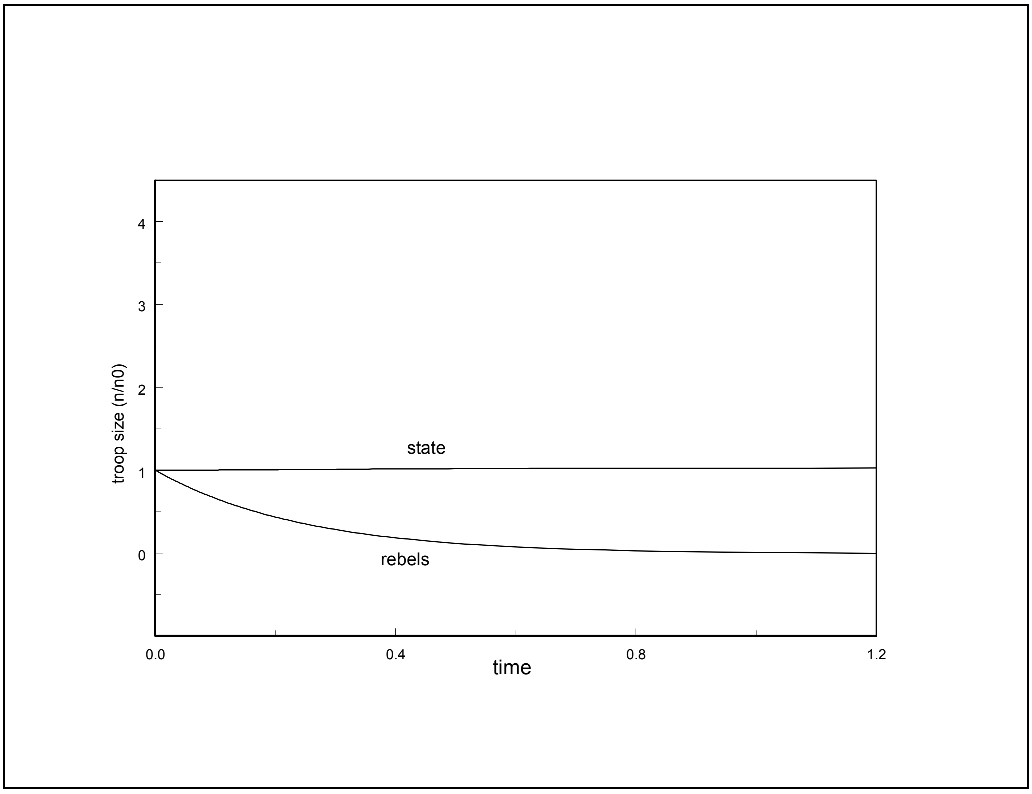


Figure 5.17 Effect of decreasing the initial state strength. The value of the rebel/state ratio is*1/6*, compared to the value *1/20* used for the previous conflict

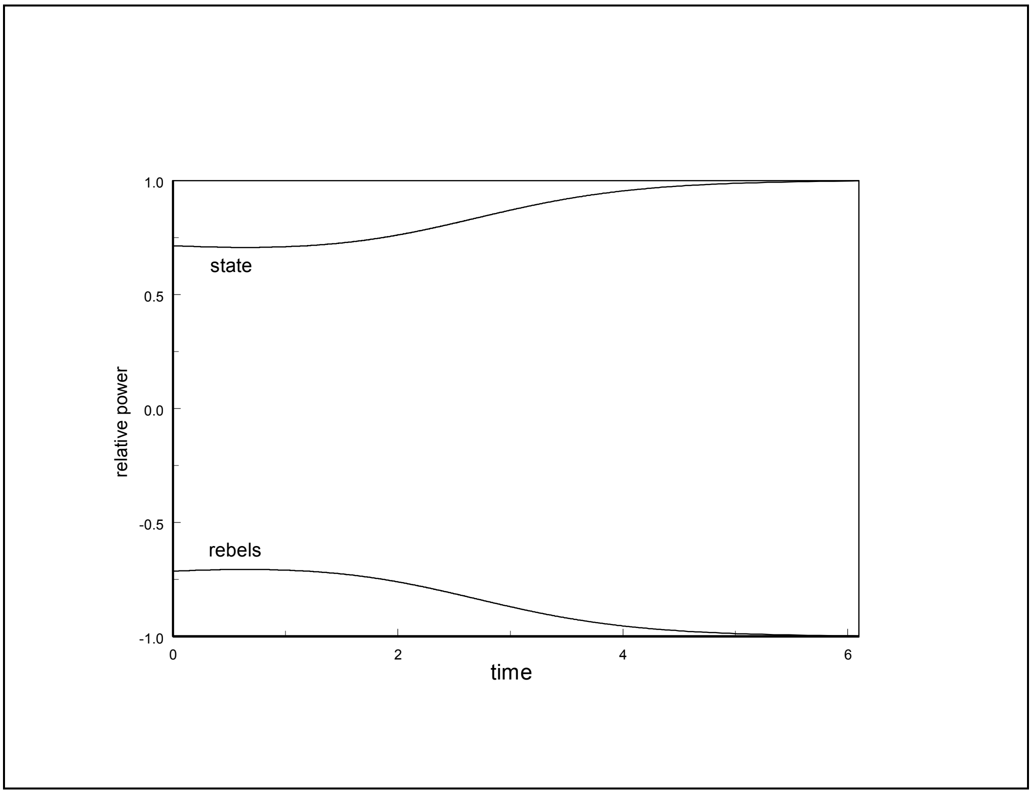


Figure 5.18 Results for the conflict illustrated in the previous figure, plotted as the variation of troop numbers, normalised in terms of the initial number, as a function of time

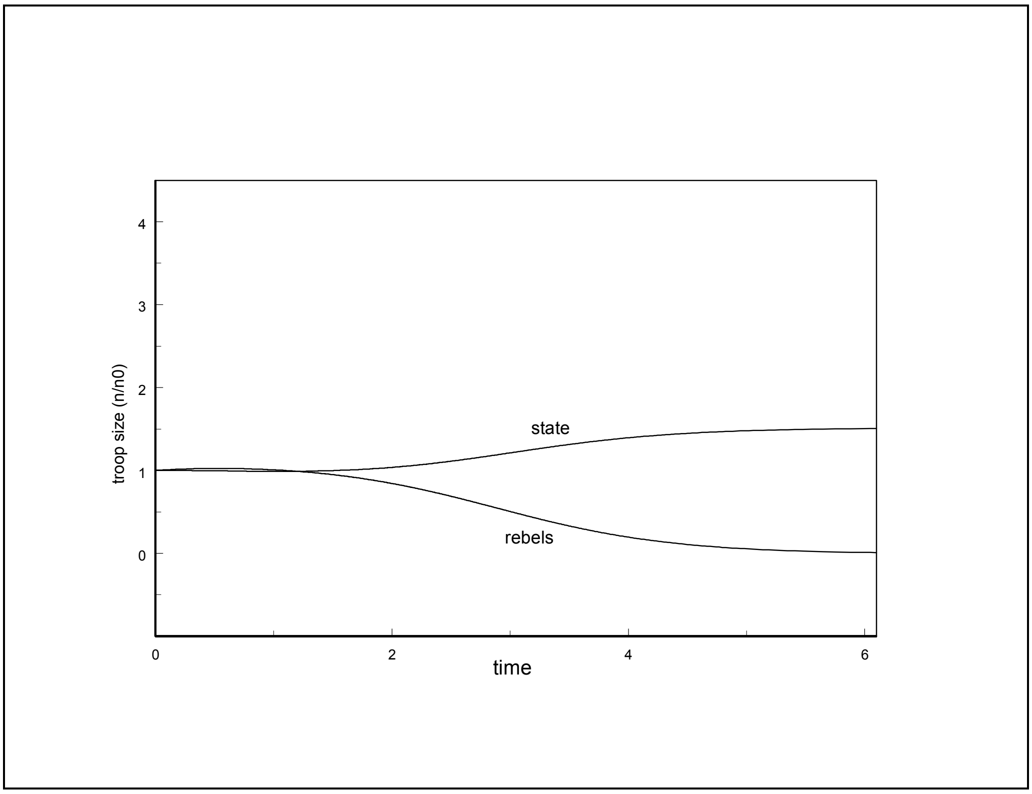


Figure 5.19 illustrates the effect on the outcome of the previous conflict if the value of the state deployment constant (A_2) is reduced by a factor of *10*. The rebels are now victorious because the state cannot deploy enough troops. The conflict also becomes more prolonged. Figure 5.20 shows the variation of troop numbers with time for this conflict. Comparison with Figure 5.18 shows that the curves representing the state and for rebels become inverted.

Figure 5.19 Influence of reducing the state troop deployment constant by a factor of *10*, in the previous conflict. Note by comparison to Figure 5.17, that the conflict outcome is reversed; rebel victory occurs

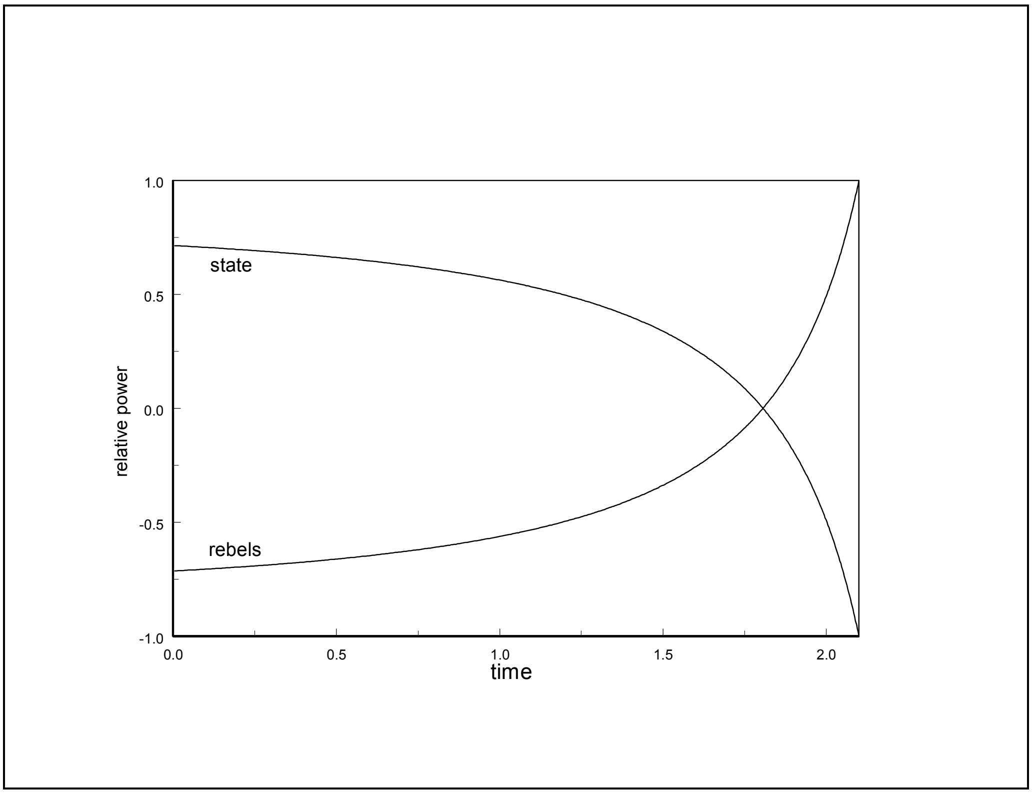
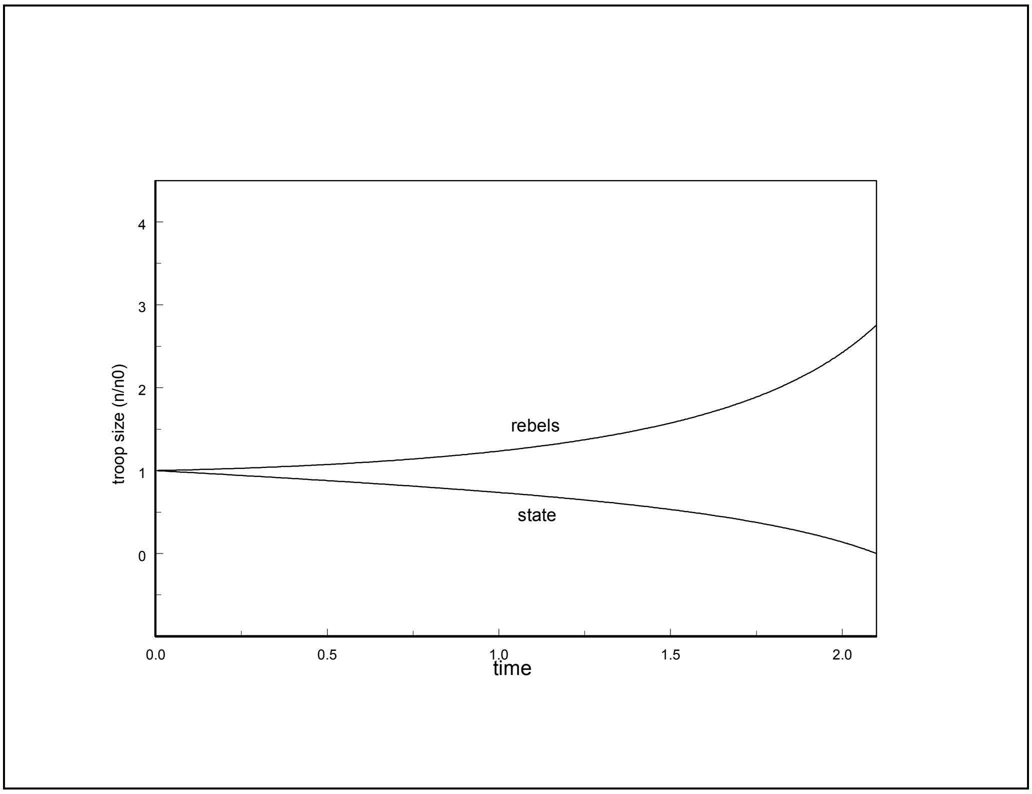


Figure 5.20 Variation of normalised state and rebel troop numbers with normalised time for the previous conflict



5.4 Modelling multi-party conflict

The models presented in the previous section were restricted to two-sided conflicts between the state and a single rebel group. In this section, the model is extended to cover conflicts with multiple rebel groups versus the state. The frequency distribution of the numbers groups involved in various conflicts was described in Chapter II. Approximately half of all civil wars occurring between 1945 and 2008 were multi-party conflicts.

