Essays on Conflict Economics

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Abstract

This thesis comprises four essays on the economic analysis of conflict, with an emphasis on non-traditional motivation among parties to the conflict. The first chapter surveys the literature on emotions and conflict economics. The second chapter proposes a theory of *peaceability* in conflict. Peaceability captures the willingness of a contenting party to fight and is arguably an important dimension of conflict not previously identified. The third chapter presents a theory of resource use and conflict, in which *blame* is an important motivation for conflict. Finally, the fourth chapter explores incomplete information as a potential source of conflict, wherein a contending party is uncertain about his opponent's true *willingness to fight*.

Declaration

I acknowledge the contribution of my supervisor, Louis Hotte, in chapters 2-4 of this thesis. Those chapters are the product of countless discussions, debates, joint effort and equal contributions by both.

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General Introduction

This thesis comprises four essays on the economic analysis of conflict, with a particular emphasis placed on non-traditional motivation among parties to the conflict. Each of these essays represents a distinct contribution to our understanding of conflict from an economic perspective.

In the first chapter, we consider emotions and aspects from psychology in the economic analysis of conflict. This survey of the literature introduces the economic analysis of conflict and investigates emotions and other psychological aspects from a broader economic perspective. Emotions and other psychological aspects provide explanations for multiple economic phenomena. For instance, notions such as fairness and reciprocity provide explanations for why individuals cooperate. In the economics literature, emotions are also viewed within the context of evolution; i.e., the puzzle of how emotions that run contrary to self-interest can be favoured by natural selection.

We argue that emotions are an under-explored notion in the economic analysis of conflict, one that merits further attention given the potential for emotions to explain how and why conflicts occur. This chapter also introduces some concepts that appear in the subsequent chapters.

In Chapter 2, we consider a situation in which a prize can be apportioned between two players through one of two mechanisms: a peaceful sharing rule or conflict. Players are heterogeneous in three fundamental dimensions: peaceful shares, fighting strengths, and their *peaceabilities*. Peaceability is a measure of a player's psychological predisposition towards conflict.

We characterize all equilibrium types. It is determined that variations in the configuration of the three important dimensions of conflict yields two types of strategic tendency for a player, *opportunistic* or *matching*, and consequently, the game structure is either of the *hawk-dove* or *matching pennies* type. We show that increasing the share of a player, or her fighting strength, can increase or decrease the probability of conflict as it depends on her strategic type. We further show that low peaceability may confer an advantage to a weak fighter, that a generous initial share can be self-defeating and foster a scorched earth tactic, or that a more destructive conflict will foster peace if both players are opportunistic.

Our analysis paints a full-grid picture of the interaction between these three important dimensions in conflict. The analysis contributes to our understanding of the role of asymmetries in conflict and contributes to the broader literature on emotions and other psychological aspects in economics.

In Chapter 3, we consider a situation in which an agreement between two players on the peaceful use of a common property resource can be broken. Given an initial agreement to use the resource cooperatively, the players can choose to respect the agreement or not, and whether to break or maintain the peace, potentially leading to conflict over the gains from the resource.

Here, a player can be punished for his use of the resource through conflict. We allow for the possibility of conflict in which *both* players choose whether or not to punish the other. A punishing player incurs a psychological cost for breaking the peace. The magnitude of this cost depends on a player's intrinsic disinclination to break the peace and on how each player behaved *vis à vis* the agreement and the other player. This cost captures the *blame* a player attributes to the other player and to himself for the breakdown of peace.

We characterize how the potential for conflict through blame-motivated punishment can affect the use of resource, conflict engagement and the resources devoted to conflict. We find that the potential for conflict can lead to the under-use of the resource relative to an efficient agreement. On the other hand, we find that if the players are symmetrically and strongly disinclined to punish (break the peace) this can lead to an inefficient over-use of the resource. And in-between, a moderate symmetric disinclination can lead players to peacefully use the resource as per the agreement. We also investigate interesting cases for asymmetric intrinsic disinclinations.

This chapter contributes to our understanding of cooperation and conflict in the use of common property resources.

In Chapter 4, we explore the role of uncertainty in peace and conflict when players are uncertain about their opponent's true predisposition towards conflict (peaceability). We consider players who are heterogeneous in peaceful shares, fighting strengths and peaceabilities and solve for the Bayesian Nash equilibrium in one-sided and two-sided incomplete information settings. We illustrate two interesting scenarios in which a player has the incentive to misrepresent his true nature to his opponent. Whether a player has the incentive to misrepresent himself as *more* or *less* willing to engage in conflict depends on the configuration of the peaceful shares and fighting strengths. The configuration of peaceful shares and fighting strengths also govern whether increasing the strength of one player increases the likelihood of conflict or has a ambiguous effect.

This chapter contributes to the analysis of incomplete information as an explanation for conflict.

This thesis is structured as follows. In the first chapter, we explore emotions and conflict economics. In Chapter 2, we develop a theory of three-way asymmetries and conflict. In Chapter 3, a theory of resource use and conflict driven by blame is proposed. In Chapter 4, we explore uncertainty over peaceability as a potential source of conflict. We then conclude.

Chapter 1

Emotions and Conflict Economics

1.1 Introduction

When economists consider the role of psychological aspects in economic behaviour, the focus generally centers on *prosocial* behaviour, and more specifically *cooperation*. Admittedly, cooperation and conflict are linked; cooperation can be induced through the threat of punishment (Hirshleifer, 1987). Punishment can be viewed as a form of *one-sided* conflict. What we wish to consider is different; we are interested in situations in which *both* parties can engage in conflict.

The economic analysis of conflict (conflict economics) views appropriation as a fundamental economic activity (Anderton and Carter, 2009). The puzzle is why self-interested parties engage in wasteful conflict rather than agreeing to peaceful settlements that would be preferred by both parties (Fearon, 1995). From this perspective, conflict is viewed as the violent breakdown a bargaining process. "Rationalist theories of war" or so-called "rationalist explanations" offer explanations for this puzzle that are consistent with rational, self-interested behaviour (Fearon, 1995). Multiple economic theories of conflict are consistent with the rationalist approach (Anderton and Carter, 2009). For instance, Hirshleifer (1995) theorizes that sources of conflict reside in *preferences*, *opportunities*, and *perceptions* that reduce or eliminate the possibility of peaceful settlement.

Intuitively, alternative explanations are hidden within emotional dimensions of conflict. It is our position that the economic analysis of conflict would be enriched through further consideration of the potential emotional and psychological motivations for fighting. To investigate, we look to the broader economics literature for a better understanding of how emotions and other psychological aspects affect behaviour. Clearly, this review is not exhaustive. Nor do we delve into the *cognitive* dimensions of conflict. Cognitive psychology and conflict economics are deserving of an investigation of their own. While we touch on notions such as reciprocity and fairness, we focus our attention on emotions.

A common argument found in the economics literature is that emotions are compatible with evolution. This proves puzzling for emotions which induce behaviour that runs contrary to self-interest (Frank 1988; Hirshleifer 1987, 1993; Bowles and Gintis 2003). Hirshleifer (1993) argues that although emotions may be inconsistent with individual self-interest, they are aligned with "evolutionary self-interest" (p. 186).

In the literature, emotions offer explanations for multiple economic phenomena, namely, enforcement problems, cooperative use of the commons, contributions to public goods and other social dilemmas. For instance, cooperation may be viewed as being motivated by emotions (Bowles and Gintis, 2003) or induced through the threat of emotionally-driven punishment (Hirshleifer, 1993).

In some instances, traditional game theoretic tools are not considered suitable to capture some aspects of psychology (Geanakoplos et al., 1989); in which case the framework of *psychological game theory*, developed by Geanakoplos et al. (1989), is adapted.

Hirshleifer (1995) gives consideration to emotions, embodied by other-regarding preferences, as a potential source of conflict (i.e. war, fighting). However, our exploration of the economics literature reveals that emotions and other psychological aspects remain largely under-explored as potential motivations for conflict in which *both* parties can choose to engage. Anger and aggression present two aspects worth consideration. In psychology, "proneness for aggression" is an important variable for explaining violent behavior at the individual level and "proneness for anger" is associated with high aggression in some individuals (Anderson and Bushman, 2002). We believe the role of aggression, anger, and other notions from psychology in economic analysis of conflict warrant further investigation.

We proceed as follows. The analysis of conflict from an economics perspective is introduced in the next section. In section 1.3, we consider arguments for how emotions can be favoured by natural selection when they run contrary to self-interest. We then examine cooperation in section 1.4 and fairness in section 1.5. In section 1.6, the literature on anger and blame in psychological games are explored. In section 1.7, we discuss the potential for further consideration of emotions in the economic analysis of conflict. Section 1.8 concludes.

1.2 In the shadow of conflict economics

The analysis of conflict in economics departs from traditional economics by allowing for the possibility of costly or imperfect enforcement of property rights (Garfinkel and Skaperdas, 2007). In conflict economics, appropriation is viewed as a fundamental economic activity; self-interested agents engage in appropriation activities as a means of acquiring wealth (Anderton and Carter, 2009).[1] Unlike the activities of production and exchange, appropriation activities do not enlarge total wealth, but rather redistribute wealth, less the portion lost to fighting (Hirshleifer, 2001). Pioneers in the subject include Schelling (1960), Boulding (1962) and Tullock (1974) (Hirshleifer, 2001, as cited on p. 4-5).[2]

A trade-off is implied between production and appropriation activities (Garfinkel and Skaperdas 2007; Skaperdas 1992; Hirshleifer 1995). Conflict itself is modeled as a contest in which parties expend resources on arming in pursuit of winning a contested prize (Garfinkel and Skaperdas, 2007). The resources devoted to fighting are translated into wins or losses

[1] Appropriation is formally defined by Danielsen (1975) as follows; "appropriation involves the taking of goods held by another individual on terms that would not be chosen if both parties were acting freely" (p. 23)

[2] An overview of the recent literature on conflict and appropriation is provided by Garfinkel and Skaperdas (2007).

for each through the "technology of conflict" (Hirshleifer, 1991b). Arming can also be used as a bargaining tool (Garfinkel and Skaperdas, 2007); in which case, bargaining is said to take place "in the shadow of conflict" (Hirshleifer, 1995).

In political science, war is commonly seen as part of a bargaining process. The breakdown of bargaining into risky and costly fighting is puzzling since rational parties have the incentive to locate peaceful settlements preferable to war (Fearon, 1995). "Rationalist theories of war" ("rationalist explanations") aim to resolve this puzzle (Fearon, 1995). Three general mechanisms by which conflict is explained from a rationalist perspective are proposed by Fearon (1995). In the first mechanism, parties have different expectations about the outcome of a fight due to *private information* with incentives to misrepresent. The second mechanism involves *commitment problems*, in which one or more of the bargaining states have the incentive to renege on an agreement. Finally, the third mechanism implicates *indivisibilities* whereby the dispute admits no compromise.[3][4]

In the economic analysis of conflict, multiple sources of conflict are aligned with rationalist explanations (Anderton and Carter, 2009). Here are a few examples. Hirshleifer (1995) considers three potential sources of conflict when parties fail to agree on a peaceful settlement: *preferences* (benevolence or malevolence toward others), *opportunities* (settlement opportunities), and *perceptions* (the perceived motives and incomes in the event of failure to settle). When players bargain in the shadow of conflict, Skaperdas (2006) considers a number of potential sources of conflict, including *advanced commitments to fight*, (such as pre-commitment or preferences (Hirshleifer, 1995)), *indivisibilities*, *incomplete information*, and *forward-looking strategic sources for fighting* (for example, if winning confers strategic gains).

Some examples of these sources of fighting include Baliga and Sjöström (2015), who consider contending parties that make irreversible commitments to challenge to the status

[3]In contrast, Powell (2006) argues that bargaining indivisibilities do not present a distinct mechanism and should instead be seen as a commitment problem.

[4]According to Levy (2011), prospect theory also provides multiple hypotheses with respect to war and peace.

quo endowment, and Gretlein et al. (1996), who examine the choice to engage in conflict when parties hold private information about their relative strength. Garfinkel and Skaperdas (2000) consider strategic gains from war. In that setting, fighting provides the possibility of both immediate rewards and long-term gains in the form of reduced future armament costs and a potentially weakened opponent. Similarly, Jackson and Morelli (2009) analyze strategic armament choices and war, wherein the avoidance of future armament costs is a potential motivation for war.

Fearon (2007) argues that incomplete-information bargaining models and commitment problem models fail to explain important facts about armed conflict. For instance, incomplete information is not a plausible explanation for long-running wars in which no serious offers are made for long periods of time (instead of a rapid exchange of serious offers) (Fearon, 2007). Incorporating aspects from psychology may help explain the occurrence of conflicts. We look to the economics literature on emotions and other aspects from psychology for insights into the potential role of emotions in conflict.

1.3 Passions within economics

An overview of emotions in economic theory are provided by Elster (1998), as well as Loewenstein (2000). Rabin (1998) provides an overview of psychology and economics with attention to biases in judgment.[5]

Elster (1998) explains that there is no general framework for incorporating emotions into economic analysis. Rather, he sees economists as occasionally considering specific emotions to address specific issues. He argues that the consideration of aspects of psychology in economics has focused on *cognition*, to the neglect of emotions. Loewenstein (2000) remarks that there is growing interest in emotion from both economists and psychologists.

According to Loewenstein (2000), important decisions can incite strong emotions, which

[5]Sheremeta (2015) provides an overview of the behavioural dimensions of rent-seeking. Emotions are not considered.

can induce people to engage in extreme behaviour. For instance, Loewenstein (2000) argues that bargaining behaviour is affected by emotions such as anger. Loewenstein explains how a person may be driven to act contrary to their own economic interests by anger against the person with whom they are bargaining. On the other hand, Frank (2008) argues that the moral sentiments of sympathy and empathy are important for understanding why in some circumstances people are willing to trust an individual who has the opportunity to cheat.

Loewenstein (2000) explains that psychologists have focused on *immediate emotions*, and argues that these immediate emotions or more broadly, *visceral factors*, deserve attention from economists. By visceral factors, we mean emotions that motivate behaviour (Loewenstein, 2000). Visceral factors are at times referred to as *the passions* in the literature. The passions (visceral factors) can lead people to act in ways that are contrary to their self-interest (Hirshleifer 1993; Loewenstein 2000).

Hirshleifer (1993) distinguishes the passions from *the affections*, as classes of emotion. The affections refer to *stable* patterns of concern for the well-being of particular others (such as malevolence or benevolence) (Hirshleifer 1993). Whereas, the passions are viewed as *action-dependent*, i.e. dependent on the actions of others (such as anger and gratitude) (Hirshleifer 1987; 1993). According to Hirshleifer, both the passions and the affections can lead people to behave in ways that are contrary to self-interest.[6]

The central "evolutionary puzzle" of emotions or visceral factors is how they can be favoured by natural selection when they run contrary to self-interest. Multiple economic phenomena are examined in the context of this puzzle; let us consider a few examples.

Hirshleifer (1987) argues that emotions such as anger may be selected by evolution because they facilitate cooperation, serving as the "guarantors of commitment to carry out threats and promises" (Hirshleifer, 1987, p. 198). Examining *action-dependent* emotion,

[6] Hirshleifer (1987; 1993) argues that the impacts of the affections can be taken into account (in a utilitarian sense) and so the affections do not necessarily pose a problem for rationality. However, the passions are seen as *action-dependent*, making it difficult to interpret passionate behaviour as rational choice (Hirshleifer, 1987). On the other hand, Frank (1988) reasons that the passions are the outcome of selfish rational calculus, wherein emotions are seen as a stable phenomenon (Konrad, 1990, as cited on p. 1341).

where noncooperative behaviour by one player angers the other, he shows that cooperative behaviour can be induced through the threat of anger-driven punishment.