An important feature that emerged from the statistical analysis in Chapter II was that the number of rebel groups tends to be smaller for conflicts involving strong states and also that rebel groups commonly interact during multi-party conflicts. These interactions may take the form of cooperation, fighting or both cooperation and fighting with another group or groups. Since these features are an important aspect covered by this thesis, it is relevant to investigate how the present modelling approach might be used to provide some insight into them. Multi-party conflicts can be modelled by either ODEs or ABM. Numerical models based on ODE's are described in the following section.

5.4.1 Description of the numerical model

The first model was based on the following scheme. It is assumed that the state forces with initial size N_S are *simultaneously* in conflict with n rebel groups having initial sizes $N_1, N_2, \ldots. N_n$. Each rebel group is considered to increase in size by a self-recruitment growth process, as was assumed earlier for the case of dyadic conflicts. The recruitment expression is given by:

$$(\dot{N}_{inc})_i = A_i N_i \left((N_{\max})_i - N_i \right) \tag{5.32}$$

where A_i is the growth rate constant for the i^{th} group and $(N_{max})_i$ is the maximum number of potential rebel recruits for the i^{th} group in the total population. (The approximate form of the equation, corresponding to the case where $(N_{\max})_i >> N_i$ is: $(\dot{N}_{inc})_i \approx A_i N_i (N_{\max})_i$). The state forces are assumed to grow directly in response to the *total* number of rebels that exist at any instant, so that:

$$(\dot{N}_{inc})_S = \gamma \left(N_1 + N_2 + \ldots + N_n \right) = \gamma N_{TOT} = \gamma \sum_{i=1}^{i=n} N_i \tag{5.33}$$

where γ is the growth rate constant for the state forces.

In this version of the model, the state is assumed to fight simultaneously with all the rebel groups, with the number of state troops employed in combat with each rebel group, being partitioned in accordance with the relative size of that group with respect to the total number of rebels. Thus if the i^{th} rebel group occupies a fraction f_i of the total then:

$$f_i = \frac{N_i}{N_{TOT}} = \frac{N_i}{\sum_{i=1}^{i=n} N_i}, \tag{5.34}$$

The number of state troops fighting this i^{th} group is thus $(N_S)_i = f_i N_S$ and the attrition rate of the i^{th} rebel group is therefore given by:

$$(\dot{N}_{dec})_i = -\beta_S (N_S)_i (\xi_i N_i) = -\beta_S (f_i N_S)(\xi_i N_i) \tag{5.35}$$

where β_S is the killing rate constant for the state and ξ_i the search probability constant.

Since the number of state troops becomes depleted by a direct-fire process, the attrition rate is the sum of the attrition rates due to all rebel groups. The total attrition rate of the state is thus:

$$(\dot{N}_{dec})_S = -(\beta_1 N_1 + \beta_2 N_2 + \ldots + \beta_n N_n) = -\sum_{i=1}^{i=n} \beta_i N_i \tag{5.36}$$

where β_i are the appropriate killing rate constants of state troops by each rebel group.

In the numerical scheme, for rebel and state growth respectively, the incremental increments in numbers, in each time step Δt are thus:

$$\Delta(N_{inc})_i = (\dot{N}_{inc})_i \Delta t \tag{5.37}$$

and

$$\Delta(N_{inc})_S = (\dot{N}_{inc})_S \Delta t \tag{5.38}$$

For rebel and state shrinkage respectively, the decrements are:

$$\Delta(N_{dec})_i = (\dot{N}_{dec})_i \Delta t \tag{5.39}$$

and

$$\Delta(N_{dec})_S = (\dot{N}_{dec})_S \Delta t \tag{5.40}$$

The progress of a conflict is then calculated by solving the above set of equations numerically in a manner similar to that used for the two-sided conflict examples in the previous section. This involves calculating the various ΔN values from each of the above equations for small time steps Δt and then updating the numbers using the algebraic sums as follows:

$$(N_S)_{t+\Delta t} = (N_S)_t + \Delta(N_{inc})_S + \Delta(N_{dec})_S \tag{5.41}$$

$$(N_i)_{t+\Delta t} = (N_i)_t + \Delta(N_{inc})_i + \Delta(N_{dec})_i \tag{5.42}$$

During the course of the computation, the total time elapsed was obtained by summing the Δt values and the relative power for each group p_i and for the state, p_S was calculated from the expressions:

$$p_i = \frac{N_i(t) - N_S(t)}{N_i(t) + N_S(t)} \tag{5.43}$$

$$p_S = \frac{N_S(t) - N_i(t)}{N_i(t) + N_S(t)} \tag{5.44}$$

In the first instance, a hypothetical conflict was modelled that assumed no rebel or state recruitment occurred during the conflict (i. e. *all* $A_i = 0$ and $\gamma = 0$). The initial state troop size was *2000* and four rebel groups were assumed with sizes *200*, *400*, *600 & 800* respectively. All β_i and ξ_i values were assumed to be *0.01* and *0.0003* respectively. The results are illustrated in Figure 5.21 and indicate a straightforward victory for the rebel forces.

The next conflict modelled was identical except that the state initial size was increased from *2000* to *8000*. The results are shown in Figure 5.22, which indicates that the much stronger state now leads to a state victory, this time after a more extended time period. This ‘long-tail’ is again characteristic of asymmetric conflicts because the rebels become harder to locate as they decrease in number. The details of the converging rebel curves in the long-tail region are illustrated more clearly in Figure 5.23, which shows part of Figure 5.22 plotted on an expanded scale. The results of the hypothetical conflict illustrated in Figures 5.22 and 5.23, confirm the expectation that a state victory can be assured if its initial size is increased sufficiently. By the same token, the expectation that with the same number of troops but with a higher killing power, state victory would be achieved. This is indeed confirmed in Figure 5.24, where the state killing probability was increased in the computation by a factor of *20*.

Figure 5.21 Representation of an asymmetric conflict between the state ($N_S = 2000$) and four rebel groups (with sizes *200*, *400*, *600*, *800*). It is assumed that no recruitment occurs (i.e. all $A_i = 0$ and $\gamma = 0$). Rebel victory is indicated in all cases. (It is assumed that all $\beta_i = 0.01$ and $\xi_i = 0.0003$)

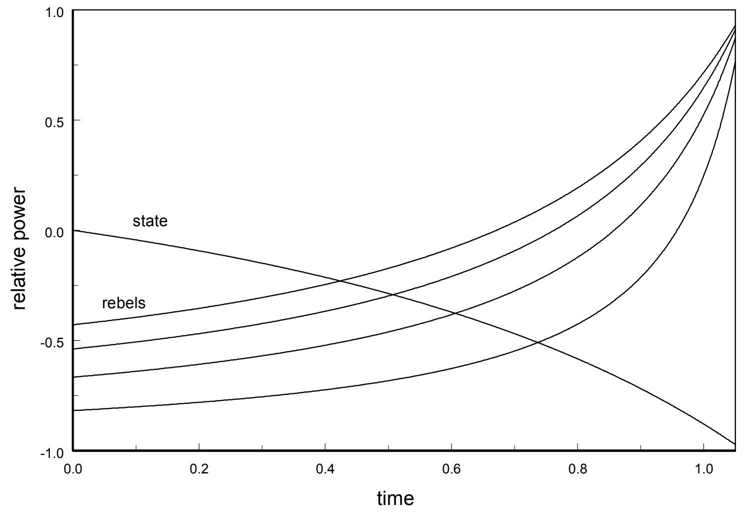


Figure 5.22 As for the previous conflict but with the state size increased from *2000* to *8000*. This now results in a state victory. Note the more extended timescale that results because of the asymmetric conflict

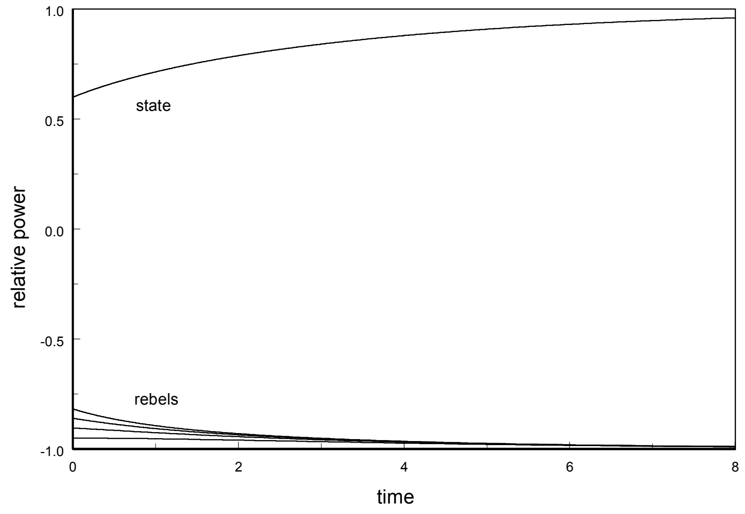


Figure 5.23 Enlarged part of the previous figure, showing details of the convergence of the curves

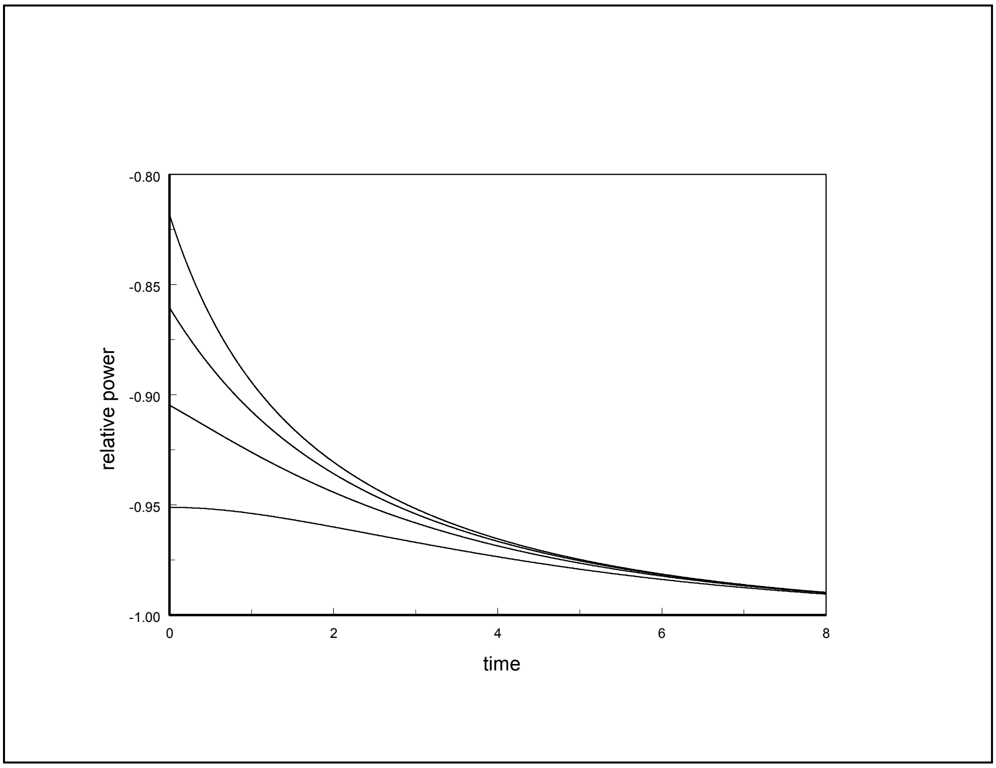
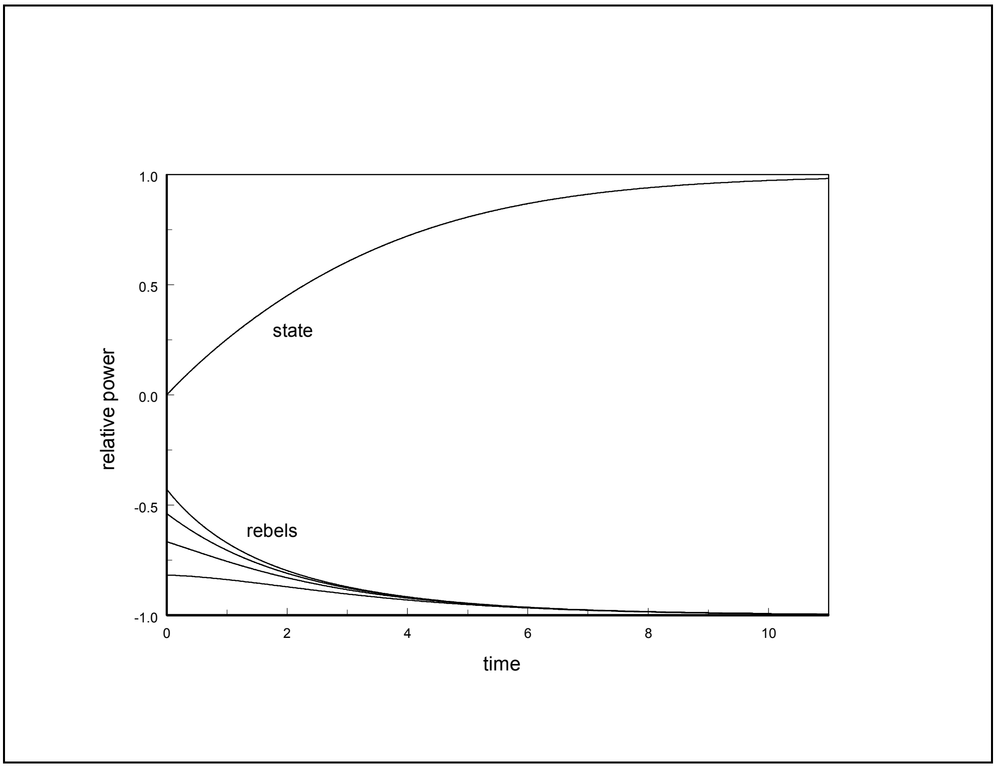


Figure 5.24 The same conflict as that illustrated in Figure 5.21 except the state killing power was increased by a factor of *20*. This now leads to a state, rather than rebel victory



In the models leading to the results illustrated in Figures 5.21 – 5.24, no account is included for the effect of concurrent group recruitment or the deployment of state troops. In the next model, both rebel recruitment and state deployment were enabled in the computation. The influence is shown in Figures 5.25 and 5.26. In the computation, rebel recruitment was characterised by the value $A_i = 0.00001$ for all rebel groups.

Figure 5.25 illustrates that the outcome with the state recruitment constant $\gamma = 0.005$ is rebel victory, whereas Figure 5.26, with the state troop deployment rate increased by a factor of *10*, the result is rebel defeat. These outcomes confirm the expectations that arise from changing the relative rates of recruitment and deployment. An important feature to be noted in Figure 5.26 is the convergence of the curves for the rebel groups, with the curves becoming almost coincident at the longest times. This convergence occurs because it is easier for the state to locate and kill the rebels in the early stages when the groups are larger and more difficult when they are smaller.

Figure 5.25 The same conflict as that illustrated in Figure 5.21, but with rebel recruitment and state deployment enabled in the numerical model

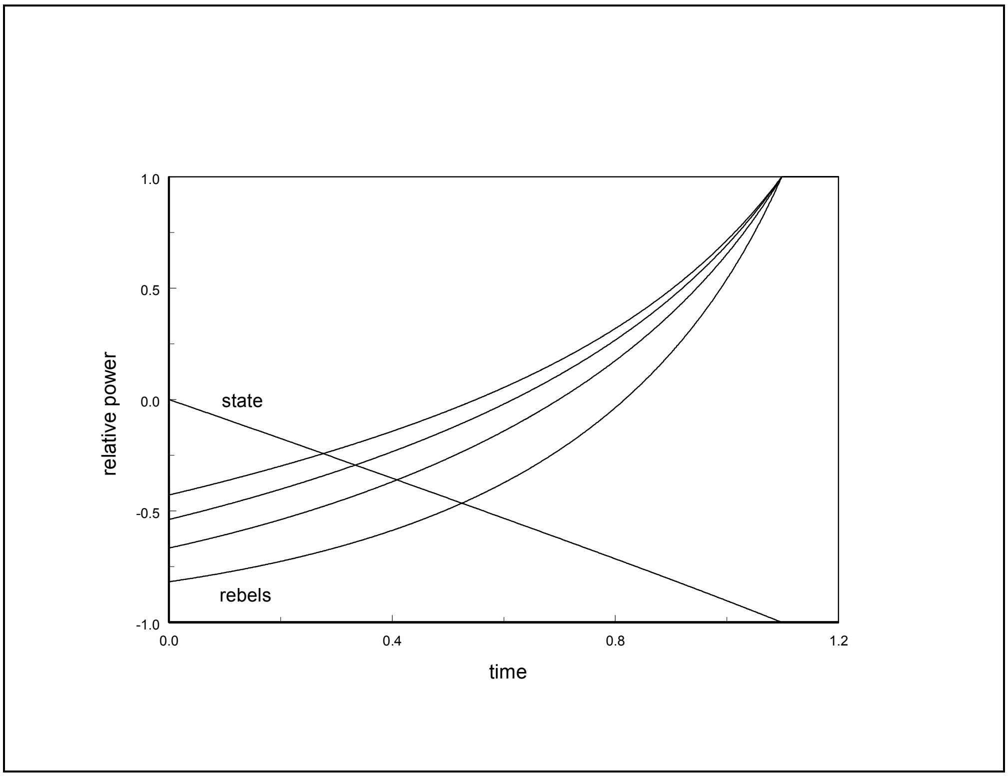
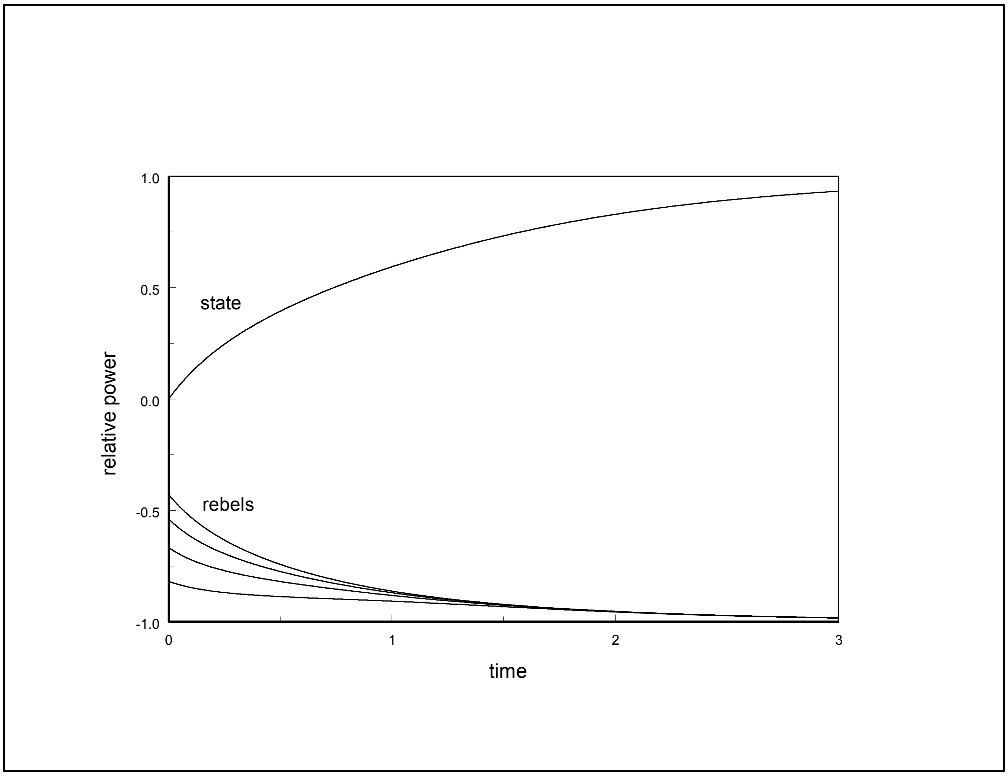


Figure 5.26 As for Figure 5.25 but with state deployment increased by a factor of *10*



5.4.2 Modelling rebel group interactions

The numerical models described above provide a platform from which a wide range of hypothetical interaction strategies of rebel groups can be modelled with relative ease. One result that emerged from the statistical analyses in Chapter II is that there is a higher likelihood of alliance formation between groups that are militarily small relative to other groups in the conflict. To test the effect of this type of interaction strategy, the conflict illustrated in Figure 5.26 was modified such that the two smallest groups were allowed to combine at the (arbitrary) value of normalised time of *0.5*. The results are shown in Figure 5.27 and on an expanded scale in Figure 5.28. These figures clearly show that on initiation of the alliance, the curve representing the smaller rebel group drops to zero as it loses its members to the larger group and the curve for the other group increases as it gains members. The important result is that after forming an alliance, the curve for the newly-aligned group soon becomes almost coincident with the closely-converged set of curves for all the other groups. This is an important finding, in that it mirrors the results obtained from the statistical modelling in Chapter IV, namely that when small groups merge there is little ultimate impact on a group's longevity. This is explained by the fact that gains made from forming an alliance are balanced by the increased rate of attrition experienced as a result of increased group size.

Figure 5.27 Representation of the same conflict as that shown in Figure 5.26 but with the two smallest groups merging at a value of normalised time *0.5*

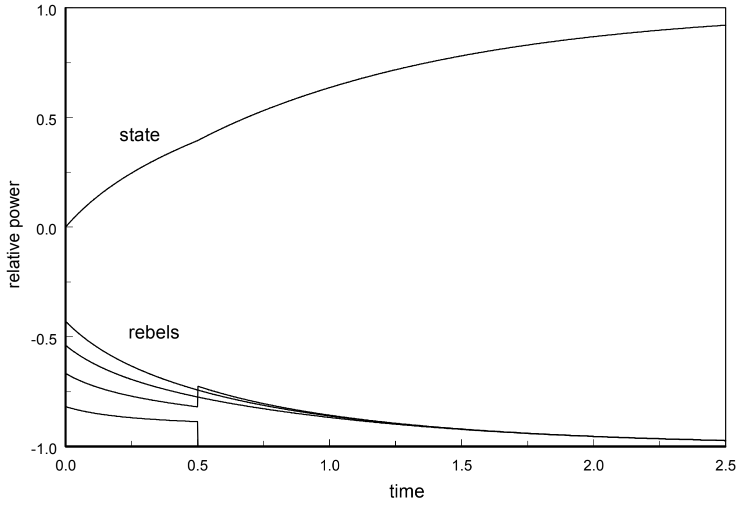
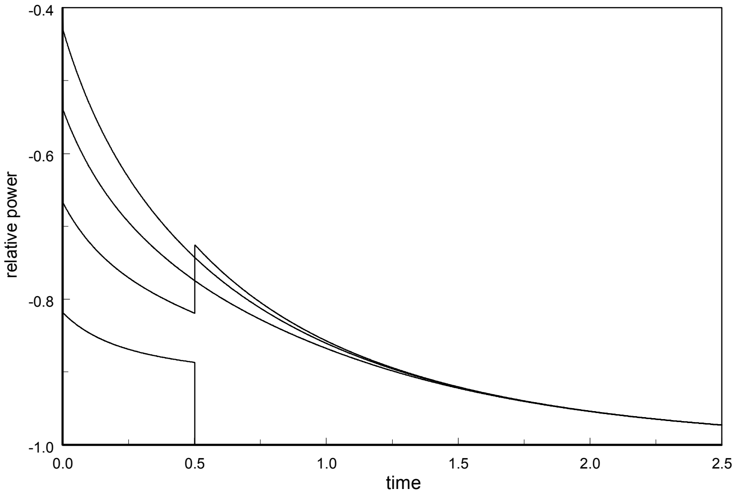


Figure 5.28 Enlarged portion of the previous figure



In Chapter II, another important statistical finding was that rebel groups are more likely to engage in inter-rebel violence when they are either militarily large or militarily small relative to their peers, a result replicating that obtained by Fjelde and Nilsson (2012) who used a different construct of relative rebel group size. Inter-rebel violence can be modelled relatively easily in the present model by including a subroutine in the program that is utilised after each incremental time step in the computation. Thus if the i^{th} and j^{th} rebel group fight each other in a guerrilla conflict, a subroutine identical to that described earlier by equations (5.17, 5.18, 5.19 and 5.20) can be incorporated for this purpose, where the subscripts *1* and *2* in these equations are replaced by *i* and *j*.

The outcome of fighting between the largest and smallest group in the conflict depicted in Figure 5.26 is shown in Figure 5.29. The onset of inter-rebel violence is assumed to commence at the (normalised) time *0.5*. The kill-rate constants and the search probabilities are taken to be identical to the earlier values. For these specific values, the progress of the conflict is changed only slightly by inter-rebel fighting, as can be observed by comparing Figures 5.29 and 5.30 with the corresponding case where fighting does not occur (in Figure 5.26).

Figure 5.29 Outcome of a conflict identical to that illustrated in Figure 5.26 but with the assumption that the largest and smallest groups engage in a guerrilla conflict commencing at the normalised time *0.5*

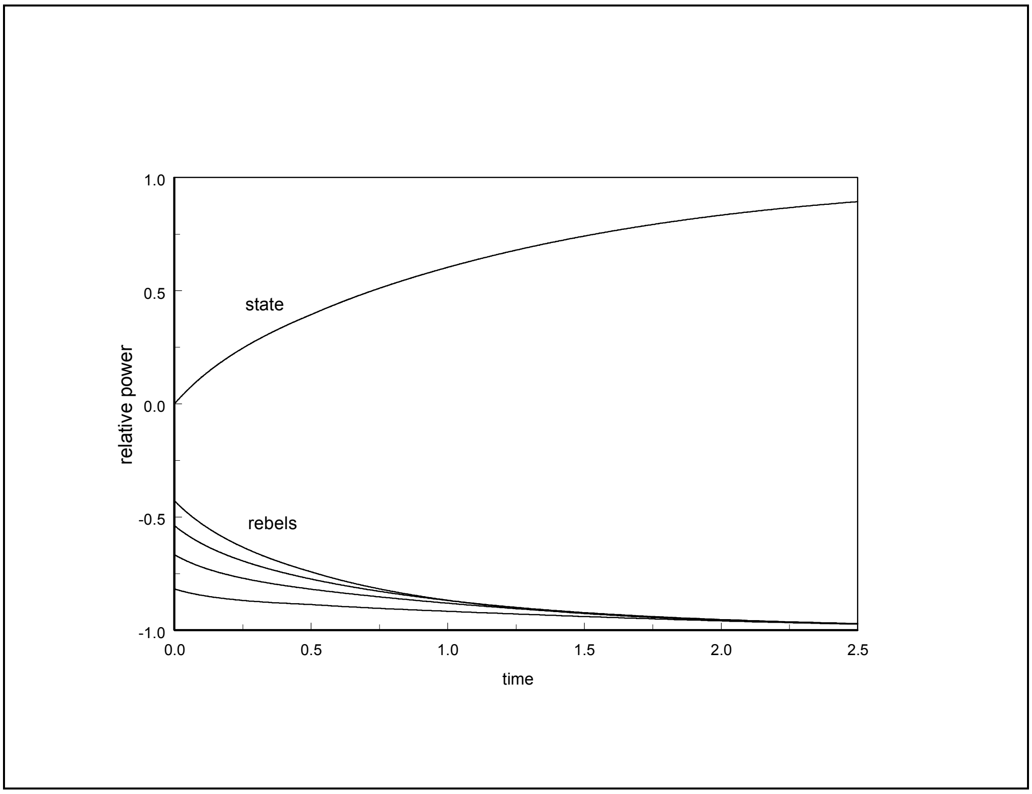
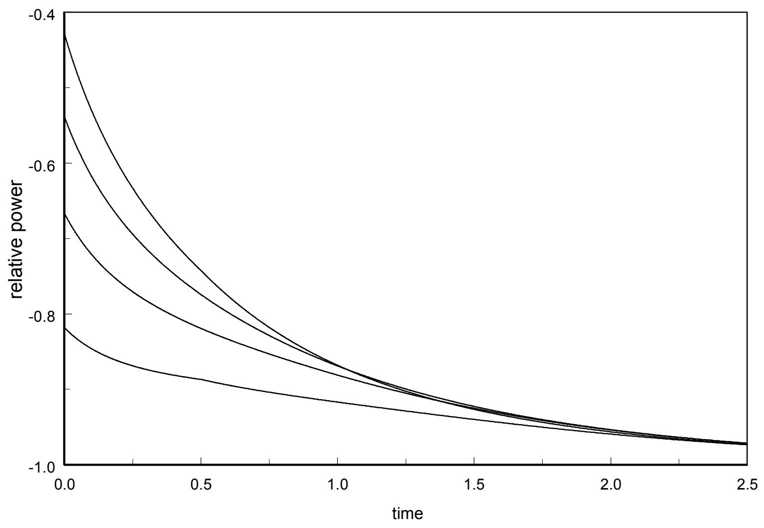


Figure 5.30 Enlarged portion of the previous figure



In the case where the kill rate constant for both fighting groups is increased by an order of magnitude, the influence of fighting between the two groups has a more profound influence on the curves. This is illustrated in Figures 5.31 and 5.32. The change in the rate of loss of troops from both groups is now clearly illustrated.