Friedman and Singh (2009) examine vengeance in the context of the evolutionary puzzle; i.e. how has vengeance survived if acting on vengeance is contrary to one's own material interest. Vengeance is considered in a basic social dilemma setting in which a vengeful player expresses anger towards a defecting player through punishment. They show that the threat of vengeance can induce trust and cooperation.

Frank (1998; 2011) considers sympathy and moral sentiment in light of evolution and self-interest. Frank argues that sympathy and moral sentiment must have been naturally selected because they provide some benefit. Emotions like sympathy may have been selected because they function as self-control devices (Frank, 2011). For instance, sympathy can help people to be patient in repeated social dilemmas; people who are sympathetic to their partners are less likely to impulsively defect, thereby reaping the long-run benefits of cooperation (Frank, 2011).

In short, although emotions may run contrary to individual self-interest, they may have survived because they are consistent with "evolutionary self-interest" (Hirshleifer, 1993, p. 186). A prime example of behaviour that runs contrary to self-interest is cooperation, discussed in the next section. As previously mentioned, the breakdown of cooperation can lead to *one-sided* punishment (a form of conflict).

1.4 Explanations for cooperation

Understanding cooperative behaviour has been an ambition of economists for decades. Cooperation is "an individual behavior that incurs personal costs in order to engage in a joint activity that confers benefits exceeding these costs to other members of one's group" (Bowles and Gintis, 2003, p. 2). Fehr and Gächter (2002) explain that cooperation is puzzling; (costly) punishment can induce cooperation, but no individual has an incentive to punish free riders despite the benefit to the group. Bowles and Gintis (2003) note that the Folk theorem provides an explanation for cooperation in *repeated* games, but the explanation is no longer plausible for large groups. The puzzle of why self-interested individuals cooperate thus remains.

Bowles and Gintis (2003) argue that much of cooperation can be explained by both a predisposition to respond to cooperative behaviour with cooperation and a predisposition to respond to free-riding behaviour with retaliation, which they refer to as *strong reciprocity*.[7] The authors explain that some prosocial emotions, such as shame, guilt, empathy, and sensitivity to social sanction, induce individuals to engage in cooperative behaviour and that others motivate the punishment of norm violators.

Experimental evidence also supports the notion that emotions play an important role in cooperation and punishment. Here are a few important findings. Fehr and Gächter (2002) investigate altruistic punishment as a explanation for cooperation and find evidence that altruistic punishment can induce cooperation. Their findings also indicate that free riding causes strong negative emotions among cooperators. They argue that these emotions are likely the mechanism behind altruistic punishment. Xiao and Houser (2005) explore the expression of negative emotion and costly punishment. They find that constraints on emotion expression can increase the use of costly punishment, and argue that costly punishment might be used as the expression of negative emotions. Cubitt et al. (2017) investigate the link between betrayal aversion and conditional cooperation (i.e. cooperation conditional on cooperation by others) and find a correlation between cooperation preferences, beliefs and betrayal aversion. They speculate that an emotional cost of betrayal could be a characteristic of conditional cooperators.

We turn our attention to the notions of fairness and reciprocity in the next section to

[7] Bowles and Gintis (2003) suggest that explanations of cooperation in other species apply to cooperation in humans but do not provide a complete explanation. These explanations are namely kin-and reciprocal-altruism (Bowles and Gintis, 2003). Altruism via kin selection is otherwise known as kin altruism. Kin selection considers the role relatives play when evaluating the genetic fitness of a given individual (Encyclopaedia Britannica, 2018). Reciprocal altruism is the exchange of altruistic acts (suffering a cost to confer a benefit) between individuals so as to produce a net benefit on both sides (Trivers, 2006).

further explore the psychological aspects of punishment.

1.5 Fairness and reciprocity

Actions that promote fairness are sometimes consistent with the pursuit of individual self-interest, sometimes not. (Frank, 2008)

Fairness is the notion that "people like to help those who are helping them, and to hurt those who are hurting them" (Rabin, 1993, p. 1281). Fairness is otherwise known as reciprocity; "people are reciprocal if they reward kind actions and punish unkind ones" (Falk and Fischbacher, 2006). Responding to kind actions with kindness is commonly referred to as *positive reciprocity* and to unkind actions with punishment as *negative reciprocity.* Negative reciprocity can be viewed as a form of *one-sided* conflict.[8]

In order to respond in kind to an action, the kindness of that action must be evaluated (Falk and Fischbacher, 2006). Intentions, as well as the consequences of an action are important for evaluating kindness (Falk and Fischbacher, 2006). For instance, Falk et al. (2003) consider the importance of intentions when examining fairness, spite, and reputation formation as potential sources of conflict in variations of a simple ultimatum game. They find that fairness can motivate conflict, wherein negative reciprocity (conflict) can be triggered by the perception of being treated unfairly.[9]

Fairness can help to explain the "puzzle of the commons"; a puzzle involving the cooperative use of a common resource. The puzzle stems from the *tragedy of the commons* (Hardin, 1968), in which the excess appropriation of resources used in common is consistent with individual rational, self-interested behaviour (Falk et al., 2001). However, empirical findings show that sanctioning can improve the prospect for the cooperative use of the resources (Falk

[8]Retaliation as reciprocity is distinct from *spite* (another important source of conflict), the latter being motivated by a desire to harm that is independent of perceived fairness (Falk et al., 2003)

[9]In contrast, Pillutla and Murnighan (1996) found that anger was a better explanation for rejection of offers than perceptions of unfairness when examining anger, spite and fairness experimentally.

et al., 2001). Falk et al. (2001) argue that these findings are surprising because sanctioning is costly and therefore inconsistent with rational, self-interested behaviour. They suggest that the puzzle can be explained by allowing for informal sanctions to be motivated by reciprocity. In their model, reciprocally-motivated players (informally) sanction self-interested players, leading to less appropriation.

Rabin (1993) and Dufwenberg and Kirchsteiger (2004) formally analyze fairness within the framework of *psychological game theory*. To capture aspects of fairness, Rabin (1993) allows for belief-dependent motivations in which a player "cares not only about his own payoff, but depending on [the other player]'s motives, he cares also about [the other player]'s payoff" (p. 1285). Building on this analysis, Dufwenberg and Kirchsteiger (2004) develop a theory of sequential reciprocity to focus on reciprocal motivation in extensive games.

The framework of psychological game theory is discussed further in the next section.

1.6 Anger and psychological games

The emotion of anger attributes blame to others (Tedeschi and Felson, 1994). This attribution of blame depends on the perception of an offender's actions, and "whether [those] actions are perceived as intentional and malevolent or foreseeable and controllable" (Tedeschi and Felson, 1994, p. 248). The behaviour of the offender is evaluated according to expectations about how people should behave in order to determine whether the offender is blameworthy. A person who blames the offender may become angry and believe that the offender should be punished (Tedeschi and Felson, 1994).

Multiple enforcement problems can be explained by taking into account how people assign blame (Akerlof, 2016). In a theory of rule compliance, Akerlof (2016) explores notions of anger and blame, wherein anger over noncompliance depends on expectations about whether a "reasonable" person would comply. A "reasonable" person is someone who suffers a personal cost from not complying. If a "reasonable" person is expected to comply, then a failure to comply leads to anger and punishment. While Akerlof does not directly consider the role of intentions in what is considered to be reasonable, we can imagine that a "reasonable" player has good *intentions* (i.e. intends to comply with the rule).

A link between anger and unfairness is drawn by Rotemberg (2008). Looking at consumers' reactions to prices, Rotemberg supposes anger can be triggered as a reaction to prices that are perceived as unfair.

Traditional game theory may not be appropriate for analyzing the role of emotions such as anger and blame. Rather, the framework of psychological game theory, developed by Geanakoplos et al. (1989) and generalized by Battigalli and Dufwenberg (2009), is better adapted to handle aspects from psychology, particularly those that are *intention-based* (Attanasi and Nagel, 2008). In *psychological games*, payoffs depend on actions as well as on beliefs (Battigalli and Dufwenberg, 2009). A player's *hierarchy of beliefs* encompass "what [a player] thinks will happen, ... what he thinks each other player thinks will happen, and so on" (Geanakoplos et al., 1989, p. 61). The framework is adapted in settings in which motivations are *belief-dependent*; examples include Rabin (1993), Dufwenberg and Kirchsteiger (2004), Battigalli and Dufwenberg (2007), Çelen et al. (2017) and Battigalli et al. (2015). Furthermore, predictions from psychological game theory are supported by experimental evidence (Attanasi and Nagel, 2008).

Blame and aggression as expressions of frustration and anger are explored by Battigalli et al. (2015). In their approach, a player becomes "frustrated when they get less material rewards than expected" and then "hostile towards whomever they blame" (Battigalli et al., 2015, p.1). The authors' notions of frustration and anger are *belief-dependent* and so psychological game theory provides a suitable framework. Three distinct forms of anger are considered, simple anger, in which players become hostile when frustrated, anger from blaming behavior and anger from blaming intentions. The notion of blame is also explored by Çelen et al. (2017). In their notion of blame "a player puts himself in the other player's position and asks what he would do, and what beliefs he would hold, if he were in that position" (Çelen et al., 2017, p. 6). A similar notion, guilt, is analyzed by Battigalli and Dufwenberg (2007). Guilt depends on how much a player let another player down, and may also depend on the other players' beliefs about how much a player believes he let the other down (Battigalli and Dufwenberg, 2007).

We have now investigated the economic analysis of conflict and notions from psychology in the broader economics literature. This review has obviously not been exhaustive. Moreover, we focused mainly on emotional rather than cognitive aspects from psychology, the latter deserving of its own investigation. We briefly explore the emotion of anger and aggression behaviour, two intuitively important aspects of conflict, in the discussion that follows.

1.7 Discussion

Our examination of emotions and other aspects from psychology in the economics literature provides insights into the potential role of emotions in conflict. While significant attention has focused on emotions or other aspects from psychology in *one-sided* punishment or retaliation, surprisingly little attention has been directed at the role of emotions in conflict in which *both* parties can engage (i.e. fighting, war). Emotional aspects may motivate behaviour in this form of conflict as well; emotional motivations hide potential explanations for why conflict occurs when engaging in conflict runs contrary to self-interest.

Intuitively, aggression and anger are important aspects of conflict. We think of an aggressive person as someone who is prone to engage in conflict, and perceive an angry person as more likely to become violent than a calm person.

In the psychology literature, "aggression is any form of behaviour directed toward the goal of harming or injuring another living being who is motivated to avoid such treatment" (Baron and Richardson, 1994, p. 7). Violence is a severe form of aggression (Anderson and Bushman, 2002). According to Anderson and Bushman (2002), certain traits are associated with a predisposition towards high aggression, and aggressive tendencies differ for men and women. They also explain that beliefs, and various situational factors, such as frustration, provocation and aggressive cues (guns, for example), influence aggressive behavior.

The emotion of anger is closely related to aggression; anger can be seen as a route to aggression, one that may or may not lead to actual harm or violence (Anderson and Bushman, 2002). Anderson and Bushman (2002) propose that aggressive behaviour is influenced through the routes of cognition, affect, and arousal in their general aggression model (GAM).[10] Similarly, according to Berkowitz, the experience of anger may evoke or facilitate aggression but only indirectly affects behaviour (Tedeschi and Felson, 1994, as cited on p. 52). One can easily think of certain individuals who are especially quick to become angry, some of whom are more bark than bite.

Proneness for aggression (aggression-proneness) is an individual characteristic that facilitates aggressive behaviour (Anderson and Bushman, 2002). We can think of this characteristic as describing an individual's *stable* predisposition towards aggression or their aggressive tendency. The role of this characteristic in conflict is intuitively worth investigating from an economics perspective. For instance, contrary to the popular notion that men are more aggressive than women, Dube and Harish (2017) found that historically, queen-led European kingdoms and states participated in more wars than those led by a king.

Proneness for anger represents another individual characteristic potentially worth investigation in the economic analysis of conflict. Some individuals are prone to anger and highly aggressive in specific circumstances (Anderson and Bushman, 2002). In a conflict setting, the emotional volatility of contending parties could play an important role.

Elster (1998) explains that when modeling emotion as psychic costs or benefits in the utility function, the relevant aspect of emotions is their *valence*. In psychology, *valence* locates emotions on a pain-pleasure scale (Elster, 1998). The emotion of anger is negatively-

[10] Affect is a display of mood or emotion and *negative* affect includes, for example, fear and anger (Hughes, 2018). Arousal is a psychological and physiological state associated with increased wakefulness, excitement and/or activation (Cohen, 2018).

valenced (Wrzus and Luong, 2016), so we might expect anger to take the form of a psychic cost in utility - bearing in mind that the emotional experience of anger may depend on actions or beliefs.

Rick and Loewenstein (2004) distinguish between expected emotions and immediate emotions. Expected emotions are anticipated and experienced *at the outcome* of a decision, whereas immediate emotions are experienced *when the decision is made* (Rick and Loewenstein, 2004). Clearly, whether a specific emotion is anticipated or immediate is important to consider when modeling emotions in conflict.

We also recognize the strategic potential of some emotions in conflict. Evolutionary psychology tells us that emotional expressions are highly informative and that signaling anger can be beneficial (Cosmides and Tooby, 2000). Simply put, anger can be useful in some circumstances. For instance, anger can be useful as a bargaining tactic (Sell et al., 2009) or be used to deter an enemy (Elster, 1998). As previously mentioned, anger can also be used as a commitment device (Frank 1988; Hirshleifer 1987).

Moving forward, aggression and anger are natural starting points from which to consider psychological aspects of conflict. Should traditional game theoretic tools prove unsuitable, the framework of psychological game theory can be adapted.

Finally, a comment on falsifiability is warranted before we conclude. From the perspective of the philosopher Karl Popper, "theories are informative only if they are falsifiable" (Boland, 2003, as cited on p.23). Moreover, according to Joop Klant, a methodologist of economics, variability of parameters implies that a theory is unfalsifiable (Boland, 1997, as cited on p.253). Similarly, one can argue that models of bounded rationality are not falsifiable if changing the bounds can explain any behaviour (Boland, 2003). A theory of conflict that incorporates psychological aspects could face similar arguments.[11]

[11] The importance of falsifiability remains a source of debate among economists. In reference to game theory and mathematical economics, Aumann states most elegantly: "We strive to make statements that, while perhaps not falsifiable, do have some universality, do express some insight of a general nature; we discipline our minds through the medium of the mathematical model; and at their best, our disciplines do

1.8 Conclusion

We have considered emotions (and other notions from psychology) from an economics perspective. In the economics literature, a significant amount of attention has been paid to the argument that emotions must be favoured by evolution. Emotions and notions such as fairness or reciprocity, are viewed as playing a potentially important role in shaping outcomes, and incorporating emotional dimensions can explain some behaviour that runs contrary to self-interest. Notably, the framework of psychological game theory is often adapted in economic analysis that incorporates notions from psychology, such as blame and reciprocity. By allowing for belief-dependent payoffs, this framework is often regarded as more suitable for capturing psychological aspects, particularly when intentions play a crucial role.

We believe that emotions have been under-explored in the analysis of conflict. While some consideration is given to emotions in motivating *one-sided* punishment, less attention has been given to their role when *both* parties can engage. This is surprising, given the intuitive relevance of emotions like anger- or aggressive behaviour- in conflict settings. More so, given the potential for emotional motivations to provide explanations for conflict. We believe that further consideration of the role of emotions (such as anger) and aggression in the economic analysis of conflict is warranted. The incorporation of emotional components into the theory could offer important insights into why and how conflicts occur.

have beauty, simplicity, force and relevance." (Aumann, 1985, 17).

Chapter 2

Peaceability and Conflict

2.1 Introduction

> If a peaceable man finds himself wearing knuckle-dusters, it is small exoneration that he keeps his hands in his pockets and smiles benignly upon the world. Sooner or later some piously bellicose soul will push him into a fight: then it were better that he had bare knuckles. (Percy 1964)

Barry and Kim are partners in gold prospecting. They agree that if they hit gold, they will share the proceeds 50-50. Barry is 6 foot 2 inches, weighs 200 pounds, and has a quiet nature who doesn't like a fight. Kim is 5 foot 6 inches, weighs 140 pounds, is hot-tempered and so easily gets into a fight.