Figure 5.31 Representation of the same conflict as that shown in Figures 5.29 and 5.30, but the kill rate constant for both fighting rebel groups is increased by a factor of *10*

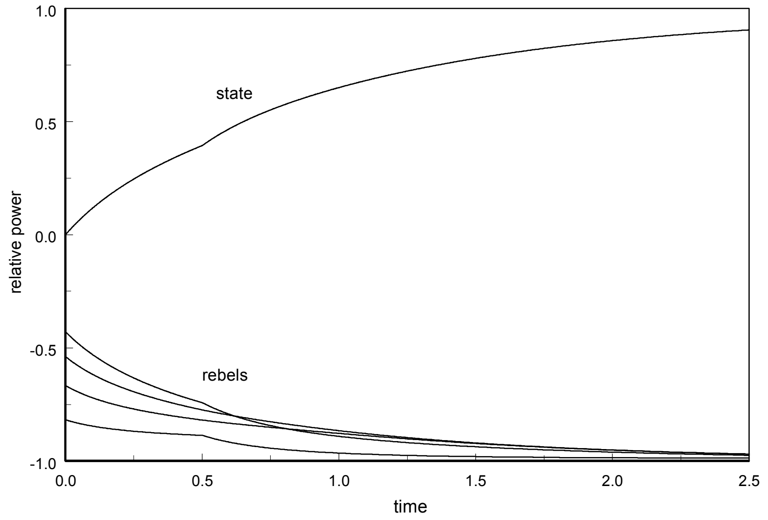
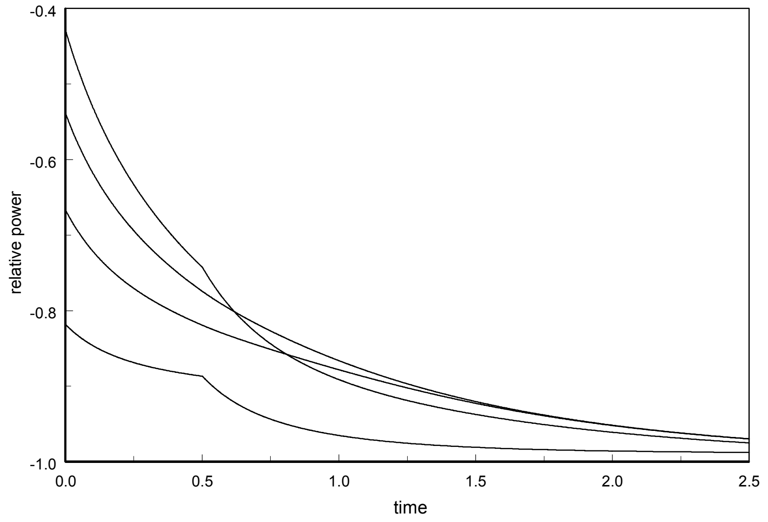


Figure 5.32 Enlarged portion of Figure 53.1



5.5 Concluding remarks

In this chapter, various ways in which civil conflict can be modelled have been explored by using an expression, based on the concept of 'relative power' described by Christia (2012). General numerical models of two-sided conflict were developed and various aspects were investigated, including the optimal definition of relative power, the different mechanisms of two-sided conflict (direct-fire, guerrilla and asymmetric warfare), inclusion of a stochastic element (both to the number of rebel troops and the rebel group killing constant) and inclusion of terms for rebel recruitment and the deployment of government troops.

A comparison of ordinary differential equation (ODE) modelling and agent-based modelling (ABM) allowed an assessment of the suitability of these two types. ABM was found to be particularly suited to the modelling of guerrilla warfare due to an inherent feature of ABM programming software, where agents can be programmed to move randomly and collide with other agents (thus replicating the *search-and-kill* characteristic of guerrilla warfare). ABM was found to be less suited to the modelling of direct-fire and asymmetric warfare because both of these types of warfare involve a direct-fire mechanism on at least one side. Since a direct-fire mechanism does not require the agents to *search* for their opponent before more making a kill, the random movement of agents around an artificial environment (which is inherent in ABM) is superfluous.

The work presented in this chapter showed that Christia's general concepts provide an excellent basis from which models of multi-party conflict can be developed. The concept of relative power and how it varies throughout a conflict provides a highly effective and clear visual representation of conflict dynamics and rebel group interactions. Striking differences are illustrated in the characteristic curves representing the different types of conflict.

Civil wars are commonly asymmetric and conflicts are more protracted owing to the fact that the rebel agents becomes increasingly difficult to locate as they decrease in number. This means that rebels can be at a significant advantage despite their small size. In the context of civil war, this might explain why some conflicts, involving weak rebels, are protracted. This work has shown that implementing a random element to numerical models of conflict can dramatically change the duration and outcome of war. Similarly, the effects of rebel recruitment and government deployment are shown to have important influences on conflict outcomes in ways that might be expected intuitively.

In the second part of this chapter, the general model of two-sided conflict was extended to multi-party civil wars. This represents a novel contribution to conflict modelling, since previous computer based simulations of civil war have all been limited to two-sided conflict. This model has great potential to explore hypothetical rebel interaction strategies. Various aspects were modelled including simultaneous conflict between the state and four rebel groups of different initial sizes, varying the rates of rebel group recruitment and government deployment of troops and modelling of two rebel group interaction strategy types, alliance formation and inter-rebel violence. The simulations of multi-party asymmetric conflict (in which all rebel groups fought the state simultaneously) revealed convergence in rebel group sizes over time. This finding has important implications in that it provides possible information regarding the mechanism responsible for the empirical finding in Chapter IV that alliance formation does not have a strong effect on group longevity. This is simply explained by the convergence in the curves at longer times.

Overall, this chapter has demonstrated that differential equation modelling and agent-based simulation techniques have great potential for modelling rebel group interactions in multi-party civil wars. The development of the relative power concept provides an excellent basis from which multi-party conflicts, and subsequently rebel group interactions, can be simulated. These simulations can be used to model a wide range of conflict processes, including stochastic events, rebel group recruitment of civilians, government responses and the deployment of troops. Importantly, in relation to the theme of this thesis, they can be used to model rebel group interaction strategies such as alliance formation and inter-rebel violence.

5.5.1 Possible extensions to the multi-party conflict model

An obvious extension to the currently developed multi-party conflict model would be to explore the effect of varying the number of rebel groups according to their known frequency distribution described in Chapter II. Similarly, the initial sizes and capabilities of the rebel groups could also be varied according to those in the empirical data set. For example, the data from Cunningham *et al.* (2009) includes information on rebel group characteristics, including the initial size, their arms procurement capability (a proxy for the killing rate constant) and their mobilisation capability (a proxy for the recruitment term). In addition, one of the findings of Chapter II, that the number of rebel groups varies as an inverse function of state strength, would provide an additional degree of realism in the multi-party model.

In the present illustrations of group interactions, it is assumed that the onset of interaction simply occurs at an arbitrarily chosen time. While this is useful for illustration purposes, it is not likely to accurately model real-world events. An obvious way forward is to explore various criteria that are likely to determine the onset of interactions other than to simply chose an arbitrary time. A possible alternative criterion that might provide insight into the onset of interactions concerns possible uses of the metric 'relative power'. The multi-party model presented earlier explores only the relative power that exists between the state and each of the rebel groups. But relative power between rebel groups themselves may provide important clues in unravelling the reasons for the different types of interaction strategy that are known to occur. The statistical findings presented in Chapter II suggest that rebel groups who are militarily weak relative to their peers are more likely to form alliances, whereas groups who are militarily strong and those who are militarily weak relative to their peers are more likely to engage in inter-rebel violence. In other words, weak rebel groups align to balance their power against the state, whereas strong rebel groups target weak groups for elimination via inter-rebel violence. The relative power between groups could be used to model the initiation of interactions accordingly. For example, when the relative power between two rebel groups crosses a threshold, inter-rebel violence between those two groups could be initiated.

Instead of using the relative power between groups as a criterion for initiating interactions, a further approach could be the use of the *rate of change in relative power* (either between the rebel group and the state, or between the rebel groups themselves). When this exceeds a certain critical value, or when there is a discontinuity in its variation, this might trigger some type of interaction. The initiation of rebel group interactions might be modelled using a matrix, where rebel groups consider their own power relative to the state and to each (or all) of the other rebel groups in the conflict. This could give further insight into the findings of Chapter III and other empirical research (see Fjelde and Nilsson 2012), which show that conflicts involving strong states are more likely to encounter alliances between groups, whereas conflicts involving weak states are more likely to encounter inter-rebel violence between groups.

Another extension to the multi-party model would involve modelling the target choices made by rebel groups in a manner driven not by power considerations, but rather by identity-based factors. This could give insight into explaining the statistical findings presented in Chapter II, which provided evidence in support of this argument. One of the difficulties in the modelling of identity-based attributes lies in their qualitative nature. However, the network approach developed in Chapter II, gives a measure of the degree of ideological similarity between groups and this provides a possible way of overcoming this issue. Thus each rebel group could be assigned an array of identity-based attributes at the initialisation stage of the computer program. These could be used either to direct the rebel group's interaction decisions (or target choices) entirely, or use them as a weighting factor on interaction decisions made on the basis of relative power. Interaction decisions might also be made by rebel groups in terms of cost-benefit considerations. This might have the advantage that it allows rebel groups to sometimes adopt the interaction strategy of *operate independently* in cases where the costs of interacting always outweigh the benefits.

The model presented earlier in this chapter concerns the state in simultaneous conflict with all of the rebel groups, but it is an easy matter to model the potential scenario of sequential battles (Akcinaroglu 2012). In these types of conflict, the state fights a battle with one rebel group then switches to a battle elsewhere with another. This allows the other group to rest and recuperate (and possibly recruit new members). This occurred in Liberia for example, where the two rebel groups *MODEL* and *LURD* engaged in clashes with the Liberian state within days of the other's battle. These battles were highly dispersed, covering a range of locations including Monrovia, Buchanan, Klay and Grand Bassa. Crucially, this meant that after each battle, one group could replenish its resources, whilst the state was subjected to another battle elsewhere.

As a general final comment, the numerical models presented in this chapter could be used to investigate the micro-level mechanisms underpinning civil conflict duration and outcome. Multi-party conflicts last longer (Cunningham 2006) and they are less likely to terminate by negotiated peace agreement (Cunningham 2006; Nilsson 2010) but the statistical models used in previous research (and in the previous chapters of this thesis) have not been able to directly test the mechanisms responsible for these effects. The numerical models presented in this chapter, have great potential for uncovering the micro-level mechanisms responsible for conflict duration and outcome. To accomplish this, sensitivity studies could be performed and the various model parameters could be tuned, or set according to empirical distributions, so that the simulated conflict outcomes match those observed in the real world. It might then be possible to gauge what micro-level factors lead to certain macro-level war dynamics.

Conclusions to the thesis

Chapters II – V presented in this thesis were written as distinct contributions addressing different gaps in the rebel group interactions literature. These gaps were highlighted in Chapter I. The distinct contributions made by Chapters II – V are now reviewed and the conclusions for each chapter summarised below.

Chapter II investigated the determinants of two types of rebel group interaction strategy; alliance formation and inter-rebel violence. Two competing theories regarding the motivations for rebel group interactions were tested empirically. The first theory tested was based on the assumption that rebel group interactions are motivated solely by *power considerations* (i.e. group size), whereas the second theory tested was based on the assumption that *identity considerations* are dominant. A novel methodology based on social network analysis was utilised so that a quantitative index, which measures the degree of ideological similarity between groups, could be developed. This addressed one of the gaps in the literature, since few studies have examined the influence of social ties on group interactions. The potential use of network approaches for examining social ties between groups was also highlighted. Findings from the statistical analyses presented in Chapter II suggested that power-based factors have greater utility in explaining rebel group interactions. Identity-based factors were found to play a role in motivating cooperative alliances but there was less convincing evidence found regarding their role in motivating inter-rebel violence.

Future research on the determinants of interactions should consider using a dyadic design when appropriate data becomes available. This would be advantageous as it would allow interaction mechanisms to be tested more directly. Alternatively, future research may benefit from moving away from dyadic designs, shifting instead towards the use of network approaches since these provide an opportunity for multiple interdependencies to be explored. The utility of these network approaches was demonstrated in Chapter II. Additional factors, such as the role of geography or technology should also be explored since these features may also be important in determining rebel group interactions. The role of the state (and various state-level attributes such as military/administrative capabilities or state ability to induce collaboration) should also be included in empirical models in future research. These state attributes were not specified in the models presented in Chapter II, since the aim was to test two prominent theories relating directly rebel group-level attributes (identity and group size).

But since rebel groups in civil war inherently exist in the presence of state forces, interactions between rebels and other group dynamics (such as defection) should not be considered as being independent from the state.

Another useful line of enquiry for future research concerns the question of why some conflicts contain multiple rebel groups. This question was briefly addressed in Chapter II but further empirical research is needed and the theoretical explanations of why multi-party conflicts arise in the first place (and why some conflicts involve larger numbers of rebel groups) need developing.

Chapter III set out to answer the question of why some rebel groups form alliances with their peers while other groups, driven by apparently similar identity-based motives, engage in inter-rebel violence. This addressed one of the gaps in the literature since previous empirical research has not considered that the motives for inter-rebel violence and alliance formation might be the same (i.e. both cooperative and conflictual interactions might be driven by the same identity-based motives). The main contribution made in Chapter III was the proposal of novel theory based on Walter's (1997) theory of credible commitments. The main theoretical argument put forward was that rebel groups who are ideologically similar to their peers are more likely to form alliances if they are perceived by other groups as being able to credibly commit to an alliance. If a group lacks alliance credibility however, it was argued that they are more likely to engage in inter-rebel violence.

These expectations were tested using two contrasting methodologies, namely logistic regression modelling with the inclusion of moderating variables (i.e. variable interaction terms) and classification and regression trees (CARTs). Since CARTs have not been utilised in previous research on rebel group interactions, this aspect represents a novel contribution. The potential utility of CART analysis for conflict research has also been demonstrated. Rebel group alliance credibility was measured against two criteria: (*i*) the level of external threat faced by the rebel groups and (*ii*) the organisational characteristics of the groups themselves. Some evidence was found in support of the theoretical arguments put forward.