After six months of prospection, they hit gold in a remote, isolated spot. Each must make a decision: peacefully respect the sharing arrangement or attack the other. This decision must be made before knowing what the other has truly decided.

If both decide to attack, a fight ensues which will most likely be won by Barry. But while Barry may win "materially", he suffers a significant psychological cost from fighting, on top of potential physical harm. As for Kim, he will probably end up with nothing materially, suffer physical harm, but he is not much tormented for having gotten into a fight.

If Kim decides to attack while Barry refrains, Kim keeps the entire gold prize with near certainty while not being very tormented by his aggressive behavior. Barry is left with nothing but he is at least spared the psychological and physical costs of a fight. If, rather, Barry attacks while Kim does not, Barry keeps the entire prize but suffers the psychological cost of his aggressive behavior; Kim is left with nothing and suffers no psychological cost.

What will Kim and Barry do? Share peacefully, fight, or concede? How does the initial sharing arrangement impact on their decisions? For instance, suppose instead that the initial sharing had been set at 75-25 in favor of Kim, say because he supplied the tools and experience. Would this change affect their decisions differently if the players' fighting strengths or mindsets were different? For instance, does this change in sharing values differentially affect the equilibrium if Barry and Kim are both carrying a six-shooter pistol, thus equalizing forces?[1] If so, how and why?

What if Kim had gone prospecting with Don instead? Don differs from Barry mostly by the fact that he is just as hot tempered as Kim.

Explaining why parties engage in wasteful conflict instead of accepting a peaceful sharing arrangement is a central question in conflict analysis. Two well-studied core determinants are the terms of the (peaceful) *sharing arrangement* and the players' *strengths* under conflict. A third determinant that is arguably just as important, but has received less attention in theoretical analysis, is that of a player's psychological (or emotional) predisposition for peace; we refer to this determinant as a player's *peaceability*.[2]

[1]See Umbeck (1981) for an argument about the importance of pistols as strength "equalizers" between gold diggers during the 1848 gold rush in the American west.

[2]A word regarding terminology is warranted here. We use the term *peaceability* because we find that it fits best with the flow of our discussion. We use it according to one definition typically found in dictionaries, such as the following one from Wiktionary: "peaceable. Adjective. Favouring peace rather than conflict; not aggressive, tending to avoid violence (of people, actions etc.)." The term *bellicosity* will sometimes be used, where higher bellicosity is equivalent to lower peaceability. The important point is that this refers to a person's *state of mind* about engaging into conflict which is distinct from the *decision to engage*. In psychology, one encounters the expression *aggression proneness* (Benjamin 2016). In war politics, the terms *hawkish*, *dovish* and *pacifist* are often used. Here, the term *emotional* can be understood as pertaining to *expected emotion* (Rick and Loewenstein, 2004), discussed in Chapter 1.

The idea that emotions should play an important role in explaining conflict was already well recognized by Schelling (1960). The ensuing theoretical literature, however, has mostly concentrated on the emotions of *one* party only, who moreover must respond by a one-sided punishment, as portrayed by Hirshleifer (1987). What we have in mind is different: we wish to account for psychological predispositions on *both* parties, and in situations where *both* parties must decide whether to engage in conflict or not. Consider tensions between nations- the predisposition of *both* leaders likely plays a key role. For instance, a leader's peaceable attitude may only be fruitful when paired against another peaceable leader (Doyle, 1983).

Accounting for the psychological predispositions of both parties when both parties can choose whether or not to engage, contributes to our understanding of peace and conflict by painting a full-grid picture of the *three-way* interactions between an initial Sharing arrangement, Fighting strengths, and the players' Peaceabilities – the *SFP* configuration – under a complete information setting. Indeed, we could not find a game theoretic model of conflict that considered heterogeneity in these three dimensions.

Note that the *SFP* configuration is taken as exogenous to our analysis, i.e., we do not attempt to explain where the initial sharing arrangement or fighting strengths come from and, most crucially for us, what determines peoples' peaceabilities. One can think of this setting as the last stage of a multi-stage game in which the parties have agreed on a sharing arrangement and/or built-up fighting abilities. As for their peaceabilities, they may depend on past actions or be intrinsic to the individuals; we simply take them as given at this stage in order to anticipate their impact on peace and conflict. (More on this below.)

We consider a modified version of a basic conflict model with two players. The players are offered to share a prize according to an exogenous sharing rule. Players can then choose between acting peacefully or engaging into a potential fight. Peaceability is represented by a psychological (fixed) cost of engagement. The fighting technology is such that if a player engages into a fight while the other does not, then the first player collects the entire prize at no physical cost. Based on purely material self-interest, players would therefore always engage into a fight; the fact that they don't can therefore only be due the presence of peaceability. This setting allows us to simply and starkly bring out the role of peaceability in conflict.

We first determine that the configuration of the sharing rule and the players' fighting strengths – the SF configuration – will dictate if a player has a tendency to behave as either of two types: an *opportunist* or a *matcher*. (Borrowing language from the *hawk-dove* game, we refer to a player who plays HAWK against DOVE and DOVE against HAWK as an *opportunist* and a player who matches HAWK against HAWK and DOVE against DOVE as a *matcher*.) How a player actually behaves in strategy depends on her peaceability level; thus the "tendency" qualifier.

We then identify the set of all possible Nash equilibria under complete information in pure and mixed strategies and perform some comparative statics experiments by considering variations in the SFP configuration.

In the absence of peaceability, the unique Nash equilibrium is thus one in which both players engage into a conflict. Conversely, high enough peaceability for both players will induce a unique peaceful equilibrium in which both players accept the sharing rule as a dominant strategy. With lower peaceability, other equilibria emerge. The results reported next are illustrative of the complexity of the interactions in the three dimensions.

We show that, to a weak player, being quite bellicose may be a blessing or a curse. Indeed, a low peaceability may confer a strategic advantage to a weak fighter as it may lead the stronger player to concede the whole prize. In other situations, however, a more bellicose player may induce a confrontation with a stronger fighter and thus make both players worse off.

We also find that being too privileged under the peaceful sharing rule can be self-defeating as it may lead to an equilibrium in which the privileged player ends up conceding everything to the other. This curse is more likely to occur when a player's privilege is combined with a high peaceability or a more destructive conflict.

If the SFP configuration is such that both players behave as opportunists, then the game takes the form of a (asymmetrical) hawk-dove game and therefore admits three different Nash equilibria, one of which in mixed strategies. But in cases where an opportunist is facing a matcher, the game takes the form of a (asymetrical) matching-pennies game and therefore admits a unique Nash equilibrium, in mixed strategies.

In a mixed-strategy Nash equilibrium, an increase in the bellicosity of one player will not always affect the likelihood of a peaceful outcome and payoffs in the same manner. If the SFP configuration is such that the player behaves as an opportunist (matcher), then peace becomes less (more) likely and her expected payoff decreases (increases). When both players behave opportunistically, the likelihood of peace increases if the conflict technology is rendered more destructive; the prediction is ambiguous if one player behaves as a matcher.

As mentioned above, psychology already plays an important role in pioneering work on conflict from Schelling (1960), making use of game theoretical reasoning. The introduction of emotions in more formal theoretical modeling in economics has taken off in the late 1980s. For instance, Hirshleifer (1987) and Frank (1988) used emotions with the aim to explain the presence of human cooperation in one-shot games with an evolutionary perspective.[3] Geanakoplos et al. (1989) more generally introduced the concept of *subgame perfect psychological equilibrium*. This work was accompanied by a flurry of experiments on the role of altruistic punishment as a cooperation-inducing mechanism among humans (Fehr and Gachter 2002; Bowles and Gintis 2011). The emphasis is on one-sided punishment without possible retaliation by the punished.

In psychology, "proneness for aggression" is an important variable used to explain violent behavior at the individual level (Anderson and Bushman 2002). This proneness may be a stable characteristic of the individual (person factors) or depend on past events (situational

[3]Trivers (1971), a biologist, made similar arguments.

factors).[4] Hirshleifer (1993) argues that the distinction is relevant in order to explain co-operation in one-shot games; in his terminology, the *affections* are action-independent and stable over time while the *passions* are action-dependent. Our analysis does not distinguish between the two, and it accounts for *both* parties' psychological predispositions instead of just one.

In the literature on the politics of war, our analysis contributes to Levy (2011;2013), who makes the case that a complete theory of war should consider psychological variables.[5] Indeed, Levy forcefully underscores the role played by the psychological predispositions of political leaders in explaining war. In a way, we incorporate Levy's main argument into the model developed by Powell (2002), which looks at the interactions between the sharing rule and fighting power but ignores the role of psychology.

More generally, our model is closest to that of Gretlein et al. (1996) who similarly analyze a conflict setting in which contenders must choose between either engaging with a fixed cost, or accepting a peaceful sharing rule with the risk of ending up conceding the entire prize. They look at how asymmetries in both players' strengths and the status quo shares interact, while assuming symmetrical fixed costs. In a similar setting, Baliga and Sjostrom (2004;2012) make a forceful case about the importance of fixed cost asymmetries; their analysis, however, posits (the equivalent of) symmetrical status quo shares and fighting strengths. As far as we could tell, no-one has yet considered heterogeneities in the three dimensions; our results show that this is relevant to explain conflict in a model that remains tractable.

A noteworthy recent study in the experimental economics literature is Herbst et al. (2017). They conduct experiments in a laboratory setting where subjects can either accept to share peacefully or engage into conflict. They look at the interactions between peaceful shares and fighting abilities. Although the authors do not explicitly mention the role of

[4]Our model could in fact be construed as a game-theoretical application of the general aggression model (GAM) described in Anderson and Bushman (2002).

[5]In economics, a rational decision-maker is one who maximizes an objective function (which may include psychological costs and benefits) under some constraints. In the cited literature on the politics of war, "rational" behavior corresponds to calculations based on purely material interests and ignores psychological costs. See Fearon (1995) for an excellent treatment on "rationalist explanations for war".

heterogeneities in the subjects' psychological predisposition for conflict, one might assume that their results represent an average over them.

The paper is organized as follows: The game is described in the next section. In section 2.3, we consider the situation in the absence of peaceability. We solve for all possible equilibria under asymmetric SFP configurations in section 2.4 and conduct some comparative experiments in section 2.5. Section 4.4 concludes.

2.2 The game

2.2.1 The general setting

There is a prize of value $V > 0$ to be shared between two players, denoted 1 and 2. The *sharing rule* (exogenously) dictates that player i receives a share s_i, $i \in \{1, 2\}$, of the prize. With $s_1 + s_2 = 1$, this *peaceful outcome* entails no waste and is thus considered Pareto-optimal. The total value of the part received by player i is denoted by $g_i = s_i V$, so that $g_1 + g_2 = V$. We assume throughout that each player is offered a strictly positive part, i.e. $0 < g_i < V, \forall i$. The sharing rule can be represented by either vector $S = (s_1, s_2)$ or $G = (g_1, g_2)$.

Each player has the option to contest the peaceful sharing rule by engaging into a fight for a different share of the prize. If both players opt to fight, then wastage occurs because this entails a combination of fighting (or rent seeking) efforts along with eventual destruction of value. In order to remain as general as possible regarding the fighting technology, we represent the fighting equilibrium with the following reduced form: At the outcome of the fight, player i appropriates a value $f_i = r_i V$, $i \in \{1, 2\}$, with $r_1 + r_2 \leq 1$ and $r_1, r_2 \geq 0$. Fighting costs, wastage and destruction are thus represented by the fact that $r_1 + r_2 < 1$. We will refer to f_i as player i's *fighting power* and vector $F = (f_1, f_2)$ as the *power configuration.*

The players must decide whether to engage into a fight or not.[6] This choice is simulta-

[6]We assume that the decision to engage in conflict is binary. In an alternative setting, one might consider

neous and is represented by $\varepsilon_i \in \{IN, OUT\}$, where IN denotes the choice of engaging and OUT means that the player is not going to fight. The final payoff for player i is denoted $v_i(\varepsilon_i, \varepsilon_j)$.

A player's peaceability is represented as follows: when player i decides to engage, he automatically incurs a psychic cost b_i. The higher the b_i, the higher the psychic cost of engaging and thus the more peaceable is player i. To simplify, we assume that $b_i \geq 0$ such that peaceability is at its lowest when $b_i = 0$.[7]

If both players choose to engage, a *fight* ensues. Conversely, if both decide not to engage, *peace* ensues and the prize is apportioned according to the sharing rule.

The case in which player i engages while player j does not is referred to as a *concession* by player j. Here, only player i incurs the psychic cost. For brevity's sake, we assume that $v_i(IN, OUT) = V - b_i$ and $v_j(IN, OUT) = 0$, i.e., a conceding player yields the entire prize to the other player. While some generality is certainly lost in making this assumption, we believe it is worth the gain in the concise analysis and insights it yields given our primary goal of untangling the three-way interactions between the sharing arrangement, peaceability and strength. The game in reduced form is illustrated in figure 2.1.

		Player 2	
		IN $(HAWK)$	OUT $(DOVE)$
Player 1	IN $(HAWK)$	$f_1 - b_1, f_2 - b_2$	$V - b_1, 0$
	OUT $(DOVE)$	$0, V - b_2$	g_1, g_2

Figure 2.1: The game in reduced form

For expository purposes, we will often refer to a player that chooses IN as a *hawk* and a player that chooses OUT as a *dove*. We however prefer to retain IN and OUT as the real choices because the payoff matrix does not always correspond to that of a hawk-dove game. This will also allow us to make the distinction between acting hawkish and being bellicose.[8]

a non-binary conflict engagement decision similar to *challenging the status quo* in Baliga and Sjöström (2015). We leave this possibility for future work.

[7]A negative value for b_i would correspond to a willingness-to-pay to engage into a fight or hurt the other player. This could occur, for instance, with the presence of hatred against another player, or a desire for revenge. We leave the analysis of this possibility for future work.

[8]The game, as described, can also be thought of as a subgame of a larger game.

Before we characterize the various equilibrium types, the following definitions and concepts will prove useful.

2.2.2 Some definitions and concepts

Definition 1 ***Net gain from engaging (*** NGE ***)*** *Let* $\pi_i(\varepsilon_j)$ *be the gain that player* i *makes from engaging net of the payoff from not engaging. We have* $\pi_i(OUT) = g_j - b_i$ *and* $\pi_i(IN) = f_i - b_i$.

As the analysis will underscore, the NGE is the most fundamental concept for interpreting conflict and peace equilibria. Indeed, while one may be inclined to compare the *final payoffs* from engaging against a hawk versus a dove, such payoffs do not account for the *opportunity cost* of engaging; the NGE does. Player i's NGE is thus conditional on the strategy of player j: if j plays OUT, then the opportunity cost corresponds to forgoing peace; if j plays IN, the opportunity cost is the outcome of a concession.

Definition 2 ***Opportunism*** *Let* O_i *be player* i*'s differential* NGE *when player* j *plays* OUT *versus* IN*. We have* $O_i \equiv \pi_i(OUT) - \pi_i(IN) = g_j - f_i$ *and refer to this value as a measure of player* i*'s opportunistic inclination.*

We call player i *opportunistically inclined* (*opportunistic* for short) when $O_i > 0$, and we refer to *opportunistic behaviour* as a situation in which one will choose to engage against a dove but not a hawk. A necessary condition for opportunistic behavior by player i is $O_i > 0$. Player i will then behave as an opportunist if, and only if, his peaceability level falls within the range $b_i \in (f_i, g_j)$.