Results from the logistic regression modelling suggest that rebel groups who are ideologically similar to their peers are less likely to form alliances if they are also new entrants to a conflict. One theoretical explanation for this effect is that new entrants to a conflict lack the previous history that is required to build to trust. Since these groups lack trust, they also lack alliance credibility in the eyes of their peers and so, they are less likely to be able to form alliances. In the CART analysis, a conditional relationship between ideology and rebel group fractionalisation was also found, which indicates that groups who are ideologically similar to their peers are most likely to base their interaction decisions on the cohesiveness (i.e. organisational characteristics) of their peers. Once again, this provides some evidence in support of the theoretical proposition that credibility (proxied by group cohesion) influences rebel group interactions.

Results obtained from the logistic regression modelling and CARTs were generally in agreement. The CART for rebel group cooperation showed that the most important predictors of alliance formation (in order of importance) were ideology, the level of external threat (i.e. state strength) and the organisational characteristics of rebel groups (i.e. group fractionalisation and leadership turnover). This confirmed the robustness of results obtained from the logistic regression models, with the exception of two results (for new entrants, which was found to be important in the logistic regression models but not in the CART analysis, and leadership turnover, which had explanatory power in the CART analysis but was not found to be statistically significant in the logistic regression models). The CART for inter-rebel violence showed that the most important predictors of rebel group fighting (in order of importance) were strong rebels (i.e. groups that are militarily large relative to their peers), ideology and the organisational characteristics of rebel groups (i.e. leadership turnover and group fractionalisation). This confirmed the robustness of results obtained from the logistic regression models, with the exception of two results (for weak rebels and new entrants, which were statistically significant in the logistic regression models but not in the CART analysis).

Theories of rebel group interactions (discussed and tested in Chapters I – III) assume that rebel groups interact to avoid elimination, to maximise their chance of victory or to increase their bargaining power against the state. But previous empirical studies have not established whether groups who adopt interaction strategies do indeed have improved prospects in civil war (such as avoiding early elimination or achieving a decisive victory against the state). Chapter IV addressed this gap in the literature by examining the effect of alliance formation and inter-rebel violence on rebel group survival and termination-type.

Results from Chapter IV suggest that interaction strategies have no effect on rebel group survival. Put differently, rebel groups who interact have the same hazard of termination as groups who operate independently for the entire duration of war. One explanation for this effect could be that rebel groups adopt interaction strategies out of desperation, as a matter of last resort. In these instances, gaining strategic advantages may not be possible if the interactions were not initiated early enough to ensure their survival. An alternative explanation might be that rebel groups who increase their capacity as a result of interacting with their peers may simply become more heavily targeted by the state as a result of their increased size. But, if rebels are able to strike alliances early on, so that cooperation is maintained over a number of years, results show that groups are more likely to achieve favourable conflict outcomes. Rebel groups who form durable alliances are less likely to suffer defeat, they are less likely to concede to peace settlements and they are more likely to achieve decisive war outcomes (i.e. avoid the outcome of ongoing conflict).

Results from Chapter IV also show that rebel groups who engage in inter-rebel violence are more likely to terminate by peace agreement. This might occur because the targets of non-state violence become pressured into accepting peace deals out of fear of being eliminated by another group, whereas the initiators of non-state violence may be offered sweeter deals by the state as a result of their large capacity. These results have several implications for policies regarding conflict resolution. Firstly, states could maximise the likelihood of peaceful resolution by capitalising on opportune moments for offering negotiated deals. If there is some expectation that rebel groups might form alliances (for example if the groups share the same identity or if there are a number of groups who are militarily weak relative to their peers), then states have a higher chance achieving peaceful resolution if negotiations take place before a group is able to increase its bargaining power by aligning with its peers. If violent conflict breaks out between rebel groups, the state may also benefit from offering peace deals, instead of waiting for the groups to eliminate one another.

The empirical contributions reviewed in Chapter I, and the analyses presented in Chapters II – IV, all used statistical modelling methods to test theories relating to rebel group interactions in multi-party civil wars. The main issue with these approaches is that they do not provide any information regarding the underlying mechanisms of the phenomenon under study. Chapter V set out to address this issue by investigating the potential uses of ordinary differential equation (ODE) modelling and agent-based simulation (ABM) for the modelling of rebel group interactions. The advantage of these methods, compared to the statistical modelling methods used in Chapters II – IV, is that the generative mechanisms underlying certain macro-level conflict outcomes are specified in the models. This means that if the model outcomes can be validated using empirical data, then information can be gained regarding the possible underlying mechanisms responsible for those effects.

The simulations performed in Chapter V were based on the expression described by Christia (2012), who suggests that civil conflict processes can be modelled using the metric of 'relative power' between two sides (i.e. the state and a rebel group). General models of two-sided conflict were developed using both ODE modelling and ABM. Various extensions to Christia's expression were investigated, including the optimal definition of relative power, the different mechanisms of two-sided conflict (direct-fire, guerrilla and asymmetric warfare), inclusion of a stochastic element (both to the number of rebel troops and the rebel group killing constant) and inclusion of terms for rebel recruitment and the deployment of government troops. A comparison of ODE modelling and ABM allowed an assessment of the suitability of these two types. ABM was found to be particularly suited to the modelling of guerrilla warfare due to an inherent feature of the ABM programming software, where agents can be programmed to move randomly and collide with other agents. ABM was found to be less suited to the modelling of direct-fire and asymmetric warfare, again because of the nature of ABM programming software, which inherently models a guerrilla warfare mechanism (with a *search* strategy for both sides), instead of a direct-fire mechanism that is required for the modelling of direct-fire and asymmetric warfare.

In the second part of Chapter V, the general model of two-sided conflict was extended so that multi-party conflicts could be simulated. This represents a novel contribution to conflict modelling, since previous ODE models and ABMs have been limited to two-sided conflict. Various aspects were explored including simultaneous conflict between the state and four rebel groups of different initial sizes, varying the rates of rebel group recruitment and government deployment of troops and modelling the two rebel group interaction strategy types, alliance formation and inter-rebel violence. The most important finding emerging from the multi-party conflict simulations was that, in an asymmetric conflict with all rebel groups fighting simultaneously against the state, there is convergence in rebel group sizes over time. This means that if a rebel group forms an alliance, the gains made through increased military capabilities are, in effect, lost because the allied group gets eliminated more quickly by the state, converging to the size they would have originally been had they not aligned. This provides one possible explanation for the empirical result obtained in Chapter IV, which showed that groups who form alliances do not decrease their hazard of termination compared to groups who operate independently.

In summary, Chapter V demonstrated that differential equation modelling and agent-based simulation techniques have great potential for modelling rebel group interactions in multi-party civil wars. The development of the relative power expression proposed by Christia (2012) was found to provide an excellent basis from which multi-party conflicts, and subsequently rebel group interactions, could be simulated. One of the main advantages of using numerical algorithms, such as ODE modelling and ABM, is that the possibilities for extending a general model, once it has been built, are vast. A number of suggestions for possible extensions to the multi-party model were outlined and these add weight to the overall conclusions that ODE modelling and ABM, represent a positive way forward for civil conflict research.

Overall, this thesis has contributed to the civil conflict literature by addressing several gaps in previous research. Two prominent theories regarding the motivations for rebel group interactions have been tested empirically. Novel theory regarding the conditions that influence the interaction decisions made by rebel groups has been developed. Empirical data on rebel group characteristics and civil war dynamics has been analysed using different methods, including statistical modelling methods and machine learning techniques (namely classification and regression trees). The utility of network approaches and of classification and regression trees for future civil conflict research has been demonstrated. The potential use of computer based simulation techniques (such as ODE and ABM) for the modelling of rebel group interactions has also been explored.

Importance of research to current conflicts

The findings presented in this thesis have important implications for the counter-insurgency tactics deployed in current conflicts. In 2014, the UK and US ended their combat operations in Afghanistan after nearly 15 years of military intervention. This intervention was originally initiated in response to concerns regarding the increasing power of the *Taliban*, but it subsequently led to US invasion as a result of the US led 'War on Terror' after the 9/11 attacks in 2001. One of the distinguishing features of the recent bout of conflict in Afghanistan has been the number of UK and US fatalities incurred as a result of routine patrols. For example, the UK armed forces suffered a total of *454* fatalities, of which, *224* (~ *49%*) were killed by improvised explosive devises (IEDs) whilst on patrol (BBC 2015).

The findings presented in Chapter V of this thesis showed that rebels gain huge advantages in asymmetric warfare because the state forces must search for the insurgents before making a kill (in the case of Afghanistan, the *Taliban* were difficult to find because they were dispersed in villages, deserts and mountains), whilst insurgents are able to kill state forces through a direct-fire mechanism (in the case of Afghanistan, the *Taliban* were able to achieve a direct kill by placing IEDs on the routine patrol routes of the UK and US forces). Thus, by conducting routine patrols, the US and UK forces were, in effect, increasing the *Taliban's* direct-fire capabilities.

The main implication of the findings presented in Chapter V is that the state forces must ensure that the direct-fire capabilities of the insurgents are reduced. This could be achieved by removing routine patrols from operations and by minimising the number of troops on the ground; perhaps by replacing troops with intelligence officers and specialised field agents. These discussions demonstrate the importance of intelligence-led operations and the premium that should be placed on intelligence in future conflicts. The advantages associated with asymmetric warfare (highlighted in Chapter V) might also explain the increasing world-wide trend towards the use of suicide-bombers by insurgent and terrorist groups (i.e. suicide bombers are more difficult to locate than troops on the ground, meaning that they represent a more efficient means of violent protest).

The findings of this thesis are also highly relevant to the current conflicts taking place in Iraq and Syria, from which the insurgent group *Islamic State of Iraq and the Levant* (*ISIL*) has formed. Ideology has been a major factor governing the behaviour of *ISIL*, who is an extremist Islamic jihadi group comprised of Sunni Arabs from Iraq and Syria. The group emerged during the Iraq insurgency that ensued as a result of the 2003 invasion of Iraq by Western forces. In 2004, the group (now named *ISIL*) pledged allegiance to the ideologically similar Islamic jihadist group *al-Qaeda* and in 2006, it forged alliances with other Sunni Muslim groups to form the *Mujahedeen Shura Council*. These alliances were forged on the basis of ideological ties, as discussed in Chapters I and II.

But, in the absence of an external threat (i.e. a legitimate Iraqi government and the weakened neighbouring state of Syria), these allied group's started vying for political power and in 2014, *al-Qaeda* cut ties with *ISIL* on the basis of organisational characteristics, citing the failure of *ISIS* to consult and its notorious intransigence (Reuters 2014). *ISIL* has since engaged in combat with a large number of rival groups, successfully gaining control of territory, natural resources and recruits. These dynamics provide further anecdotal evidence in support of the theory proposed in Chapter III.

The main counter-insurgency lessons resulting from the Iraq war and *ISIL* have been well documented; state forces must ensure that a vacuum of stable governance is not left in the aftermath of the removal of state leadership. This could be achieved by establishing elections, installing a democratic government and by providing military training and equipment to the state army. Indeed, the lessons learnt from Iraq and *ISIL* have guided the current counter-insurgency policies being in implemented in Afghanistan by the US and UK.

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Appendix I - Predicting the number of rebel groups in civil wars

The aim of Chapter II was to test the determinants of rebel group interactions. Several different types of statistical models were utilised, one of which was the two-step Heckman selection model. In the first stage of the Heckman selection model, the dependent variable, *multiple groups*, was coded a binary outcome variable (where *0* signified that a rebel group operated in a two-party conflict and *1* signified that a rebel group operated in a multi-party conflict). The variable, *multiple groups*, was coded in this way so that the multi-party conflict observations could be analysed in the second stage of the Heckman selection models. One problem with coding *multiple groups* as a binary variable is that it is only possible to assess the effect that the independent variables have on the *probability* of multi-party conflict. In other words, it is not possible to assess the effect that the independent variables have on the *number* of rebel groups in a conflict. To address this aspect linear regression analysis is employed in this appendix. The dependent variable is:

Number of groups: a continuous variable signifying the number of overlapping groups that are listed in the dataset for each conflict-year.

The same independent variables are used as before (in Chapter II). These are selected on the basis of their association with the likelihood of civil war. If an independent variable is highly associated with an increased likelihood of civil war, it is possible that the same independent variable will also be associated with larger numbers of groups. This argument is based on the notion that if some factor increases the *opportunity* for civil war, it may also increase the opportunity for the numbers of rebel groups. These are coded as follows:

Military quality (expressed as the natural logarithm, ln[military quality]): a proxy for state strength that is widely used and recommended by Bennett and Stam (1996). Military quality is calculated by taking the military expenditure of a country divided by the number of military personnel, transformed by taking the natural log. Data are taken from Lacina (2006). This variable is included because state strength is associated with conflict opportunity. Previous research has shown that poorer states are more likely to experience civil war (Collier 2000, Collier and Hoeffler 2004; 2007, Fearon and Laitin 2003). Thus, if state weakness provides more opportunity for civil conflict, it could be argued that weak states would be more likely to have larger numbers of rebel groups.

Democracy: a continuous variable ranging between *0* and *10*, where *10* signifies that the country is entirely democratic and *0* signifies that the country is entirely undemocratic. Data are taken from Lacina (2006). This variable is included because democracy is also associated with conflict opportunity. Hegre *et al.* (2001) have shown that mixed regimes, which are neither fully democratic, nor extremely repressive, are most likely to experience internal conflict. This argument is based on the notion that highly authoritarian states are less likely to experience civil war because potential rebels are less likely to mobilise when they perceive the cost of group formation to be high. Highly democratic states are also less likely to experience civil conflict because they have institutionalised channels through which opposition groups can be accommodated (Tilly, 1978). In the middle of the range however, where regimes are not repressive enough to prevent mobilisation but also not accommodative enough to channel opposition through institutional mechanisms, conflict is most likely (Muller and Weede 1990; Hegre *et al*. 2001; Fearon and Laitin 2003). Thus, if intermediate levels of democracy are associated with increased opportunity for conflict, it could be argued that these states will be prone to conflicts with higher numbers of rebel groups.