When $O_i < 0$, we say that player i is *inclined to match* (*matcher* for short). When $O_i < 0$, player i will opt to fight a hawk but chooses peace against a dove, i.e. *match*, if, and only if, $b_i \in (g_j, f_i)$. Note that this difference in behavior between opportunistically inclined and matching inclined holds even though the final payoff from fighting a dove is always higher than that from fighting a hawk.[9]

It is interesting to note that in contrast with peaceability, opportunism is not entirely intrinsic to a player. Indeed, this behavior rests on the three-way SFP configuration. For instance, given a certain peaceability level b_i, player i may start behaving opportunistically because player j is offered a larger share. In general, there is increased scope for opportunistic behavior by player i whenever O_i increases, which would occur with either of the following changes:

a) f_i decreases because fighting is more destructive generally;

b) f_i decreases because player i is made relatively weaker;

c) g_j increases because player j is offered a larger share under peace.

It is also important to note that there is always scope for opportunism by at least one player while the possibility that both players be inclined to match is precluded by $r_1+r_2 \leq 1$. Matching behavior by i can come about as the result of more strength (higher f_i) or a higher share (higher g_i) under peace.

Definition 3 ***Comparative opportunism*** *Let CO_{ij} be player i's differential opportunism with respect to player j, i.e., $CO_{ij} \equiv O_i - O_j = (g_j - f_i) - (g_i - f_j)$.*

The concept of comparative opportunism will be useful when it comes to perform comparative static experiments.

2.3 The absence of peaceability

We denote the engagement decisions as follows: $\Sigma = (\varepsilon_1, \varepsilon_2)$ where $\varepsilon_i \in \{IN, OUT\}$.

[9] One may be tempted to call the matcher's behavior as equivalent to the *tit-for-tat* strategy (Axelrod 1981). But that would be misleading as the later requires multiple interactions between the players. A matcher's behavior corresponds more closely to the *silver rule* proposed by Hirshleifer (1993), with the distinction that in our case, the behavior is not entirely intrinsic to a player, as discussed next.

Proposition 2.1 *In the absence of peaceability, i.e.,* $b_1 = b_2 = 0$*, the Nash equilibrium (NE) in pure strategies* $\Sigma = (IN, IN)$ *is the unique equilibrium.*

Proof: With the help of figure 2.1, it is straghtforward to verify that IN is a dominant strategy for both players. QED

We thus see that regardless of the sharing rule, players will always engage into a fight when peaceability is negligible.

This underscores the potentially important role of peaceability gradients in inducing peaceful equilibria.

2.4 Asymmetric peaceability

We now consider cases with $b_i \geq 0, \forall i \in \{1, 2\}$. We begin by considering pure strategy equilibria only. Mixed-strategy equilibria will be considered in section 2.4.2.

2.4.1 Pure strategy Nash equilibria

2.4.1.1 Peace equilibria

We refer to an equilibrium where both players accept the sharing rule, i.e. $\Sigma = (OUT, OUT)$, as a *peace equilibrium*. We have the following proposition:

Proposition 2.2 ***Peace as a NE in pure strategies***

The necessary and sufficient conditions for a peace equilibrium in pure strategies are

$$g_j - b_i < 0, \forall i \neq j. \tag{2.1}$$

Proof: i) Sufficiency: We have $v_i(OUT, OUT) = g_i$. We must show that no player can gain by choosing IN while the other player chooses OUT. We have $v_i(IN, OUT) = V - b_i =$

$g_i + g_j - b_i$. With $b_i \geq g_j$, we have $v_i(IN, OUT) \leq v_i(OUT, OUT)$. QED

ii) Necessity: Assume $b_i < g_j$ for some $i \neq j$. Then, for any $b_j \geq 0$, we have $v_i(IN, OUT) = V - b_i = g_i + g_j - b_i$. With $b_i < g_j$, this implies $v_i(IN, OUT) > v_i(OUT, OUT)$. Hence, peace is not a NE in pure strategies. QED

Proposition 2.2 implies the following two corollaries, which we state without proof:

Corollary 2.3 ***On peace and power***

Variations in the fighting power of the players has no effect on the peace equilibrium in pure strategies.

Corollary 2.4 ***On the existence of a peace equilibrium*** *A necessary condition for a peace equilibrium in pure strategies to exist is that the sum of the players' peaceabilities exceed the value of the prize, i.e.,*

$$b_1 + b_2 > V. \tag{2.2}$$

Moreover, there exists a sharing rule that achieves peace with certainty if, and only if, the above inequality holds.

Interpretation: Recall that engaging against a dove leads to a concession in which the dove gives up his entire peaceful share. For player i, engaging against a dove will thus bring the additional material gain g_j, but she will suffer psychic cost b_i. The difference yields the net gain from engaging (NGE) against a dove. If this NGE is negative for both players, then peace is a NE in pure strategies (sufficiency). Moreover, if the NGE is positive for one player when the other plays OUT, then that player will prefer to engage against a dove so that peace cannot be a NE in pure strategies (necessity). The absence of a role for fighting power comes from the fact that a concession involves no fighting.

2.4.1.2 Conflict equilibria

Let us now refer to an equilibrium where both players fight, i.e. $\Sigma = (IN, IN)$, as a *conflict equilibrium.*

Proposition 2.5 ***Conflict as a NE in pure strategies***

The necessary and sufficient conditions for a conflict equilibrium in pure strategies are

$$f_i - b_i \geq 0, \forall i. \tag{2.3}$$

Proof: i) Sufficiency: We have $v_i(IN, IN) = f_i - b_i$. We must show that no player can gain by choosing OUT while the other player chooses IN. We have $v_i(OUT, IN) = 0$. With $b_i \leq f_i$, we have $v_i(OUT, IN) \leq v_i(IN, IN)$. QED

ii) Necessity: Assume that $b_i > f_i$ for some i. Then, for any $b_j \geq 0$, we have $v_i(OUT, IN) = 0$ and $v_i(IN, IN) < 0$. Hence, conflict is not a NE in pure strategies. QED

This yields the following corollary:

Corollary 2.6 ***On conflict and peaceful sharing***

Variations in the peaceful sharing arrangement has no effect on the conflict equilibrium in pure strategies.

Interpretation: Recall that conceding against a hawk yields zero material gain and zero psychic cost. If player i engages against a hawk, she thus gets an additional material gain of f_i and suffers psychic cost b_i. Hence, $f_i - b_i$ denotes the NGE against a hawk. If that value is positive for both, then both players will prefer to engage against a hawk (sufficiency). But if it is negative for one player, then that player prefers to concede (necessity). Moreover, since a concession involves giving up the entire peaceful share, its value has no bearing on the conflict equilibrium in pure strategies.

It is interesting to note that while the unique NE in pure strategies for both peace and conflict depend on the peaceabilities, the one for peace compares peaceabilities with the sharing rule but ignores the fighting strengths, while the one for conflict does the converse by comparing peaceabilities with the fighting strengths but ignores the sharing rule.

2.4.1.3 Concession equilibria

We now look at the third type of NE in pure strategies which is characterized by the fact that one player chooses to engage while the other does not. This is referred to as a *concession equilibrium*.

At this point, it will be necessary to distinguish between two possible situations, one in which $O_i > 0$, $\forall i$, the other in which $O_i > 0$ and $O_j < 0$, $i \neq j$).[10] We have the following proposition:

Proposition 2.7 ***Conceding as a NE in pure strategies***

1) A sufficient condition for a concession equilibrium as a NE in pure strategies is $b_i \geq f_i$ *and* $b_j < g_i$, $i \neq j$.

2) Two opportunistic players ($O_i > 0$, $\forall i$*):*

a) Assume that $b_i > g_j$ *and* $b_j < g_i$. *Then concede by* i *is the unique NE in pure strategies.*

b) Assume that $b_i > f_i$ *and* $b_j < f_j$. *Then concede by* i *is the unique NE in pure strategies.*

3) An opportunistic player facing a matcher ($O_i > 0$ *and* $O_j < 0$, $i \neq j$*):*

a) Assume that $b_i > f_i$ *and* $b_j < g_i$. *Then concede by* i *is the unique NE in pure strategies.*

b) Assume that $b_i < g_j$ *and* $b_j > f_j$. *Then concede by* j *is the unique NE in pure strategies.*

Proofs: Part 1) Take $\varepsilon_i = OUT$ and $\varepsilon_j = IN$. We then have $v_i(OUT, IN) = 0$ and $v_j(OUT, IN) = V - b_j$. We must show that no player can gain by unilaterally deviating. Indeed, we have $v_i(IN, IN) = f_i - b_i < 0$ and $v_j(OUT, OUT) = g_j < V - b_j = g_j + g_i - b_j$. QED

[10] The case with $f_i > g_i$, $\forall i$, is ruled out as it implies that conflict creates value instead of wastage and destruction.

For parts 2 and 3, note that peace and conflict pure strategy equilibria are ruled out by the fact that their respective N&S condition is not respected.

Part 2.a) Assume not. Then $\Sigma = (IN, OUT)$ is the only other admissible NE in pure strategies. We have $v_i(IN, OUT) = V - b_i = g_i + g_j - b_i < v_i(OUT, OUT) = g_i$ since $b_i > g_j$. Hence player i would prefer to play OUT. A contradiction. QED

Part 2.b) Assume not. Then $\Sigma = (IN, OUT)$ is the only other admissible NE in pure strategies. We have $v_j(IN, OUT) = 0 < v_j(IN, IN) = f_j - b_j > 0$. Hence player j would prefer to play IN. A contradiction. QED

Part 3.a) Assume not. Then $\Sigma = (IN, OUT)$ is the only other admissible NE in pure strategies. We have $v_i(IN, OUT) = V - b_i = g_i + g_j - b_i < v_i(OUT, OUT) = g_i$ since $b_i > g_j$. Hence player i would prefer to play OUT. A contradiction. QED

Part 3.b) Assume not. Then $\Sigma = (OUT, IN)$ is the only other admissible NE in pure strategies. We have $v_i(OUT, IN) = 0 < v_i(IN, IN) = f_i - b_i > 0$ since $b_i > g_j$. Hence player i would prefer to play OUT. A contradiction. QED

We have now characterized all NE in pure strategies. These are illustrated in figure 2.2, where the distinction is made between case a) with two opportunistically inclined players and case b) in which player 1 is inclined to match and the other is opportunistically inclined. These two cases lead to distinct, and sometimes opposite, predictions.

2.4.1.4 Case a) Two opportunistic players ($O_i > 0$, $\forall i$)

Recall that $O_i \equiv g_j - f_i$. We therefore have $g_j > f_i; \forall i \neq j$. This case is illustrated in part a) of figure 2.2. The sharing line is defined by equation $g_1 + g_2 = V$ and fighting outcomes must lie below that line because of wastage and destruction.

In accordance with propositions 2.2 to 2.7, we identify five regions in the $b_1 - b_2$ plane characterized by their different conflict outcomes. In the *peace* region, the players' peaceability levels are such that both accept the sharing rule. In the *conflict* region, on the other

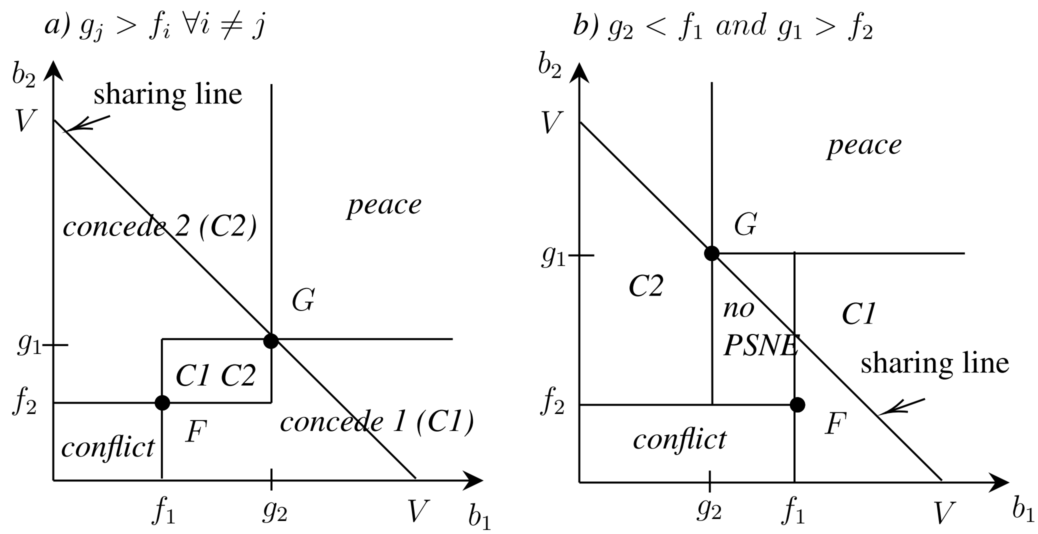

Figure 2.2: The pure strategy Nash equilibria

hand, they are such that both decide to engage into a conflict. The two regions labelled *concede* i (Ci) correspond to situations where player i concedes while player j takes all after suffering a psychic cost. This leaves a fifth region, denoted $C1C2$, which admits two pure strategy equilibria: one in which player 1 concedes, another in which player 2 concedes, as will be determined in section 2.4.2.

2.4.1.5 Case b) An opportunistic player and a matcher ($O_i > 0$ and $O_j < 0$, $i \neq j$)

Part b) of figure 2.2 illustrates the case when player 1 is inclined to match. We find the same initial four equilibria as in section 2.4.1.4 above. The difference in this case is that no NE in pure strategies exists in the box identified by $g_2 < b_1 < f_1$ and $f_2 < b_2 < g_1$. We now turn to mixed-strategy equilibria.

2.4.2 Mixed strategy Nash equilibria

Let σ_i be the probability that player i engages by choosing IN, $i \in \{1, 2\}$. Given σ_j, player i will choose a mixed strategy only if she is indifferent between engaging or not, i.e.,

$E[v_i(IN, \sigma_j)] = E[v_i(OUT, \sigma_j)]$, where $E[\cdot]$ denotes the expectation operator. We have:

$$\begin{aligned} E[v_i(IN, \sigma_j)] &= \sigma_j v_i(IN, IN) + (1 - \sigma_j) v_i(IN, OUT) \\ &= \sigma_j f_i + (1 - \sigma_j)V - b_i \qquad (2.4) \\ E[v_i(OUT, \sigma_j)] &= \sigma_j v_i(OUT, IN) + (1 - \sigma_j) v_i(OUT, OUT) \\ &= (1 - \sigma_j) g_i \qquad (2.5) \end{aligned}$$

By equating the above two values, and after a bit of simple algebra using the fact that $g_i + g_j = V$ and the symmetry between the players's problems, we obtain that player i will play a mixed strategy only if player j's probability of engaging is given by the following:

$$\sigma_j^m = \frac{b_i - g_j}{f_i - g_j} = \frac{g_j - b_i}{O_i}, \; i \neq j. \qquad (2.6)$$

A mixed strategy equilibrium is thus only admissible when the following inequalities are respected:

$$0 < \frac{b_i - g_j}{f_i - g_j} < 1, \; \forall i \neq j. \qquad (2.7)$$

The associated expected final payoffs are:

$$E[v_i(\sigma_i, \sigma_j)] = \frac{b_i - f_i}{O_i} g_i. \qquad (2.8)$$

Again, there are two separate scenarios to consider:

- If $O_i > 0$, the inequalities in (2.7) require that $f_i < b_i < g_j$;
- If $O_i < 0$, the inequalities in (2.7) require that $g_j < b_i < f_i$.

Consequently, by inspection of figure 2.2, it can be seen that a NE in mixed strategies can only occur within the $C1C2$ region in part a), and the *no PSNE* (no NE in pure strategies) region in part b). The reaction functions corresponding to parts a) and b) of figure 2.2 are illustrated in figure 2.3, respectively parts a) and b). Either way, one notes from (2.8) that under a NE in mixed strategies, the expected payoff for each player i is strictly lower than her peaceful share g_i.

The shape of reaction function $\sigma_1(\sigma_2)$ can be interpreted in the following terms. When player 1 chooses to engage, there is a probability σ_2 that she will get into a fight and end up with gain f_1 and a probability $1 - \sigma_2$ that she will make a gain of V because player 2 has conceded; either way, she incurs a psychic cost b_1. The alternative is for player 1 to stay OUT, save on the psychic cost, face a probability σ_2 that she will end up conceding all and a probability $1 - \sigma_2$ that she ends up just keeping her share g_1 peacefully. There are two cases between which to distinguish.

2.4.2.1 Case a) Two opportunists

In case a), $b_1 < g_2$ implies that player 1 prefers a concession from player 2 over peace; this is typically due to player 1's relatively low peaceability (low enough b_1) in comparison to player 2's relatively large share (high enough g_2). But with $b_1 > f_1$, player 1 prefers to give up everything than to fight; this is due to player 1's relatively high peaceability (high enough b_1) in comparison to her relatively low fighting strength. In short, player 1's preferences are ordered as follows:

$$C2 \succ peace \succ C1 \succ conflict.$$

Player 1 is consequently balancing her high desire to force a concession against her strong aversion for conflict, which she considers worse than conceding everything.[11] Indeed, the desire to force a concession dominates when player 2 is unlikely to engage (low σ_2), so that player 1 chooses to engage with certainty, as illustrated by curve $\sigma_1(\sigma_2)$ in part a) of figure

[11] The ordering of preferences makes a player's opportunistic inclination clear: a concession by the opponent is the most preferred outcome, but conflict is the least preferred outcome.

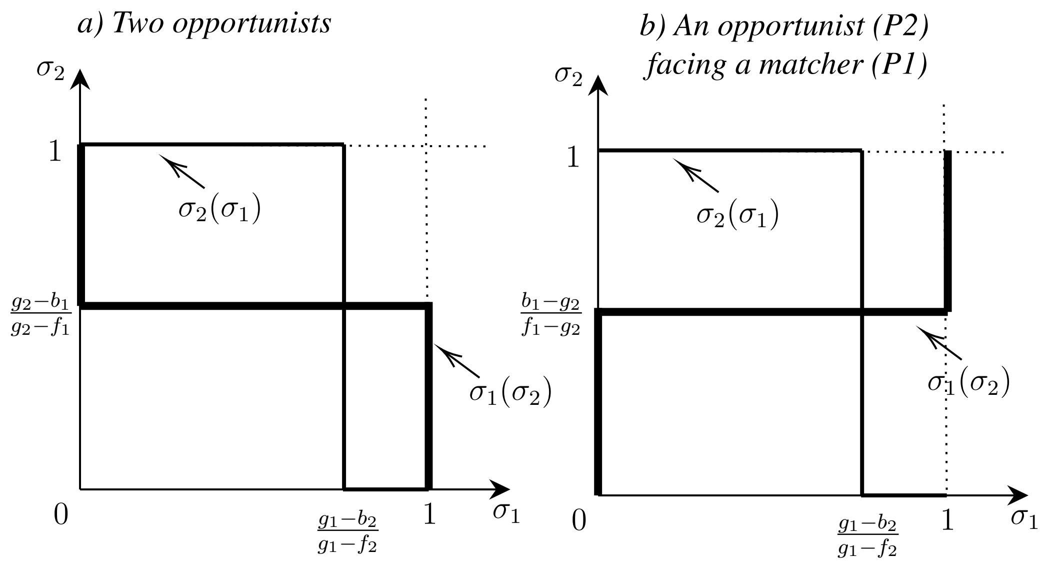

Figure 2.3: The reaction functions for the mixed strategy Nash equilibria

2.3. Conversely, player 1's aversion for conflict dominates when player 2 is too likely to engage (high σ_2), in which case player 1 chooses to disengage with certainty. There consequently exists an intermediate probability value that player 2 will engage, defined as σ_2^m in (2.6), for which player 1 is indifferent between engaging or not.

2.4.2.2 Case b) An opportunist facing a matcher

Things are different in case b). $b_1 > g_2$ implies that player 1 prefers peaceful sharing over forcing a concession from player 2 and $b_1 < f_1$ implies that she prefers to fight than to concede herself. Her preferences are ordered as follows:

$$peace \succ C2 \succ conflict \succ C1$$

Player 1 is therefore balancing her highest desire for peace against her strong fear of conceding, which she considers worse than a fight.[12] Player 1's desire for peace dominates when player 2 is unlikely to engage (low σ_2), so that player 1 chooses to disengage with certainty,

[12] Player 1's inclination to match is clear: peace is the most preferred outcome but conceding is worse than conflict.

as illustrated by curve $\sigma_1(\sigma_2)$ in part b) of figure 2.3. And conversely, player 1's fear of conceding means that she will choose to engage with certainty if player 2 is very likely to engage (high σ_2). σ_2^m in (2.6) thus determines that intermediate probability for which player 1 is indifferent between engaging or not.

In both cases a) and b), a NE in mixed strategies exists at the intersection of the reaction functions. In case a), we also recover the two previously identified concede NE in pure strategies at points $(\sigma_1, \sigma_2) = (0, 1)$ and $(\sigma_1, \sigma_2) = (1, 0)$. The game structure is therefore that of a (asymetrical) *Hawk-Dove game*.

In case b), the reaction functions are consistent with the fact that no NE in pure strategies exists. The game structure is therefore that of a (asymetrical) *matching-pennies game*.

2.5 Some predictions of the model and policy implications

In this section, we look at some implications of the model regarding changes in peaceability levels, sharing rule and fighting powers. We also discuss how the likelihood of peace and conflict can be affected by a change in those parameters. We begin by discussing cases of NE in pure strategies and then turn to NE in mixed strategies.

2.5.1 Pure-strategy Nash equilibria

2.5.1.1 Giving peace a chance

According to corollary 2.3, one notes that in order to achieve a peaceful outcome with certainty – i.e., under pure strategies – then there is no point in trying to alter the relative fighting strengths of the players. Indeed, given proposition 2.2, the relevant variables for the peace equilibrium are the psychic costs b_i and the peaceful shares g_i. Moreover, given that

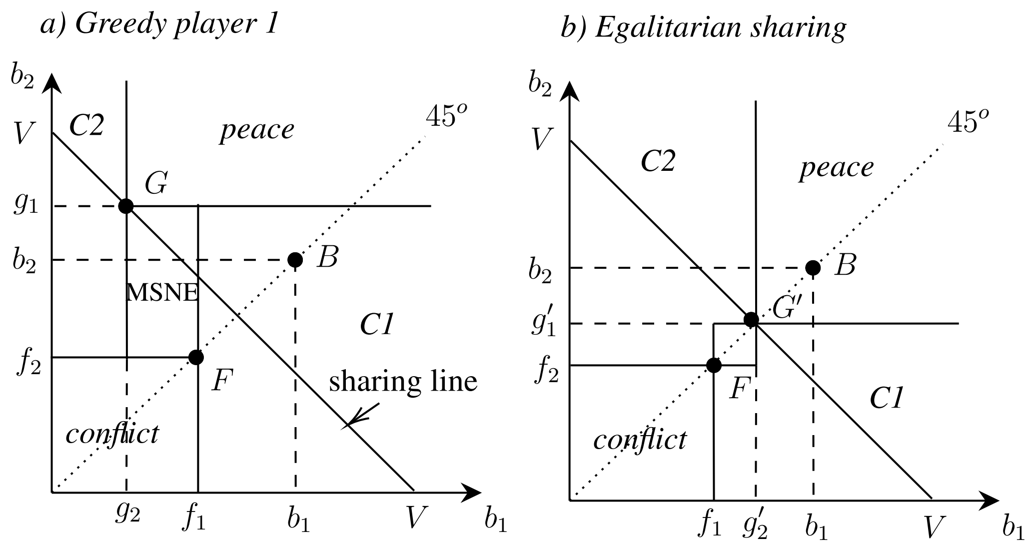

Figure 2.4: A paradox of greed

$g_i = s_i V$, the prize's value is relevant.

Recall that inequality (2.2) is a necessary condition for a peaceful NE in pure strategies to exist. Hence, if the inequality is not met, no rebalancing of the sharing rule will do. The first thing to do is then to increase either or both of the players' psychic costs of engaging, or to decrease the prize's value. Once this is achieved, then a rebalancing of the shares may still be required in order to ensure that inequality (2.1) be respected for both players. Note that the use of the sharing rule may be tricky as increasing the share of one player can only be done by decreasing the share of the other, with the risk that the latter may now choose to engage.

2.5.1.2 Unequal sharing: A greed paradox

An interesting prediction of the model is that a very unequal sharing rule can be self-defeating for the favored party. To see why, suppose that the initial sharing rule is such that player 1 receives a significantly larger share of the prize than player 2. Think, for instance, of player 1 receiving 80% of the value of the prize while player 2 receives 20%. With $g_1 \gg g_2$, the sharing point is located high up along the sharing line, say at point G in figure 2.4a.

Suppose further that the two players have otherwise identical features: they are equally good at fighting ($f_1 = f_2$) and they are equally peaceable ($b_1 = b_2$), as illustrated by points F and B on the 45^o line. Note that in order to better illustrate the impact of greed, point B has been chosen in such a way that if the sharing rule had been egalitarian - as with point G' in figure 2.4b – the equilibrium outcome would be one in which both players accept to share, each receiving payoff $g_1 = g_2 = 0.5V$. With sharing rule G, what we have instead is an equilibrium in which player 1 concedes, as point B falls into region $C1$, with respective payoffs $v_1 = 0$ and $v_2 = V - b_2 > 0$.

We therefore have a situation in which player 1's larger share not only makes him worse off compared to a situation of more equal sharing, it makes him actually worse off than player 2. And this holds even though both have equal fighting strengths and peaceable attitudes. This result calls for interpretation.

Note first that both players prefer to concede than to enter into conflict since conflict yields a strictly negative payoff for both players, i.e., $f_i - b_i < 0, \ \forall i$. There is thus a symmetry in the way in which both players view conflict, regardless of the sharing rule. The unequal sharing rule, on the other hand, introduces an asymmetry in the way they see peace, as we next explain.

Given the large share that he expects to receive under peace, player 1 is obviously quite satisfied with a peace outcome. Indeed, if he expects that player 2 is not going to engage into a fight, player 1 gains more by being peaceful than by trying to get player 2 to concede, i.e., $V - b_1 < g_1$. In other words, *OUT* is a dominant strategy for player 1 with unequal sharing rule G just as it is with equal sharing rule G'.

Player 2, on the other hand, does not have a dominant strategy under G; the fact that she receives so little under a peace outcome induces her to deviate as she expects a larger gain when player 1 concedes, i.e., $V - b_2 > g_2$. Player 2 will thus not be satisfied with a peace outcome.

One may be tempted to think of this result as another instance of the *paradox of power* proposed by Hirshleifer (1991a). The analogy would be mistaken as the mechanism is quite different. In Hirshleifer's case, players always engage into a fight and the paradox comes from the fact that even though one player has the resources to fight harder than the other, he chooses not to in equilibrium in order to devote more resources into making the prize bigger. In our case, the size of the prize is fixed and a player may prefer not to fight given the psychic cost. Moreover, the players are assumed equally good at fighting: if they decide to fight, they receive the same payoffs. The players similarly receive identical payoffs from unilaterally deviating from a peace outcome. Fighting power is thus not a factor. The only asymmetry that remains is in terms of the players' opportunity cost of rejecting peace: the very unequal sharing rule makes this cost very high for player 1 and very low for player 2.

Another important difference with Hirshleifer (1991) concerns the outcomes. In Hirshleifer's case, the paradox is defined in relative terms: in its *strong form*, the final wealth of the initially poorer side equals that of the richer side. The greed outcome here goes further: the one who was promised more ends up with less than the other. We call this a *paradox of greed*.

One way to resolve this problem from the point of view of player 1 would be to make the sharing rule more generous towards player 2. Take sharing rule $G'' = (g_1'', g_2'')$ such that $g_1'' = b_2$. One can verify that thus defined, g_2'' is the minimum share value that will make player 2 accept the sharing rule (he is in fact indifferent). Compared to the outcome under sharing rule G, player 2's welfare is unchanged while that of player 1 has strictly increased since he now receives g_1'' instead of nothing. In fact, given that $b_2 > 0.5V$, we have $g_1'' > 0.5V$, so that player 1 can secure more than half of the whole prize value. This change is thus clearly Pareto-improving and one could also find a sharing rule that makes both players better off.

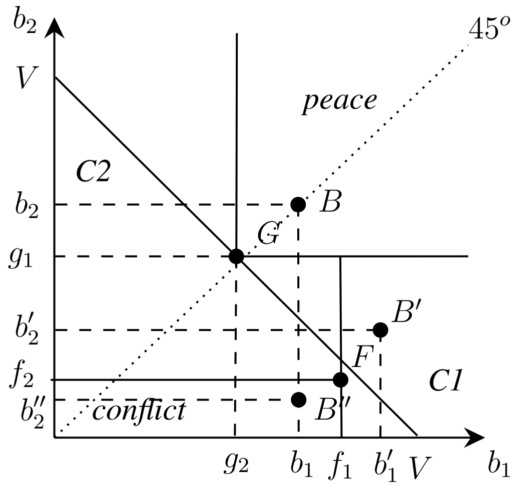

Figure 2.5: The strategic advantage of being bellicose

2.5.1.3 A rationale for scorched earth tactics

Another possibility in the previous case would be for player 1 to resort to a "scorched earth" tactic of reducing the value of the prize. Take $V' < V$ such that $V' - b_2 = g'_2$. In this case, player 2 accepts the sharing rule - she is in fact indifferent - while player 1 is made strictly better off by receiving $g'_1 > 0$. In this case, however, player 2 is made worse-off since $g'_2 < V - b_2$. One can verify that for a given sharing rule, the use of scorched earth tactic by one player in order to induce a peace outcome will always make the other player worse off.

2.5.1.4 Some pros and cons of being bellicose

We will now see that being bellicose may provide an important strategic advantage or make everyone worse off.

Let our benchmark configuration be represented by points F, G and B in figure 2.5. This is a situation where both players receive equal shares under the peaceful sharing rule and have equal peaceable sentiments. The only thing that distinguishes them is that player 1 would do better than player 2 at the outcome of a fight. The unique equilibrium in this case is a peaceful one in which both players accept the sharing rule, so that each receives half of the prize's value.

Let us now consider the heterogeneous peaceablities represented by point B' where player 2 is more bellicose (less peaceable) than player 1. The sharing rule and fighting powers are unchanged at points G and F. The unique equilibrium is now at $C1$, i.e., player 1 concedes all to player 2. This holds, even though player 1 would be stronger at fighting and both players would be net losers in the case of a fight. In this equilibrium, player 2 is made strictly better off than in the peace equilibrium since $V - b_2' > 0.5V$. Player 1 is made worse off as he receives nothing. Hence the potential advantage of being bellicose.

Being bellicose, however, can backfire. To see why, suppose the configuration represented by points G, F and B''. In this case, player 2 is still more bellicose (less peaceable) than player 1; however, both players make a strictly positive payoff in the case of a conflict. Conflict is thus the unique equilibrium and the welfare of both players is lower than under peace. Hence, the bellicosity of player 2 has drawn both players into a sure fight that they both would rather avoid. The presence of a bellicose player can therefore be a curse for all, even though one player is significantly stronger in a fight.

2.5.2 Mixed-strategies Nash equilibria: Giving peace a better chance

Under a NE in mixed strategies, the probability of peace occurring, denoted Π, is given by the following product:

$$\Pi = (1 - \sigma_2^m) \times (1 - \sigma_1^m), \tag{2.9}$$

We begin by looking at the effects of changes in peaceability levels before turning to the effects of the sharing rule.