Ethnic fractionalisation: coded as before. The association between ethnic heterogeneity (either polarisation or fractionalisation) and the likelihood of civil war has been an area of hot debate. Polarisation occurs when a society is divided into a small number of large groups, whereas fractionalisation occurs when a society is divided into a large number of small groups. Some research has shown that the likelihood of civil war is increased when states are highly ethnically fractionalised, but not when they are ethnically polarised (Collier and Hoeffler 2004). Other research has shown that the relationship between ethnic fractionalisation and the likelihood of civil war is weak, but that civil war is most likely when societies are highly ethnically polarised (Garcia-Montalvo and Reynal-Querol 2004; Østby 2008). The rationale behind these arguments is that heterogeneous societies, which are divided along ethnic lines, are more prone to grievances arising between groups. In turn, these grievances increase the likelihood of war. If ethnic heterogeneity increases the likelihood of war, it could also be argued that it increases the numbers of rebel groups that are motivated to participate in war.

Results of the linear regression analysis are shown in Table AI.1. The coefficients for all three independent variables are statistically significant at the *<0.01* level. Predicted values for these relationships are plotted in Figures AI.1 – AI.3. These were generated using the **margins** and **marginsplot** commands in STATA.

The coefficient for *ln[military quality]* is negative, indicating that weaker states encounter conflicts involving larger numbers of rebel groups. This result is in-line with the expectation detailed above, although the causality of this effect is ambiguous (as noted in Chapter II). The presence of a weak state could encourage more rebel groups to engage in conflict in the first place, or alternatively the presence of multiple groups could mean that the state is weakened more than if it was fighting a single rebel group.

The coefficient for *democracy index* is also negative, indicating that higher levels of democracy are associated with lower numbers of rebel groups. This is contrary to the expectation that a curvilinear relationship between *number of groups* and *democracy index* might exist, with the largest numbers of groups occurring at intermediate values of democracy. The standard errors on this result are small, which is indicative of high precision regarding this statistic. In Figure AI.2, the confidence intervals are also small. These aspects suggest that the assumption of a linear relationship between *number of groups* and *democracy index* is correct. This was confirmed by inclusion of the squared term, *democracy index*^{2}, into the model, which was not statistically significant. Although this result is contrary to expectations, the effect is extremely small, as is evident in Figure AI.2. The coefficient for *ethnic fractionalisation* is positive indicating that higher degrees of ethnic diversity in a population are associated with larger number of rebel groups entering into conflict against the state. This is in-line with expectations.

Table AI.1 Linear regression estimates for the number of groups in a conflict

Variable	Coefficient	Standard error
ln [Military quality]	***-0.461*****	*0.043*
Democracy index	***-0.042*****	*0.016*
Ethnic fractionalisation	***1.192*****	*0.190*
Number of obs.	*798*	
F (*3, 794*)	*60.5*	
R^2	*0.18*	

*Note: ** denotes significance at p = ≤ 0.01, * denotes significance at p = ≤ 0.05*

Figure AI.1 Predicted values of number of groups for a range of assumed values of *ln*[military quality] (range = 0:12) generated from linear regression estimates

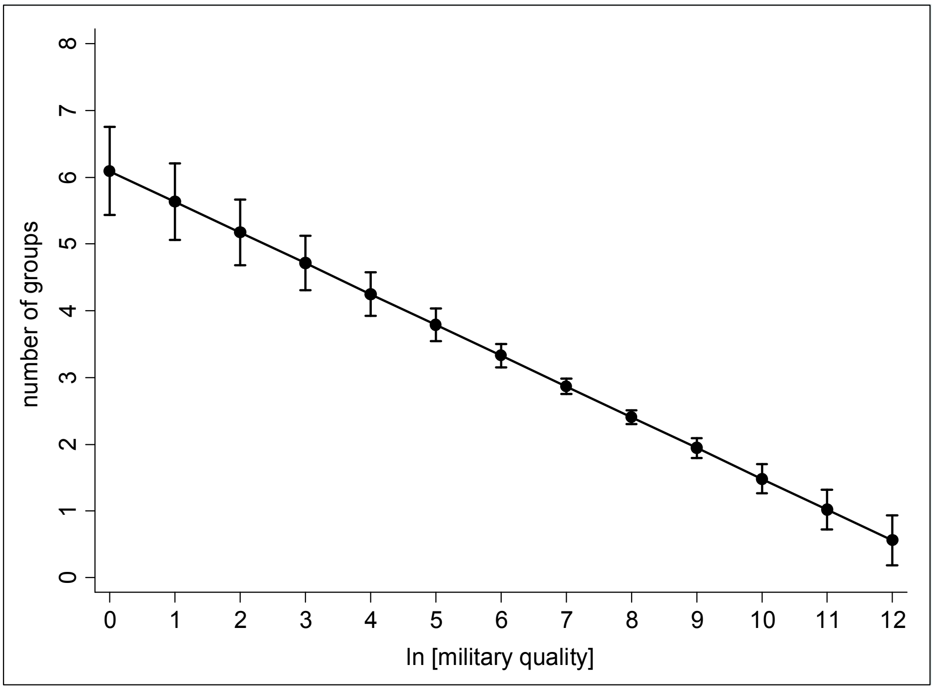


Figure AI.2 Predicted values of number of groups for a range of assumed values of democracy (range = 0:10) generated from linear regression estimates

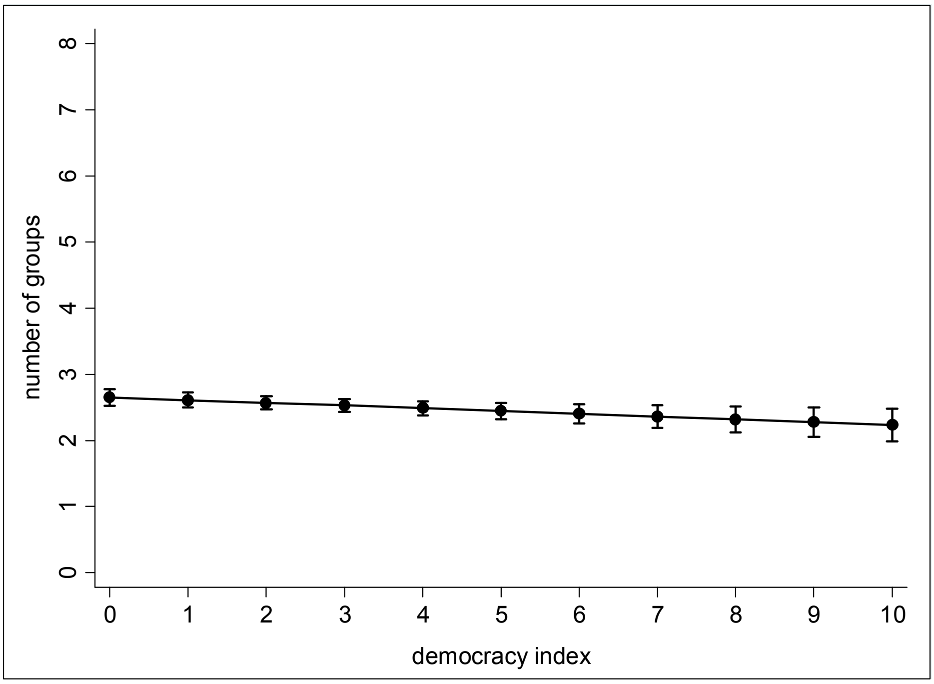
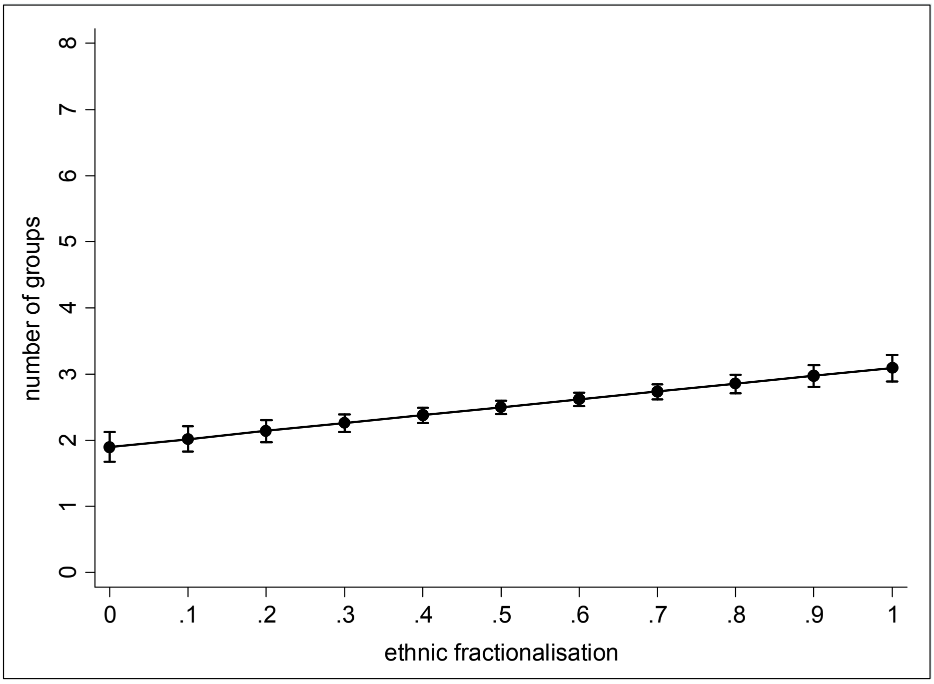
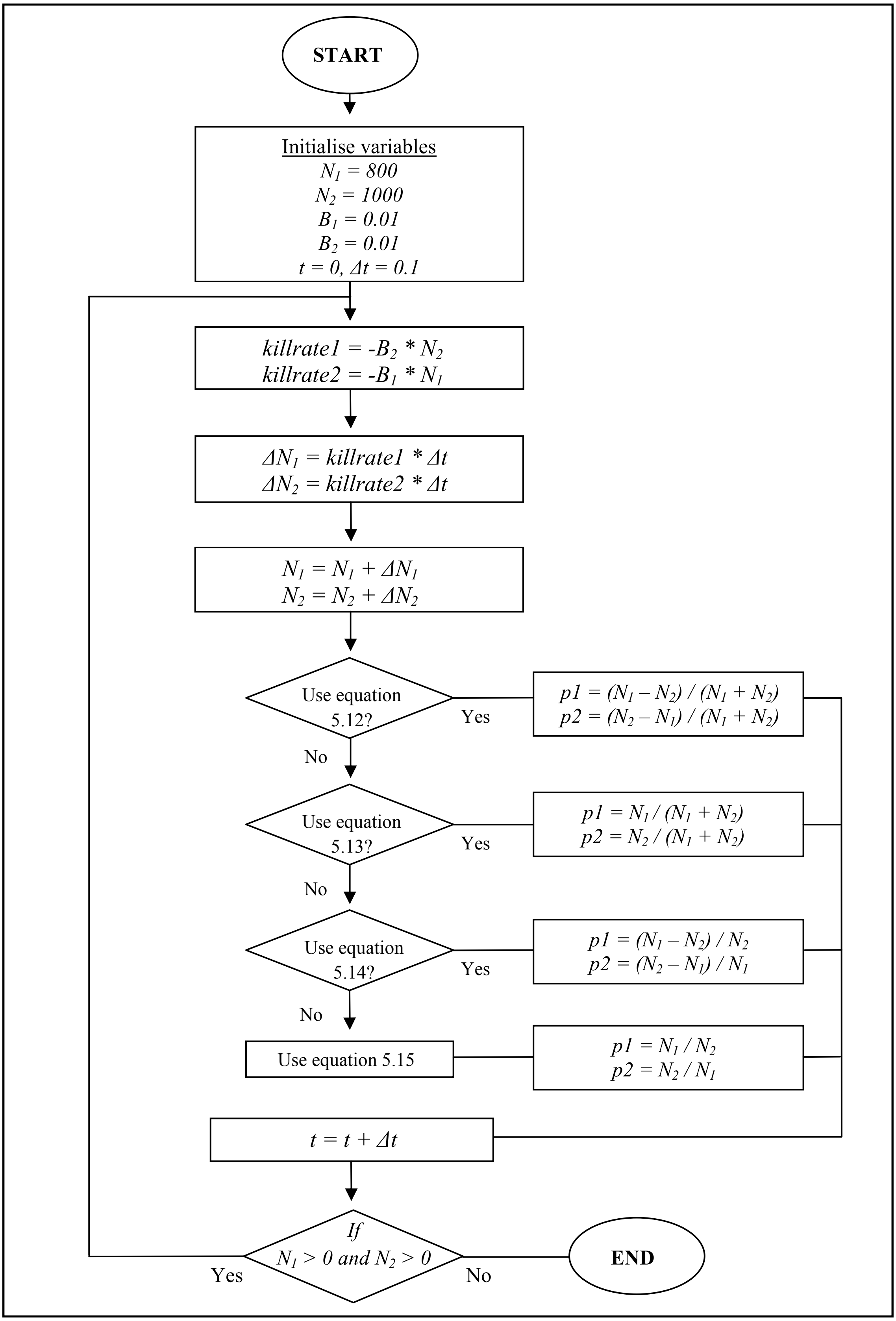


Figure AI.3 Predicted values of number of groups for a range of assumed values of ethnic fractionalisation (range = 0:1) generated from linear regression estimates