2.5.2.1 The effect of peaceability under a NE in mixed strategies

According to expression (2.6), it can be readily verified that for $i \neq j$, σ_j^m decreases with b_i if, and only if, $f_i < g_j$. Hence the following proposition, which we state without proof:

Proposition 2.8 *In a NE in mixed strategies, the likelihood of a peaceful (conflict) outcome decreases (increases) with a player's peaceability level if, and only if, the players behave opportunistically.*

This proposition underscores the non-trivial effect of peaceability on conflict as it interacts with both the peaceful sharing rule and the fighting powers. Indeed, it implies that bellicosity can actually be good for peace when a player behaves as a matcher. How can this be so? To better visualize this, let us define the *expected* NGE as follows:

$$E[\pi_i] = \sigma_j f_i + (1 - \sigma_j) g_j - b_i. \tag{2.10}$$

This expression is the mixed strategy equivalent of the NGE in definition 1; indeed, it represents the *expected* gain from playing IN net of the *expected* payoff from playing OUT, as per expressions (2.4) and (2.5). In order for player i to adopt a mixed strategy, this expected gain must be zero, otherwise he would not be indifferent. This requires that σ_j^m be such that $E[\pi_i] = 0$. Now if player i is somehow made less peaceable (lower b_i), player j must adjust σ_j^m in order to reduce the sum of the first two terms and keep the indifference. One clearly sees then that this requires putting more weight on a conflict outcome – i.e., increasing σ_j^m – if, and only if, $g_j > f_i$, i.e., if, and only if, player i behaves opportunistically.

Through inspection of expression (2.8), we also have the following corollary:

Corollary 2.9 *In a NE in mixed strategies, the expected payoff of a player decreases with his own peaceability level if, and only if, he behaves opportunistically. The expected payoff is, however, unaffected by the other player's peaceability level.*

This is another instance where being more bellicose (less peaceable) is not necessarily a blessing. Indeed, within a NE in mixed strategies range, a matcher gains from being bellicose (less peaceable) while an opportunist loses.

2.5.2.2 The effect of the sharing rule under a NE in mixed strategies

Given expression (2.6), one can verify through differentiation that σ_i^m increases with g_i *iff* $b_j - f_j \geq 0$, i.e., an increase in player i's peaceful share leads him to increase his probability of engaging *iff* his opponent behaves opportunistically. Now given that an increase in g_i is necessarily associated with a decrease in g_j, this also means that an increase in player i's peaceful share leads player j to decrease her probability of engaging *iff* player i behaves opportunistically. We must therefore again distinguish between the cases with two opportunistic players from cases in which an opportunistic player faces a matcher.

If both players are opportunistic, then an increase in the peaceful share of player i – and thus a decrease in g_j – leads to an increase in σ_i^m and a decrease in σ_j^m. The resulting effect on the likelihoods of peace and conflict is thus ambiguous *a priori*. Through differentiation of expression (2.9), one can verify, however, that $\partial\Pi/\partial g_i \geq 0 \Leftrightarrow O_i \leq O_j$.

If player i is an opportunist and player j is a matcher, then an increase in g_i leads to decreases in both σ_i^m and σ_j^m. And conversely, if player i is a matcher and player j is an opportunist, then an increase in g_i leads to increases in both σ_i^m and σ_j^m.

The above leads us to assert the following, which we state without proof:

Proposition 2.10 ***Peaceful shares and conflict under a NE in mixed strategies*** *Under a NE in mixed strategies,*

a) if both players are opportunists, then a (local) increase in the peaceful share of player i increases (decreases) the likelihood of a peaceful (conflict) outcome iff *player i is comparatively less opportunistic than player j.*

b) if player i is an opportunist and player j is a matcher, then a (local) increase in the peaceful share of player i increases (decreases) the likelihood of a peaceful (conflict) outcome.

c) if player i is a matcher and player j is an opportunist, then a (local) increase in the peaceful share of player i decreases (increases) the likelihood of a peaceful (conflict) outcome.

Through differentiation of expression (2.8), it can be verified that within a NE in mixed strategies, player i's expected gain increases with his peaceful share g_i if, and only if, $f_i \leq b_i$, which corresponds to player i behaving opportunistically. We therefore have another version of a greed paradox occurring when a player behaves as a matcher.

2.5.2.3 The effect of fighting power under a NE in mixed strategies

One can readily verify through differentiation of expression (2.6) that σ_i^m increases with f_j *iff* player j behaves opportunistically. Now one could think of two fundamental reasons why f_j would increase: One possibility is that relative strengths have changed such that player j is made stronger (higher f_j) and i is made weaker (lower f_i); another possibility is that the conflict has become more destructive in general, such that both players' strengths have decreased (f_i and f_j both decrease). Let us consider these two possibilities in turn.

Suppose that an increase in f_i is matched by a decrease in f_j. If both players are opportunists, then σ_i^m decreases while σ_j^m increases and we are left with an ambiguity as to the effect of a relative change in relative strengths on the likelihood of conflict in a NE in mixed strategies. If player i is an opportunist and j is a matcher, then both σ_i^m and σ_j^m increase; in this case, increasing player i's relative power raises the likelihood of conflict. Conversely, if player i is a matcher and j is an opportunist, then both σ_i^m and σ_j^m decrease, so that increasing player i's relative power lowers the likelihood of conflict.

Suppose instead that the conflict is made more destructive, so that both f_i and f_j decrease. In both contenders are opportunists, then both σ_i^m and σ_j^m decrease, so that the probability of peace (conflict) increases (decreases). If the case where one contender is a matcher, the effect of a more destructive conflict on the probability of its occurrence is ambiguous.

The upshot is that under a NE in mixed strategies, if one seeks to increase the likelihood of a peaceful outcome through a reshuffling of the conflict outcome, one should take care to distinguish between making the conflict more destructive generally or making one player relatively stronger while considering the interactions with the peaceful sharing rule.

Regarding the expected gain of player i, differentiation of expression (2.8) indicates that it will increase with own power f_i if, and only if, $b_i \geq g_j$, which can only occur if player i behaves as a matcher. For an opportunist, being made more powerful has the paradoxical effect of decreasing the expected gain. Note that increasing the power of an opponent does not affect the expected gain of a player.

2.6 Conclusion

The purpose of this paper has been to analyze the role of peaceability in conflict. We have argued that player's peaceabilities are an important determinant of conflict, alongside the sharing arrangement and the player's strengths. We have identified three types of outcomes that can be produced from the interaction between these three determinants: a peace outcome, in which both players accept the sharing rule; a conflict outcome, in which the players engage in wasteful conflict; a concession outcome, in which one player concedes the prize to the other player. We have identified the Nash equilibria in pure and mixed strategies for various configurations of the determinants.

We have shown that sufficiently peaceable players accepts a peace outcome whereas very bellicose players engage in conflict. We have also shown that asymmetry in players peaceabilities can lead a more peaceable player to concede the entire prize. Furthermore, we have illustrated two interesting scenarios: the paradox of greed and the advantages and disadvantages of being bellicose. In the first scenario, an unequal sharing rule can be self-defeating for the favoured player. In the second scenario, being bellicose can be beneficial for a weaker player.

Our analysis highlights the importance of emotions in conflict. Further research will endogenize peaceability to better capture these emotions.

Chapter 3

A Theory of Resource Use, Blame and Conflict

3.1 Introduction

Suppose that two goat-herders both have access to a pasture. Each herder wants to let his goats graze on the pasture, to eventually sell the goats. Neither of the herders owns the pasture, and both wish to use it. Suppose that the herders meet to form an agreement to cooperatively use the pasture. They agree on the number of goats each may graze. The agreement is designed to maximize joint profits. The herders then part ways and each may respect the agreement or deviate. When the time comes to take the goats to market, the herders inspect their goats, and discover whether or not the agreement was respected. Each herder now has a decision to make: whether to accept the outcome and take his goats to market, or pick a fight with the other herder over what has taken place.

Consider the role that emotions could play in the decision to pick a fight. Suppose that a herder *feels bad* about picking a fight, but that the intensity of this feeling depends on what has transpired. For example, a herder who has been betrayed, i.e. respected the agreement while his partner did not, may not feel bad about picking a fight. On the other hand, a herder who has betrayed his partner may feel bad about it. The anticipation of these emotions will affect upstream decisions to deviate from the agreement.

Considering that a fight between the herders would be costly and cause destruction and waste, the herders must each decide whether or not picking a fight is really worth it. Those decisions are sensitive to the emotional context.

Through this problem we explore the role of emotions when cooperation can break down and lead to conflict. We set up the problem as a one-shot game with two players, complete information and three-stages. The game describes the use of a shared resource that can lead to conflict when there is an emotional cost that is associated with the breakdown of cooperation and determined by an exogenous agreement and the players' actions.[1]

Emotions and other aspects from psychology in cooperation and conflict take various forms, here are a few examples. According to Rabin (1993), reciprocity is the concept that "people like to help those who are helping them, and to hurt those who are hurting them" (p. 1281). Fehr and Fischbacher (2002) propose that reciprocal preferences can lead to cooperative outcomes in a coordination game. They also argue that reciprocal fairness could be important for property rights. Fehr and Gachter (2000) find cooperation can be achieved through punishment, where punishment is an expression of reciprocity.

Reciprocity and the use of a common pool resource are examined by Falk et al. (2001) and Velez et al. (2009). Falk et al. (2001) consider penalties as an expression of reciprocity, and Velez et al. (2009) view conditional cooperation as the manifestation of a strategy of reciprocity. The closely related notion of fairness, as a source of conflict is investigated by Falk et al. (2003). When individuals evaluate fairness, they distinguish between the motivation behind action and the outcome of the action; an unfair action may be punished through negative reciprocity, but conflict is less likely to occur when an unfavourable outcome is unintentional (Falk et al., 2003).

Friedman and Singh (2009) model reciprocal preferences as follows: "My attitude towards

[1] A Coasian solution to the problem is not considered due to transaction costs embodied by the threat of conflict. See Allen (2000) for a treatment of transaction costs.

your payoffs depends on my emotional state, e.g., friendly or vengeful, and your behaviour systematically alters my emotional state" (p. 814). The authors model the motivation for punishment in a trust game in which punishment yields a utility bonus for punishing a defecting partner. They propose that given the option for punishment, it is possible for the threat of vengeance to rationalize cooperation and trust. Hirshleifer (1987) considers *action-dependent* preferences for anger and gratitude, and finds that anger can secure cooperation through the threat of punishment.

In this chapter, emotions take form in a psychological cost incurred for the breakdown of peace. This cost captures a player's stable individual characteristic towards conflict as well as the attribution of blame. The stable characteristic represents a player's predisposition towards conflict that is independent of the players' actions. This characteristic takes the form of an exogenous disinclination to break the peace. The cost also captures the blame a player attributes for breakdown of peace; a player attributes blame based on the actions of the other player and herself, *vis à vis* the agreement. A player's psychological cost of breaking the peace is reduced when blame is attributed to the other player, and increased when blame is attributed to oneself.

We refer to Çelen et al. (2017) for our understanding of blame. Çelen et al. (2017) consider a notion of blame that is *self-referential* as follows. A player considers the perspective of the *other* player, asking herself how she would have behaved in the other player's position. She blames the other player if she would have been nicer than the other player. Similarly, in our notion of blame, a player blames the other player when the other player behaves worse than herself, and she blames herself when she behaves worse than the other player. In contrast to Çelen et al. (2017), however, beliefs play no role in our notion of blame.

Our psychological cost is closely related to the psychological benefit in Rohner et al. (2013). The authors consider a psychological benefit of playing cooperatively to model the propensity to cooperate, where the onset of conflict signals that the aggressor has a low propensity to cooperate. However, this psychological benefit differs from our psychic cost in a key aspect: an agent's psychological benefit of cooperation is independent of the opponent's actions. We propose a psychological cost that is strongly affected by an opponent's actions.

Cubitt et al. (2017) examine the role of a psychological cost in the provision of public goods; they consider a psychological cost of trust betrayal that can vary in intensity, and is suffered in addition to monetary losses. We consider a psychological cost that can vary in intensity to analyze the role of emotions when players use a common resource in the shadow of conflict.

We set up the model in such a way that in the absence of psychological costs, the agreement breaks down and the players engage in conflict. This brings out most starkly the role played by psychological costs.

Through simulations of the game, we show that under some circumstances, a strong disinclination to break the peace for both players leads to over-use of the resource relative to the agreement, but that peace is maintained. This outcome corresponds to a free access problem over the use of a common resource, where the players are unwilling to punish deviations. At the opposite end, a weak disinclination for both players leads them to restrict their individual use of the resource, due to a lack of security over their individual gains. A moderate disinclination for both players can induce the players to respect the agreement and maintain the peace, due to credible threat of punishment for deviations. Finally, we discuss two cases in which asymmetric idiosyncratic disinclinations can lead one player to be exploited by the other player.

Additionally, we examine how the use of the resource affects the intensity of fighting in a conflict. We find that when the players under-use the resource, the fighting is less intense than if the players had initially respected the agreement.

The paper is organized as follows. The problem is described in the next section. In section 3.3, we discuss conflict intensity and the use of the resource and simulate the problem for various values for the players' intrinsic disinclinations. Section 3.4 concludes.

3.2 The problem

We consider the role of emotions in a three-stage model of resource use and conflict between two players. The players choose whether or not to respect an initial agreement on the use of a shared resource in the first stage. In the second stage, the players choose whether or not to accept the distribution of gains from the resource or to break the peace. A psychological cost is incurred by a player who breaks the peace. The psychological cost is governed by emotions over what transpired in the first stage. One's own transgression at the first stage aggravates a player's second stage psychic cost, and mitigates his partner's second stage psychic cost. At the second stage, players can be heterogeneous with respect to their psychological costs, due to actions at the first stage and/or asymmetric predispositions. Conflict over the resource can take place in a third stage of the game.

This section proceeds as follows. First, we describe the use of the resource by the players, where the only input on the resource is goats, and the output is goat meat. Next, we describe the timing of the game. Then, we discuss the players' decisions whether or not to break the peace and how hard to fight in a conflict. Finally, the psychological cost is explained.

3.2.1 Two-herder model (use of resource)

There is a resource with production technology $f(X)$; $f'(X) > 0$, $f''(X) < 0$, $f(0) = 0$ to be used by two players, 1 and 2, where X is the total input effort. Player $i, i \in \{1, 2\}$, chooses input effort $x_i \geq 0$. The players' inputs x_1 and x_2 are perfect substitutes in production, and $X = x_1 + x_2$. The constant unit cost of input x_i is c and individual output $x_i f(X)/X$ is sold at constant market price p. Player i's individual payoff from the use of the resource, in the absence of conflict, is:

$$\pi_i = px_i f(X)/X - cx_i \tag{3.1}$$

A natural agreement, x^A, on the use of the resource is $x^A = X^A/2$, where X^A is defined by the profit maximizing condition $pf'(X^A) = c$.

3.2.2 Timing

An exogenous agreement x^A is observed by all the players.[2] In the first stage of the game, the players simultaneously choose whether or not to respect the agreement, by choosing their respective inputs in production. In the second stage of the game, the players simultaneously choose whether or not to break the peace after having observed, or deduced, the input choices. If both the players break the peace, then the game proceeds to an additional (third) stage in which the players fight over the gains from the resource, otherwise the game ends.

3.2.3 Engagement

In the second stage of the game, the players simultaneously choose to *break* (B) or *maintain* (M) the peace. A player i who chooses to break the peace incurs a psychological cost $h_i(\theta_i, x_i, x_j, x^A)$. The psychological cost is determined by the exogenous idiosyncratic parameter θ_i, the inputs from the first stage, x_1, x_2, and the agreement x^A. The psychological cost is described in more detail in subsection 3.2.5.