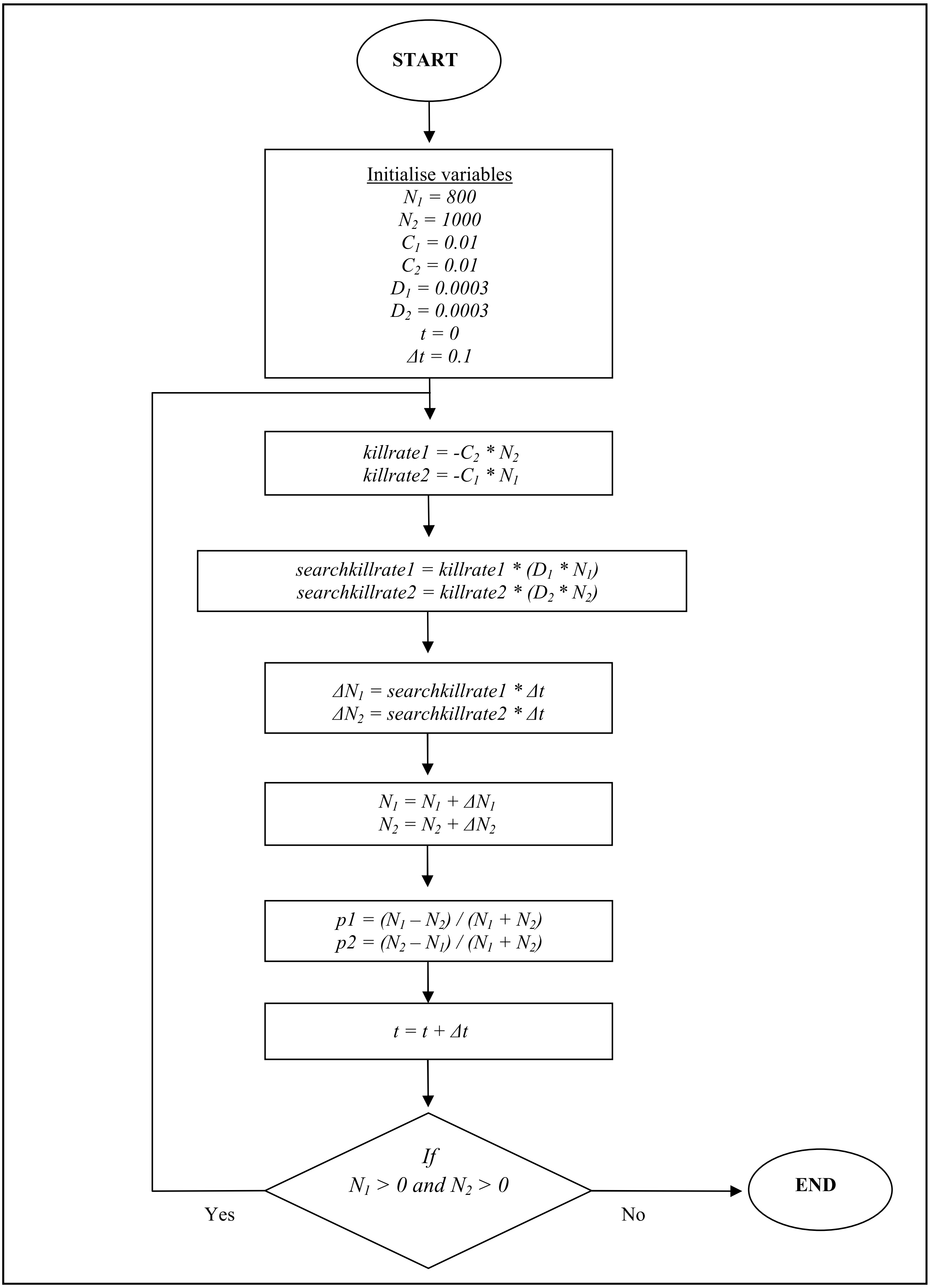


Appendix II - Flow diagrams for computer based simulations

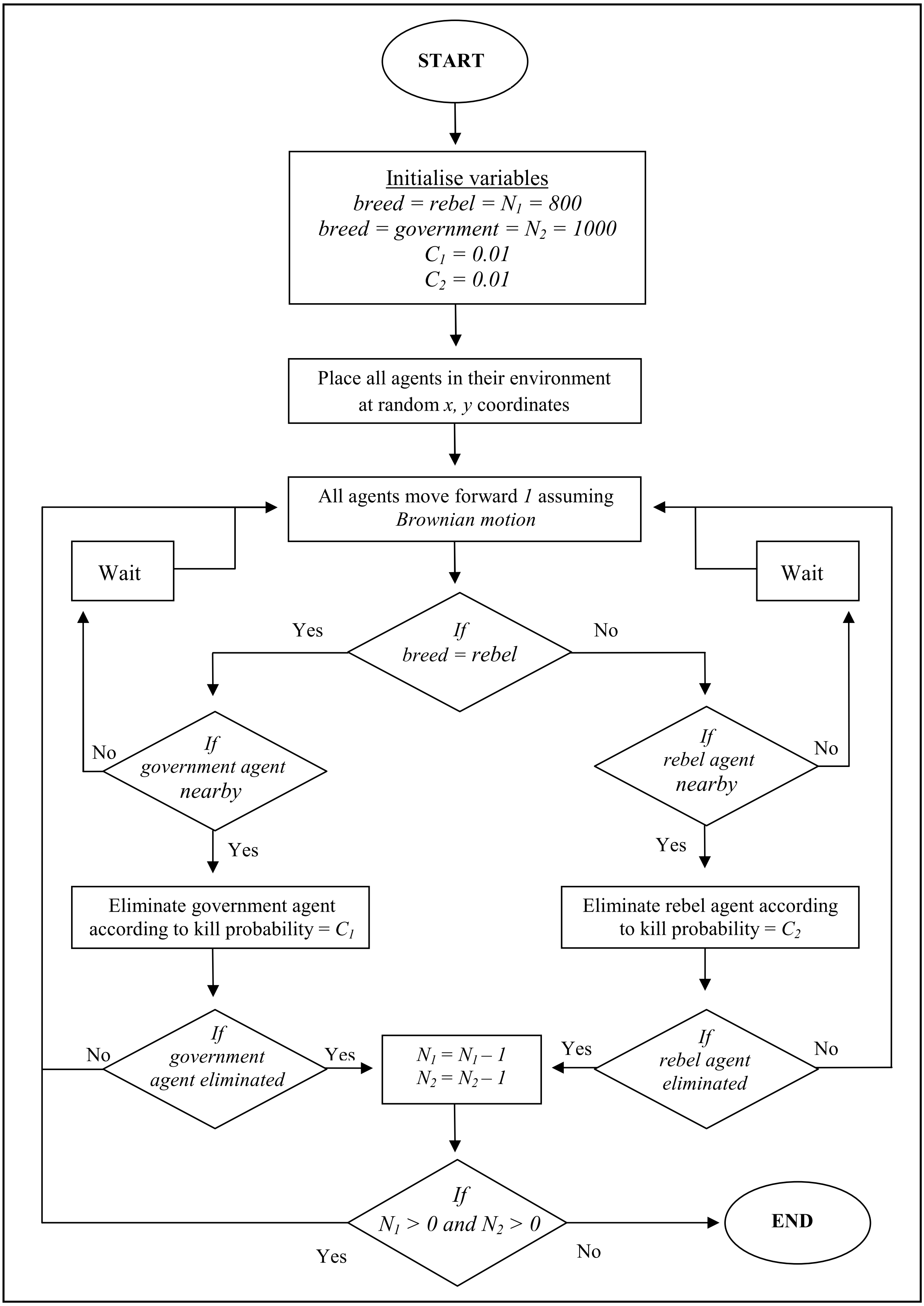
(a) Flow diagram of computational scheme used to generatcfe $p_1(t)$ and $p_2(t)$ values for equations (5.12 – 5.15) plotted in Figures 5.1 – 5.4. The case where $N_1 = 800$ is shown.



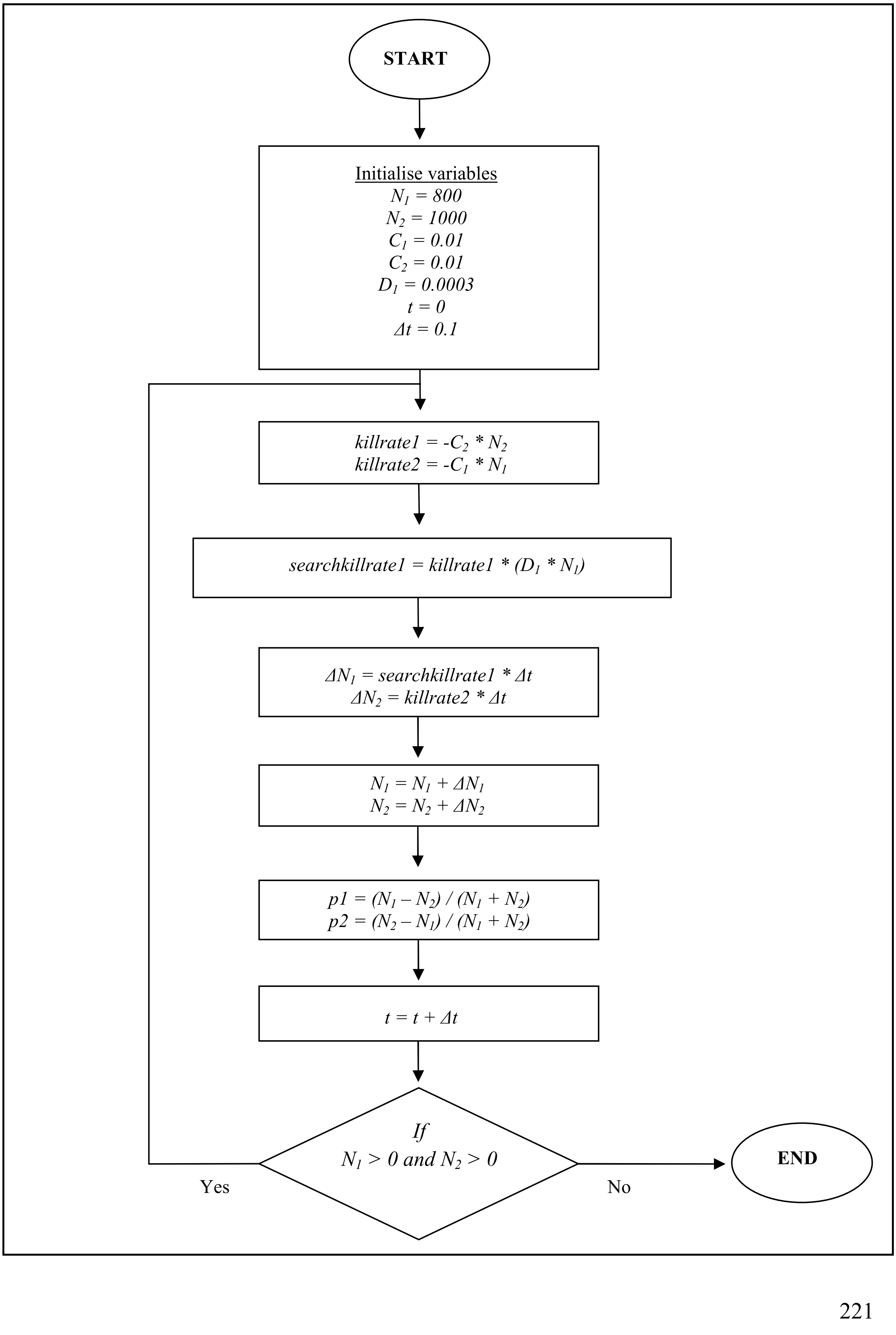
(b) Flow diagram of computational scheme used to generate $p_1(t)$ and $p_2(t)$ values for guerrilla warfare plotted in Figure 5.5. The case where $N_1 = 800$ is shown.



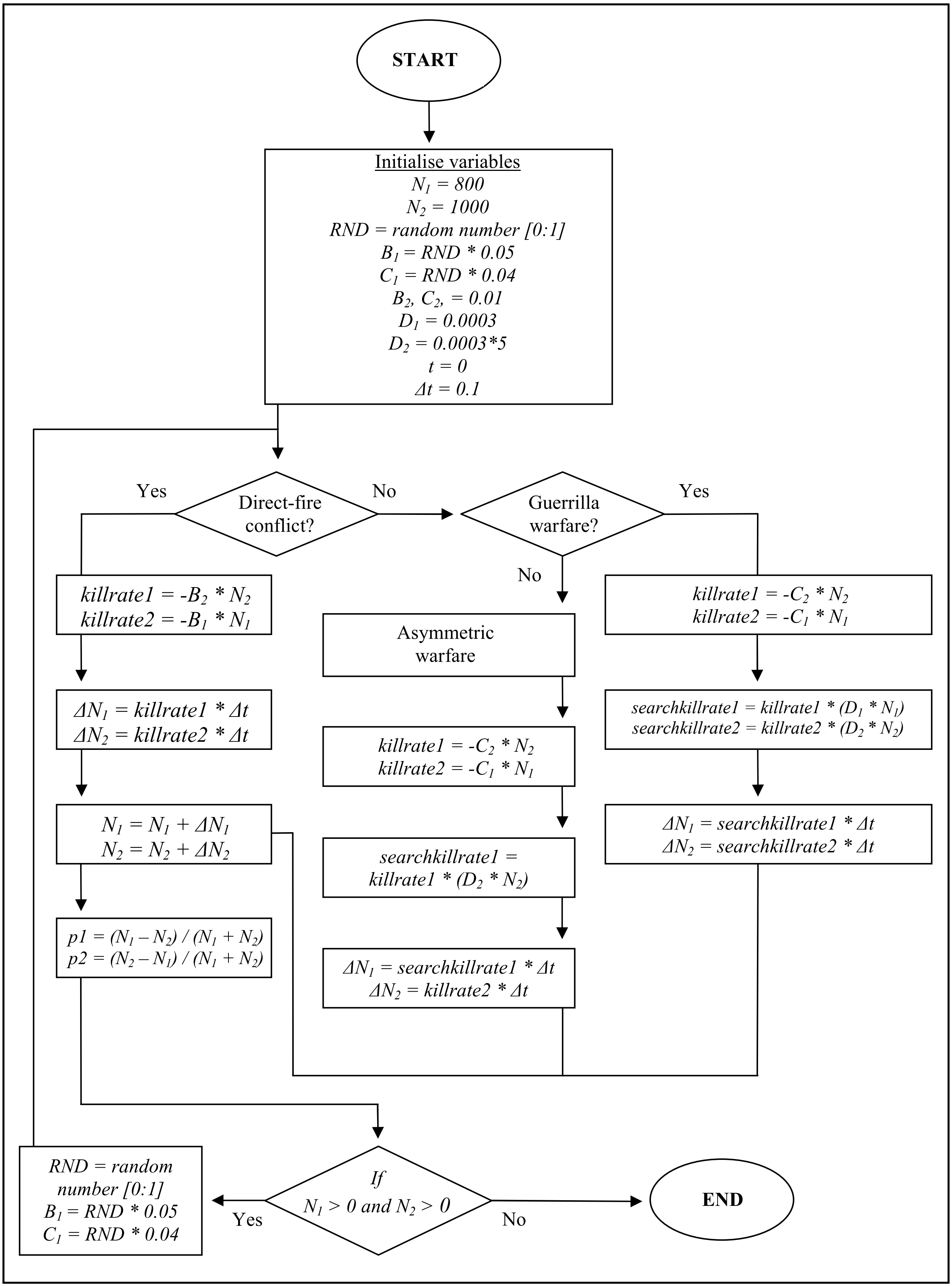
(c) Flow diagram for ABM used to generate $p_1(t)$ and $p_2(t)$ values for guerrilla warfare plotted in Figure 5.6. The case where $N_1 = 800$ is shown.



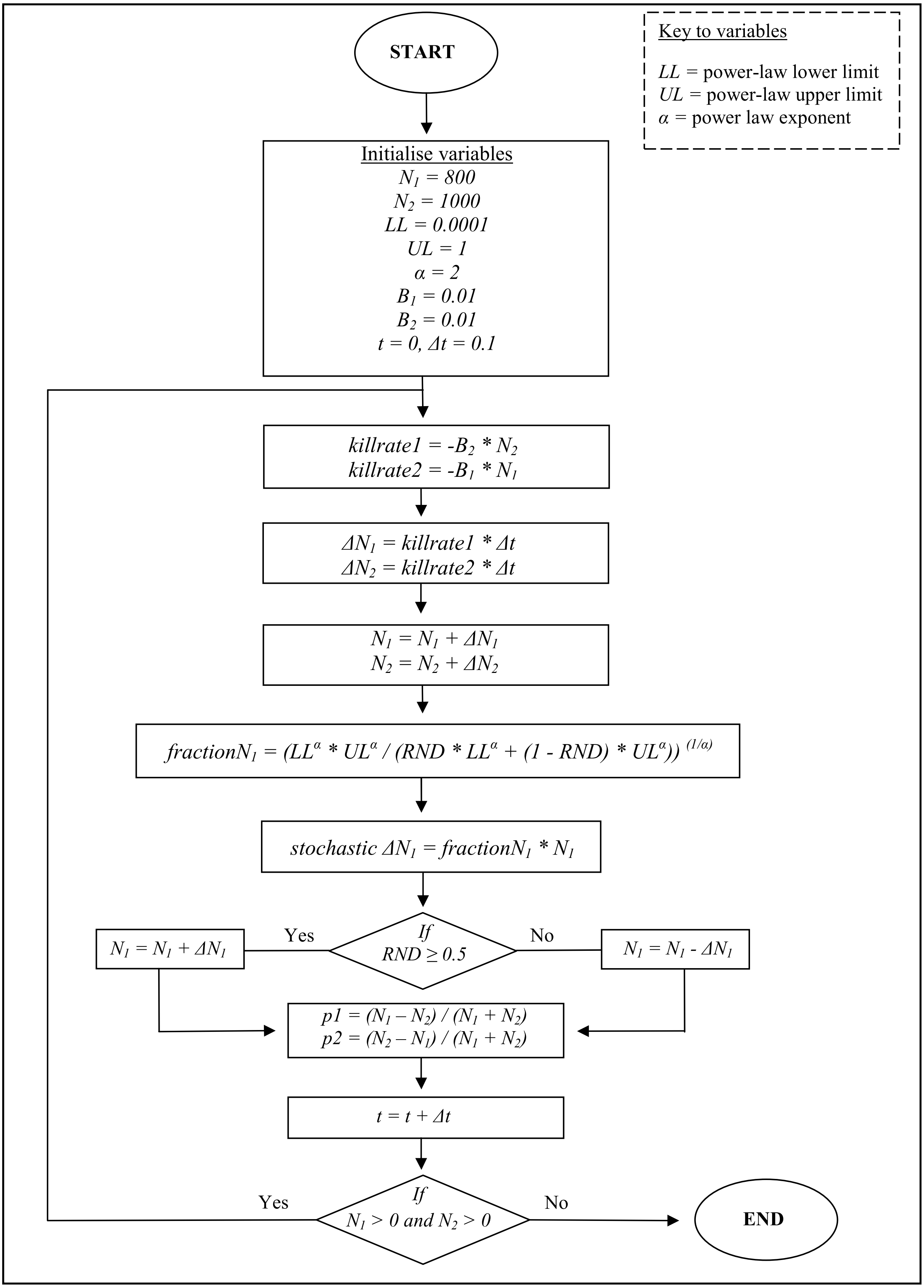
(d) Flow diagram of computational scheme used to generate *$p_1(t)$* and *$p_2(t)$* values for asymmetric warfare plotted in Figure 5.7. The case where *$N_1 = 800$* is shown.



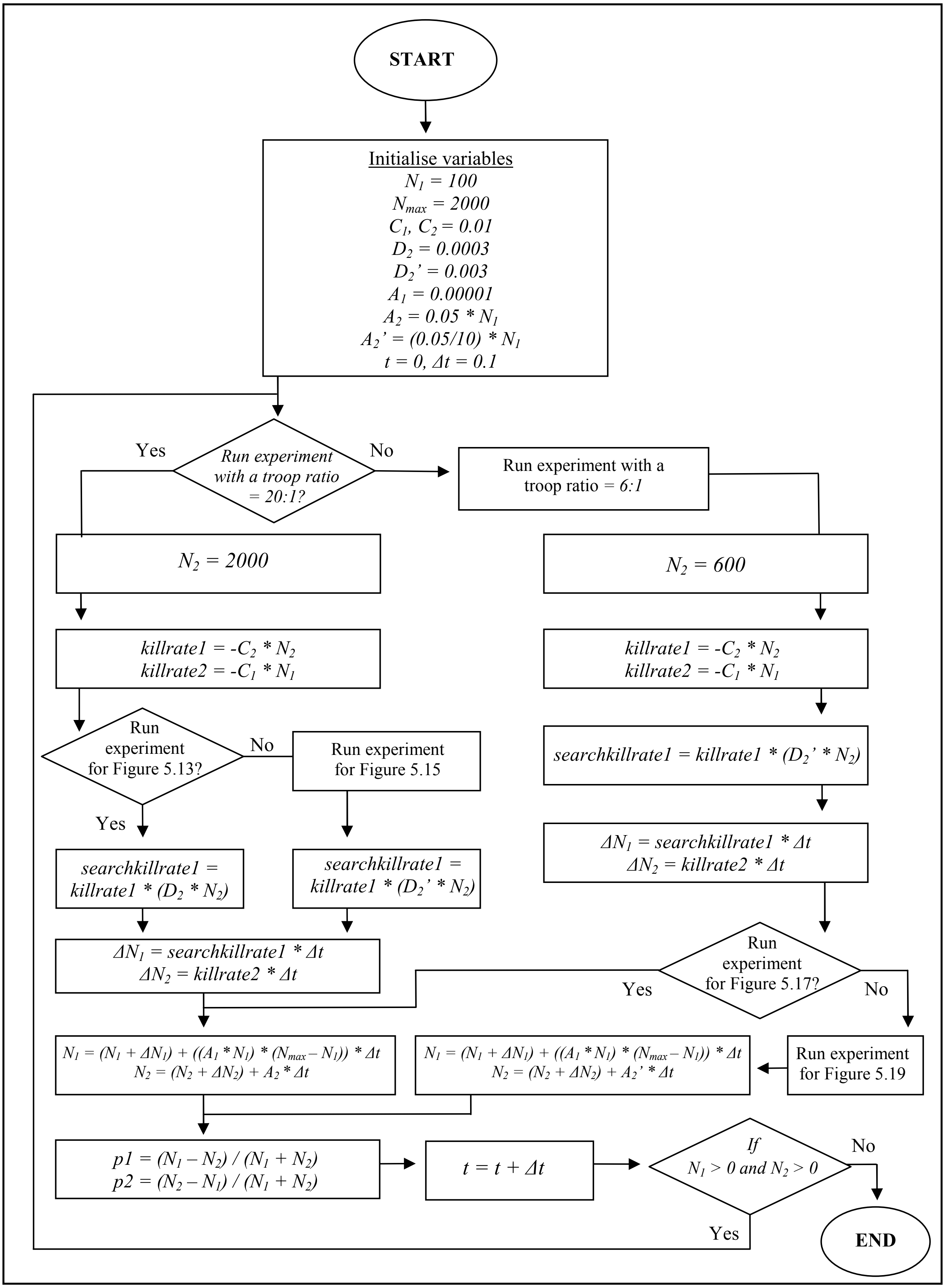
(e) Flow diagram showing the stochastic element applied to the killing probability for all types of conflict (figures 5.9 – 5.11). The case where $N_1 = 800$ is shown.



(f) Flow diagram showing the stochastic element applied to N_1 for direct-fire conflict shown in Figure 5.12. The case where $N_1 = 800$ is shown.



(g) Flow diagram showing the inclusion of terms for rebel recruitment and government deployment shown in Figures 5.13 – 5.20.



Appendix III - Modelling rebel group growth

The growth of a rebel group can be likened to the spread of an infection through a population, such that existing group members (or infected individuals) recruit (or infect) others. Such a process is described by the logistic (or limited growth) equation (Turner *et al.* 1976). The rate of growth of recruited members (*dN/dt*) is described by the equation:

$$\frac{dN}{dt} = A_1(N_{\max} - N)N \tag{AIII.1}$$

where N_{max} is the maximum number in the population available to be recruited and α_1 is a rate constant. In the early stages, when $N << N_{max}$, this equation takes the approximate form: $(dN/dt) \approx A_1 N_{\max} N$, which has the solution: $N = N_0 \exp\,(A_1 N_{\max} t)$, where N_0 is the group size at $t = 0$. This exponential growth continues until the term $(N_{max} - N)$ in equation (AIII.1) becomes increasingly important and the growth rate then decreases, eventually approaching zero as $N \to N_{\max}$. Note that when $N = N_0$ the initial growth rate is $(dN/dt)_0$ $(= \dot{N}_0)$, so that the rate constant can be expressed in the form $A_1 = \dot{N}_0 (N_{\max} - N_0) N_0$ and equation (AIII.1) can then be rearranged to give:

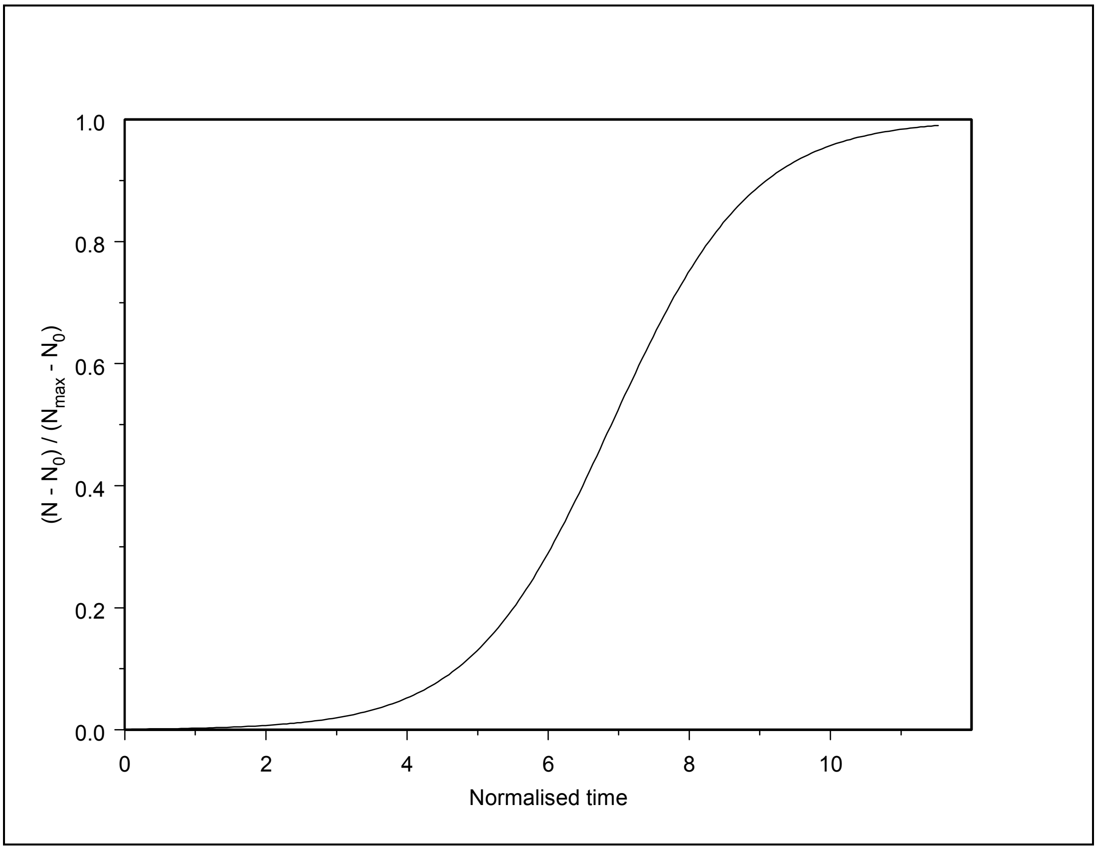
$$\frac{\dot{N}}{N_{\max}} = \frac{\dot{N}_0}{N_0}\left(\frac{1 - N/N_{\max}}{1 - N_0/N_{\max}}\right)\frac{N}{N_{\max}} \tag{AIII.2}$$

The solution of this equation gives the time dependence of the group size as follows (Turner *et al.* 1976):

$$\frac{N(t)}{N_{\max}} = \frac{1}{1 + (\frac{N_{\max}}{N_0} - 1)\exp - \left[\frac{\dot{N}_0 t}{N_0(1 - N_0/N_{\max})}\right]} \tag{AIII.3}$$

This equation represents an S-shaped growth curve and is illustrated in Figure AIII.1. The group size and time are plotted in the normalised forms $(N - N_0)/(N_{\max} - N_0)$ and $(\dot{N}_0 t / N_0)/(1 - N_0/N_{\max})$ respectively.

Figure AIII.1 Group size as a function of time according to equation (AIII.3). The size and time are expressed in the normalised forms as given in the text



Agent-Based Modelling of Group Growth

Agent-based modelling (ABM) can be used as an alternative to the deterministic method described above. The basis of ABM was described earlier in Chapter V. Here the growth of a single rebel group is modelled to reproduce and therefore validate the deterministic method described above. At the onset ($t = 0$), N_{max} agents were programmed to move by random Brownian motion over a two-dimensional surface. Of these agents, a number N_0 carried the attribute ‘recruited’. On collision with a ‘non-recruited’ agent, that agent was allowed to be recruited and therefore gain the attribute ‘recruited’ according to a user-input value of the probability $0 \leq P \leq 1$. The program produced an output of rebel number versus time. A set of growth curves obtained by this ABM are shown in Figure AIII.2 using the values $N_{max} = 1000$ and $N_0 = 50$. The initial rate $\dot{N}_0$ was determined from the average initial rate determined from *15* runs of the program. The value of A_1 was then calculated from the expression given earlier, namely: $A_1 = \dot{N}_0(N_{\max} - N_0)N_0$. The growth curve determined from deterministic methods, reproduced from Figure AIII.1, is shown for comparison. The curves are in good agreement, thus validating the compatibility of the two methods.

Figure AIII.2 Comparison of rebel group growth curves obtained by ABM and those predicted by equation (AIII.3)