		Player 2: B	Player 2: M
Player 1	B	v_1, v_2	$pf(X) - cx_1 - h_1(\theta_1, x_1, x_2, x^A), -cx_2$
	M	$-cx_1, pf(X) - cx_2 - h_2(\theta_2, x_2, x_1, x^A)$	π_1, π_2

Figure 3.1: The second stage

Figure 3.1 describes the payoff matrix for the second stage. If both players choose to break the peace, the payoff to player i is determined by a contest over the total gains from the resource (as in Hirshleifer (1995)), v_i, $i \in \{1, 2\}$, described in subsection 3.2.4. If both the players choose to maintain the peace, the payoff to player i is π_i, $i \in \{1, 2\}$ as in expression (3.1). And finally, if player i chooses to break the peace while player j chooses

[2] We choose to focus our attention on the potential for conflict given the use of the resource. An endogenous agreement could be the focus of future research.

to maintain it, we take this as a "concession" by j such that player i takes all. In this case, however, only player i suffers a psychological cost. The respective payoffs are thus: $pf(X) - cx_i - h_i(\theta_i, x_i, x_j, x^A)$ for i and $-cx_j$ for player j.

3.2.4 The contest

In the case of a conflict, conflict takes the form of a contest over the total gains from the resource.[3] The players simultaneously exert irreversible and costly efforts, $z_1 \geq 0$ and $z_2 \geq 0$, to secure the total gains from the resource, $pf(X)$. The probability of winning the total gains is described by a Tullock lottery contest success function, the probability of player 1 winning is: $g_1(z_1, z_2)$, where $g_1(z_1, z_2) = 1/2$ if $z_1 = z_2 = 0$ and $g_1(z_1, z_2) = z_1/(z_1 + z_2)$ otherwise. The probability of player 2 winning is $g_2(z_1, z_2) = 1 - g_1(z_1, z_2) \geq 0$. The payoff to player i, in the event of a conflict, is $v_i = g_i(z_1, z_2)pf(X) - cx_i - wz_i - h_i(\theta_i, x_i, x_j, x^A)$, where w is the constant marginal cost of fight effort.

3.2.5 The psychological cost of breaking the peace

The psychological cost, $h_i(\theta_i, x_i, x_j, x^A)$, is incurred only by a player i who chooses to break the peace. We assume that the psychological cost has the following properties: $h_{\theta_i} > 0$, $h_{x_i} > 0$, $h_{x_j} < 0$ and propose the following form:

$$h_i(\theta_i, x_i, x_j, x^A) = \theta_i(1 + x_i/x^A)/(1 + x_j/x^A) \tag{3.2}$$

Player i's psychological cost function has two parts, an intrinsic disinclination to break the peace, $\theta_i \in [0, \infty)$, and an emotional component that captures the *blame* player i places on player j for the breakdown of peace. For the emotional component, we refer to Çelen et al. (2017), who explain their notion of blame as follows. "The notion of blame states that for player j to judge whether player i is kind or unkind to him, player j has to put himself

[3] As previously mentioned in Chapter 1, contest models are commonly used by economists when modeling conflict.

in the position of player i, and ask if he would act in a manner that is worse than what he believes player i does, under identical circumstances. If player j would act in a worse manner than player i, then we say that player j does not blame player i for his behavior. If, however, player j would have been nicer than player i, then we say that "player j blames player i" for his actions-i.e. player i's actions were blameworthy." (Çelen et al., 2017, p. 2).

In expression (3.2), blame is expressed as follows. The blame player i places on player j is dependent on the actions of both players in the first period. Player j's actions are *blameworthy* only when player j behaves worse than player i, i.e, $x_j > x_i$, whereas, when player i behaves worse than j ($x_i > x_j$), his own actions are blameworthy. In this form, the blameworthiness of player j (i) reduces (increases) player i's psychological cost of breaking the peace. Simply put, a player cares about whether the other player has behaved worse (or better), and by how much.[4]

Clearly, the problem described in this chapter is not the only setting in which players might incur a psychological cost associated with breakdown of peace that is sensitive to the history leading up to that breakdown. For instance, what transpired over the course of a marriage likely influences how divorcing partners feel about the divorce. Or, consider two economists who agree to write a paper together- one can imagine that their individual contributions and characters affect whether the paper is completed peacefully or not.

3.3 Equilibrium

The solution concept is a subgame perfect Nash equilibrium (SPNE). To characterize the equilibrium, we begin with the last stage. First, we solve for the player's fight efforts at the third stage of the game; the fight only takes place when both players reject a peaceful distribution of the gains at the second stage of the game. Next, we characterize the conditions for conflict, peace or a concession as a result of players' breaking the peace or not, in the

[4] The psychological cost is *belief-independent* (each player knows how she herself behaved compared to the other player).

second stage. Finally, we examine how the intrinsic disinclinations to break the peace lead to the pure strategy equilibrium input choices and describe these scenarios.

3.3.1 Last stage: contest over resource

In the event of conflict, player i's best response fight effort is derived by maximizing v_i with respect to z_i. By simultaneously solving the players' best responses we obtain the unique equilibrium of the subgame, in which the players expend efforts of: $z_1^* = z_2^* = pf(X)/4w$; $\forall f(X) > 0$. The players' fighting efforts are symmetric and the psychological costs of breaking the peace do not affect conflict intensity because they are considered fixed at this stage. The final payoff from conflict to player i is:

$$v_i(z_i^*, z_{-i}^*) = pf(X)/4 - cx_i - h_i(\theta_i, x_i, x_j, x^A) \tag{3.3}$$

In a conflict outcome, the gains from the use of the resource are redistributed equally between the players and depend on the collective, rather than the individual use of the resource, as in Hirshleifer (1995). As such, an initial advantage for one player from more intense use of the resource is eliminated by conflict.

3.3.2 Second stage: breaking the peace (or not)

Moving to the second stage of the game, we look at the players' decisions to break or maintain the peace. For simplicity, we consider that a player who is indifferent between breaking the peace or not chooses to maintain the peace. If both players break the peace, then they proceed to the conflict stage, described above. If the peace is maintained by both players then they retain their respective gains from the resource as per expression (3.1). If one player breaks the peace and the other maintains it, then the peaceful player concedes his gains to the player who breaks the peace. The possible outcomes at the second stage are: conflict, peace, or a concession. The conditions for each outcome are as follows:

1. **Conflict:** The necessary and sufficient conditions for the peace to be broken by both players in pure strategies is $pf(X)/4 > h_i(\theta_i, x_i, x_j, x^A)$, $\forall i$.

   Proof: i) Sufficiency: When player j breaks the peace, the payoff to player i from breaking the peace as well is $\upsilon_i = pf(X)/4 - h_i(\theta_i, x_i, x_j, x^A) - cx_i$ for player i. We must show that, when player j breaks the peace, no player i can gain by maintaining the peace. The payoff to player i from maintaining the peace when player j breaks the peace is $-cx_i$. With $h_i(\theta_i, x_i, x_j, x^A) < pf(X)/4$, no player i can gain by maintaining the peace while player j breaks the peace. QED ii) Necessity: Assume that $pf(X)/4 \leq h_i(\theta_i, x_i, x_j, x^A)$. Then, for any $h_i(\theta_i, x_i, x_j, x^A) \geq 0$, when player j breaks the peace, the payoff to player i from maintaining the peace is $-cx_i$ and from breaking the peace is $pf(X)/4 - h_i(\theta_i, x_i, x_j, x^A) - cx_i$: the payoff for player i from breaking the peace is not greater than the payoff from maintaining it, i.e., $pf(X)/4 - h_i(\theta_i, x_i, x_j, x^A) - cx_i \leq -cx_i$. Hence, the conflict is not an equilibrium. QED

   In other words, if and only if, the psychological cost of each player is less than the gain from conflict, then conflict occurs with certainty at the second stage.

2. **Peace:** The necessary and sufficient conditions for the peace to be maintained by both players in pure strategies is $px_jf(X)/X \leq h_i(\theta_i, x_i, x_j, x^A)$, $\forall i$.

   Proof: i) Sufficiency: When player j maintains the peace, the payoff to player i from maintaining the peace as well is $\pi_i = px_if(X)/X - cx_i$. We must show that, when player j maintains the peace, no player i can gain by breaking the peace. The payoff to player i from breaking the peace when player j maintains the peace is $px_if(X)/X + px_jf(X)/X - h_i(\theta_i, x_i, x_j, x^A) - cx_i$. With $px_jf(X)/X \leq h_i(\theta_i, x_i, x_j, x^A)$, no player i can gain by breaking the peace while player j maintains the peace. QED ii) Necessity: Assume that $px_jf(X)/X > h_i(\theta_i, x_i, x_j, x^A)$. Then, for any $h_i(\theta_i, x_i, x_j, x^A) \geq 0$, when player j maintains the peace, the payoff for player i from breaking the peace is $px_if(X)/X + px_jf(X)/X - h_i(\theta_i, x_i, x_j, x^A) - cx_i$ and from maintaining the peace is $px_i f(X)/X - cx_i$: the payoff to player i from breaking the peace is greater than the payoff from maintaining it: $px_i f(X)/X + px_j f(X)/X - h_i(\theta_i, x_i, x_j, x^A) - cx_i > px_i f(X)/X - cx_i$. Hence, peace is not an equilibrium. QED

In other words, if and only if, the psychological cost of each player is at least as great as the maximum incremental gain from breaking the peace, for each player, then the peace is maintained with certainty at the second stage.

3. **Concession:** A sufficient condition for a concession by player j to occur in pure strategies is 1. $pf(X)/4 \leq h_j(\theta_j, x_j, x_i, x^A)$ and 2. $px_j f(X)/X > h_i(\theta_i, x_i, x_j, x^A)$, $i \neq j$.

   Proof: Part a) Take that player i maintains the peace and player j breaks the peace. The payoff for player i is $-cx_i$ and the payoff for player j is $px_i f(X)/X + px_j f(X)/X - h_j(\theta_j, x_j, x_i, x^A) - cx_j$. We must show that no player can gain by unilaterally deviating. Indeed, the payoff for player i from breaking the peace when player j breaks the peace, is less than the payoff from maintaining it, i.e.,s $pf(X)/4 - h_i(\theta_i, x_i, x_j, x^A) - cx_i < -cx_i$, and the payoff for player j from maintaining the peace when player i maintains the peace, is less than the payoff from breaking it, i.e., $px_j f(X) - cx_i < px_i f(X)/X + px_j f(X)/X - h_j(\theta_j, x_j, x_i, x^A) - cx_j$. QED Part b) Assume not. Then player i choosing to break the peace and player j choosing to maintain the peace is the only other admissible Nash equilibrium in pure strategies (since the other two are ruled out by the N & S condition). The payoff to player i from breaking the peace when player j maintains it, is less than the payoff from maintaining it: $px_i f(X)/X + px_j f(X)/X - h_i(\theta_i, x_i, x_j, x^A) - cx_i < px_i f(X)/X - cx_i$ since $px_j f(X)/X < h_i(\theta_i, x_i, x_j, x^A)$. Hence player i would deviate and maintain the peace. A contradiction. QED Part c) Assume not. Then player i choosing to break the peace and player j choosing to maintain the peace is the only other admissible Nash equilibrium in pure strategies (since the other two are ruled out by the N & S condition). The payoff to player j from maintaining the peace when player i breaks it, is less the the payoff from breaking it: $-cx_j < pf(X)/4 - h_j(\theta_j, x_j, x_i, x^A) - cx_j$. Hence player j would deviate and break the peace. A contradiction. QED

Hence, if the psychological cost of one player is greater than the gain from conflict, and the psychological cost of the other player is less than the maximum that he could appropriate through breaking the peace, then a concession occurs with certainty at the second stage.

4. **Mixed strategies:** Let σ_i be the probability that player i breaks the peace, $i \in \{1, 2\}$. Given σ_j, and relaxing the assumption that an indifferent player maintains the peace, player i will choose a mixed strategy only if he is indifferent between breaking the peace or maintaining it. i.e., when $\sigma_j(pf(X)/4 - h_i(\theta_i, x_i, x_j, x^A) - cx_i) + (1 - \sigma_j)(pf(X) - h_i(\theta_i, x_i, x_j, x^A) - cx_i) = \sigma_j(-cx_i) + (1 - \sigma)(px_i f(X)/X - cx_i)$. Through a bit of algebra and the symmetry of the players' problems, we obtain that player i will play a mixed strategy only if player j's probability of engaging is: $\sigma_j = (h_i(\theta_i, x_i, x_j, x^A) - x_j f(X)/X)/(pf(X)/4 - x_j f(X)/X)$. A mixed strategy is admissible if and only if $0 < \sigma_j < 1$. Consequently, a mixed strategy equilibrium can only occur when $0 < (h_i(\theta_i, x_i, x_j, x^A) - x_j f(X)/X)/(pf(X)/4 - x_j f(X)/X) < 1\ \forall i$.

The above conditions define regions for the equilibria at the second stage. These regions are characterized by the players' gains from conflict, $pf(X)/4$, the maximum gains that can be appropriated, $x_1 pf(X)/X$ and $x_2 pf(X)/X$, and the psychological costs $h_1(\theta_1, x_1, x_2, x^A)$ and $h_2(\theta_2, x_2, x_1, x^A)$, all of which are fixed at the second stage. The first stage input decisions, given the players' intrinsic disinclinations, θ_1 and θ_2, therefore govern the players' decisions at the second stage.[5]

At the second stage, there are thus four regions with unique equilibria in pure strategies: peace, conflict, a concession by player 1 and a concession by player 2. Additionally, there is

[5]Falsifiability is discussed in Chapter 1. Here, variation in the outcome is implied for constant input combinations.

Figure 3.2: Symmetric psychological costs and input use

also **either** a region with three equilibria: two in pure strategies (a concession by player 1 and a concession by player 2) and one in mixed strategies **or** a region with a unique equilibrium in mixed strategies. The additional region depends on the players' relative gains and costs. The second stage corresponds to a simplified version of the conflict engagement problem in Chapter 2 of this thesis.

3.3.2.1 An Illustration: symmetric psychological costs

To illustrate how the psychological cost can affect the outcome at the second stage, consider the following simple example. Suppose that the players have symmetric intrinsic disinclinations to break the peace, and that in the first stage the players choose symmetric input use, i.e. $\theta_1 = \theta_2 = \theta$ and $x_1 = x_2 = x$; together this implies $h_1(\theta_1, x_1, x_2, x^A) = h_2(\theta_2, x_2, x_1, x^A) = \theta$ as per expression (3.2).

Figure 3.2 illustrates the **pure strategy** outcome of the second stage for various values of θ. Starting at $\theta = 0$, θ increases along the line from left to right. We can see, when $\theta < pf(X)/4$, the outcome is conflict. When $pf(X)/4 \leq \theta < xpf(X)/X$, the outcome is a concession, and when $\theta \geq xpf(X)/X$, the outcome is peace.

This simple case illustrates how the intrinsic disinclination affects the propensity for conflict, given symmetric psychological costs. Keep in mind, however, that the players need not have symmetric psychological costs. Given symmetric intrinsic disinclinations to break the peace, a disparity in the player's use of the resource in the first stage will result in asymmetric psychological costs, as well asymmetries in gains from breaking or maintaining the peace.

3.3.3 Input efforts on resource

Moving to the first stage of the game, we look at the players' use of the resource. For tractability, we suppose a quadratic production technology: $f(X) = aX - bX^2; a, b > 0$. Additionally, we restrict the players' input use to low, intermediate, or high, i.e., $x_i \in \{x_L, x_M, x_H\}$ $i = 1, 2$. Each player may respect the agreement by choosing x_M or deviate to either a higher input, x_H, or a lower input, x_L.

We assume the following values for the parameters: $a = 10$, $b = 2$, $p = 5$ $c_1 = c_2 = 5$, $w_1 = w_2 = 1$, and the inputs: $x_L = 6/8$, $x_M = 9/8$, $x_H = 12/8$. As such, x_M corresponds to the natural agreement and x_H to a free access situation in which the players use the resource without consideration of the agreement or the potential for conflict (Cheung, 1970).

The rest of this section proceeds as follows. First, we describe the fighting intensity by input combinations. Then, we establish a benchmark case in which the players have no psychological cost of breaking the peace. Lastly, we compare the players' inputs and conflict decisions for various values of the psychic parameter θ_i, $i \in \{1, 2\}$.

3.3.3.1 Fighting intensity

At the last stage of the game, the fight effort exerted is a function of the players' first stage input choices. Figure 3.3 shows the symmetric fight effort of each player for all input combinations in an equilibrium. A low-low input combination leads to the least intense fighting, whereas deviation to a high input from the agreement by one player (intermediate-high combination) leads to more intense fighting.

		Player 2		
		x_L	x_M	x_H
Player 1	x_L	13.125	14.648	15.469
	x_M	14.648	15.469	15.586
	x_H	15.469	15.586	15

Figure 3.3: Fighting effort of each player by input combination

3.3.3.2 Benchmark: No psychological cost

We proceed as follows. First, we compute the payoffs as per expression (3.3), for all input combinations. We then solve for all pure and mixed strategy Nash equilibria at the second stage, for all input combinations. Finally, we move to the first stage and solve for the subgame perfect inputs.

In the benchmark case $\theta_1 = \theta_2 = 0$, the unique SPNE is as follows. At the first stage of the game, the players both choose the low input. At the second stage of the game, both players break the peace. In the last stage, the fight effort of each player corresponds to the low-low value in figure 3.3. The interpretation goes as follows. In the first stage of the game, no player has the incentive to unilaterally deviate from the low input level. Since conflict is unavoidable at the second stage (when $\theta_1 = \theta_2 = 0$ the players always break the peace, regardless of the input levels), the gains from a unilateral deviation in the first stage would not be retained by a player, and rather be fought over in conflict. The resulting conflict if one player were to deviate is also be more intense; we can see in figure 3.3 that the fight effort for the low-intermediate input combination is greater than for the low-low combination.

Although the intensity of fighting is at its minimum in the benchmark case, surprisingly, the players are worse off in the end than if they had respected the agreement and engaged in conflict: the lower output over-compensates for the wastage from conflict.

We follow the same process for various intrinsic disinclinations and discuss a few interesting cases. We consider only pure strategy input use for simplicity. Results can be found in Table 3.1. In Table 3.1, the first two columns indicate the intrinsic disinclination of player 1 and 2, the second and third columns indicate the input levels of player 1 and 2 at the first stage, and the fifth column indicates the final outcome as peace, conflict or a concession.

3.3.3.3 Symmetric high disinclinations

Suppose there is symmetry in the psychological cost parameter, with $\theta_1 = \theta_2 = 50$. In this case, each player has a strong disinclination to break the peace. In contrast to the benchmark case, the strong disinclination is associated with peaceful over-use of the resource relative to the agreement in the unique equilibrium. Let us see why. In the first stage of the game, each player chooses a high input level, thus violating the agreement over the use of the resource. In the second stage of the game, neither player is willing to punish the other for his deviation. Under symmetric high disinclinations, the peace is maintained despite the broken agreement.

3.3.3.4 Symmetric moderate-high disinclinations

Now let us consider symmetric psychological cost parameters, $\theta_1 = \theta_2 = 40$, wherein each player has a moderate-high disinclination to break the peace. In this case, two SPNE emerge, each of which is peaceful. In one equilibrium, each player violates the agreement by choosing a low input level at the first stage of the game and then maintains the peace at the second stage. In the other equilibrium, each player respects the agreement at the first stage and maintains the peace at the second stage.

To understand why, let us consider the agreement on the resource, we can see that if one player deviates from the agreement by choosing the high input, the following would occur: (1) the deviation increases the psychological cost of breaking the peace for the player who deviates, (2) the deviation reduces the psychological cost of breaking the peace for the player who respects the agreement. (3) the maximum that can be appropriated from breaking the peace increases for the player who respects the agreement relative to the player who deviates. The resulting disparity between the gains and losses from breaking the peace, between the two players, leads the player who respected the agreement to break the peace at the second stage of the game. The player who deviated is forced to concede his entire gains. The end result would be that the player who violated the agreement loses everything and the player who respected the agreement secures the entire gains. The threat of being forced to concede thus effectively deters each player from deviating unilaterally from the agreement to a high input. Under moderate-high symmetric disinclinations to break the peace, an equilibrium exists in which the players peacefully and cooperatively use the resource.

3.3.3.5 Symmetric low disinclinations

Let us consider one more case with symmetric psychological cost parameters, wherein each player has a low disinclination to break the peace. For $\theta_1 = \theta_2 = 20$, three SPNE emerge. In all three equilibria, the players choose low inputs in the first stage of the game. At the second stage, the psychological cost of breaking the peace for each player is low enough that each player prefers forcing a concession over maintaining the peace, but high enough that each player prefers conceding over engaging in conflict. This leads to two concession equilibria in pure strategies at low input level and an equilibrium at low input levels with mixed strategies at the second stage. For these parameter values, the result is therefore under-use of the resource relative to the agreement that can lead to, each with a positive probability, conflict, a concession by either player, or peace.

Surprisingly, the expected payoff for a player from mixed strategies, and from forcing a concession in pure strategies, are greater than his payoff in the benchmark case. However, a conceding player would, of course, be worse off compared to the benchmark.

3.3.3.6 A quarrelsome player and a moderate player

Now let us consider a case with asymmetry in the psychological cost parameters. We first consider the case with $\theta_1 = 30$ and $\theta_2 = 0$; i.e. player 1 is "moderate" and player 2 is "quarrelsome". In this case, the disparity between the psychological costs leads to a disparity in the input choices in the first stage and a concession by player 1 in the second stage. Since $\theta_2 = 0$, breaking the peace is a dominant strategy for player 2 at the second stage of the game for all input combinations. Player 1, on the other hand, maintains the peace at the second stage, for all input combinations. The outcome in the unique equilibrium is for player 1 to restrict his input at the first stage to mitigate his losses from dealing with player 2. That is, player 1 anticipates having to concede everything to player 2 in the second stage. The best response of player 2 to player 1's low input is to violate the agreement by choosing x_H at the first stage. Player 2 then appropriates everything from player 1 at the second stage.

3.3.3.7 A somewhat quarrelsome player and a peaceful player

We consider a final case with asymmetry in the psychological cost parameter, with $\theta_1 = 60$ and $\theta_2 = 20$. We refer to player 1 as "peaceful" and player 2 as "somewhat quarrelsome". In this case, the disparity between the intrinsic disinclinations again leads to asymmetric input choices between the players. At the first stage, both players deviate from the agreement: player 1 chooses a low input and player 2 a high input. At the second stage, due to a high intrinsic disinclination, player 1 is unwilling to punish player 2 by breaking the peace. In turn, despite a relatively lower intrinsic disinclination, player 2 has little to gain from breaking the peace, given the psychological penalty he would still incur. The result is that peace is maintained at the second stage, despite the broken agreement and the unequal distribution of gains from the resource. Although the gains from the resource are not equal between the players, the gains are positive for both players.

3.4 Conclusion

The purpose of this paper has been to examine the use of a contestable resource when the willingness to engage in conflict is influenced by emotions. We have considered a scenario where two players have an agreement to cooperatively use a shared resource and must decide whether or not to respect the agreement, and whether or not to force a redistribution of the gains from the resource. We have assumed that the decision to break the peace carries a psychological cost. This psychological cost is determined endogenously by the players' choices to respect or not the agreement on the use of the resource and an intrinsic disinclination to break the peace.

We have described the scenario through a three-stage game of resource use and conflict. In the first stage, the players each choose their respective inputs in a two-herder model of resource use. In the second stage of the game, the player each choose whether or not to force a redistribution of the gains, given each player's input choice and intrinsic disinclination.

θ_1	θ_2	P_1 input	P_2 input	Outcome
0	**0**	**low**	**low**	**Conflict**
0	10	low	low	Conflict
0	20	intermediate	low	P_2 concedes
0	30	high	low	P_2 concedes
0	40	high	low	P_2 concedes
0	50	high	low	P_2 concedes
10	10	low	low	Conflict
10	20	intermediate	low	P_2 concedes
10	30	intermediate	low	P_2 concedes
10	40	intermediate	low	P_2 concedes
10	50	intermediate	low	P_2 concedes
10	60	intermediate	low	P_2 concedes
20	20	low	low	P_2 concedes
20	20	low	low	P_1 concedes
20	20	low	low	Mixed
20	30	low	low	P_2 concedes
20	40	low	low	P_2 concedes
20	50	intermediate	low	Peace
20	60	high	low	Peace
30	30	low	low	Peace
30	40	low	low	Peace
30	50	intermediate	low	Peace
40	40	low	low	Peace
40	40	intermediate	intermediate	Peace
50	50	high	high	Peace
50	60	high	high	Peace

Table 3.1: SPNE for various values of θ_1 and θ_2

There are three possible outcomes in the second stage: the concession of the gains from the resource by one player to the other, conflict over the gains from the resource, or peace, in which each player retains his individual gain from the resource. In the conflict outcome, we have modeled the conflict as a contest over the gains from the resource such that the psychological costs do not affect conflict intensity. Finally, we have simulated the game for various values for the players' intrinsic disinclinations to break the peace.

We find that the fighting in conflict is less intense under certain circumstances, when the players have under-used the resource compared to when the players have over-used the resource or respected the agreement. Also, we have found that under some circumstances, when the players have symmetric, low intrinsic disinclinations, the players under-use the resource relative to the agreement and engage in conflict over the resource. When the players have symmetric high initial disinclinations, the players over-use the resource relative to the agreement and maintain the peace. Whereas, when the players have symmetric intermediate intrinsic disinclinations, the players can respect the agreement by cooperatively using the resource and maintain the peace. We also describe two scenarios with asymmetric intrinsic disinclinations, one in which a concession occurs and one in which the peace is maintained despite one player being exploited.

Our analysis highlights the importance of an agreement and the potential for emotions to affect the use of a shared resource when there is a potential for conflict. Further research could include identifying the input strategies available to each player, such as a deterrence input strategy, or introducing a bargaining problem.

Chapter 4

Posturing of Bellicose Souls

4.1 Introduction

Hirshleifer tells us we can not know the true relative benefits and costs of the choice between cooperation and conflict, and rather we must act on the basis of perceptions (Hirshleifer, 2001).

The two well-studied core determinants of conflict are the terms of the (peaceful) *sharing arrangement* and the players' *strengths* under conflict. A third determinant, *peaceability,* referring to a player's predisposition towards conflict, also plays a key role (Chapter 2). However, a player's peaceability is likely the main source of incomplete information as it is difficult to observe. As far as we could tell, no-one has yet considered how perceptions about an opponent's predisposition towards conflict interact with the two core determinants in situations of potential conflict.

We examine the role of uncertainty regarding peaceability in a simple model of conflict, as conceived in Chapter 2. In that model, players are offered to share a prize according to an exogenous sharing rule, and choose between accepting the sharing rule or engaging into a wasteful fight that leads to a different sharing outcome. Peaceability in the model takes the form of a fixed cost incurred by a player who chooses to engage. The fighting technology is such that if a player engages into a fight while the other does not, then the first player collects the entire prize. In this paper, we examine the problem when there is either one-sided or two-sided incomplete information about peaceabilities.

In the one-sided incomplete information setting, we explore how beliefs about an opponent's true nature affect the decision to engage in conflict (or not) when there is uncertainty regarding the true nature of the other player. In the two-sided information setting, we examine how variations in the configuration of fighting strengths and peaceful shares affect the probability of conflict when the true nature of each player is known only to himself.

In a similar setting, Baliga and Sjöström (2012) analyze a conflict game with incomplete information; they assume, however, (the equivalent of) symmetrical status quo shares and fighting strengths. More recently, Baliga and Sjöström (2015) consider the role of asymmetric strengths when there is uncertainty about an opponent's cost of making a challenge. But they do so in a different conflict setting where those strengths depend on the presence of a first-mover advantage and status quo shares are still assumed equal. In our analysis, we allow for asymmetries along the three important dimensions of conflict: the peaceful shares, fighting strength and fixed costs (peaceability).

Another important paper worth mentioning is Gretlein et al. (1996), who consider the decision to engage in conflict (or not) when parties have private information about their relative strength. What we consider here is different; we are concerned with uncertainty regarding a players' predisposition towards conflict that is distinct from his strength. While Gretlein et al. assume symmetric fixed costs of engaging, we allow for asymmetry in the cost associated with conflict engagement. This allows us to analyze the role of uncertainty regarding an opponent's true nature towards conflict.

In our model, peaceability is understood as a predisposition to avoid conflict, and expressed as fixed cost of engaging; it's worth noting that fixed costs associated with conflict can take many forms depending on the context. Here are some examples. In the case of war between countries, one thinks of the costs of preparing an army before actual confrontations begin; i.e. armament costs (Gretlein et al. 1996; Baliga and Sjöström 2015) and the losses from reduced trade during hostilities (Brito and Intriligator, 1985). When it comes to ending a conflict, one purpose of peace treaties and nonaggression pacts is to increase the initial cost of resuming conflict for its violator that take the form of reputation costs (Mattes and Vonnahme, 2010). Similarly, by publicly committing not to go to war, the leader of a country raises the fixed cost of "revoking the commitment" (Ellingsen and Miettinen, 2008). In the case of a trial, the parties may have to incur large preparation costs before the actual trial begins (Gretlein et al., 1996). If two former partners must split the gains after dissolving a partnership, each may anticipate to suffer significant psychological costs (guilt or emotions) associated with engaging into a conflict with a (former) friend or loved one; this would apply to business partnership as well as divorce situations (Dufwenberg, 2002). In all of these settings, one can easily imagine situations with uncertainty about an opponent's fixed cost.

In the one-sided incomplete information setting, we obtain that the introduction of uncertainty about another player's peaceability either increases or decreases the scopes for conflict and peace equilibria compared to the setting with complete information described in Chapter 2. We show that which effect prevails hinges on the configuration of the players' fighting strengths and peaceful shares.

Now, imagine that in some situations, one may wish to impress a peaceable (or not so peaceable) nature. Roosevelt promised Americans: "Your boys are not going to be sent into any foreign wars" during the 1940 election campaign and prior to the United States entering World War II (Encyclopaedia Britannica, 2019b). In the recent past, Ronald Reagan and Mikhail Gorbachev agreed to a reduction in nuclear arsenals; Reagan is often perceived as having been bellicose in his initial attitude towards the Soviet Union (Encyclopaedia Britannica, 2019a).

In the one-sided information setting, we illustrate how a player who's true peaceability is unknown to his opponent has the incentive to misrepresent his true nature. In a scenario that highlights the potential for *bellicose posturing*, a player who is truly peaceable and a player who is *bellicose* by nature both have the incentive to portray themselves as bellicose. Keep in mind that bellicosity pertains to an individuals' eagerness to fight; and so a less peaceable player is often referred to as *more bellicose* in the analysis.

In another scenario, the potential for *peaceable posturing* emerges in which a player has the incentive to portray himself as peaceable, regardless of his true nature. Whether the player has the incentive to portray himself as bellicose or peaceable depends on the configuration of peaceful shares and fighting strengths.

In the two-sided information setting, we illustrate scenarios for variations in the sharing rule and fighting strength configuration. In a scenario with symmetrical strengths and shares, we show that increasing the peaceful share of one player increases the probability that he engages in conflict and decreases the probability that his opponent does the same, when conflict is highly non-destructive. Conversely, when conflict is highly destructive, increasing the peaceful share of a player decreases the probability that he engages in conflict and increases the probability of engagement by his rival.

Also in the two-sided incomplete information setting, we obtain that increasing the relative strength of one player increases the probability that she engages, but the effect on the likelihood of conflict depends on the configuration of fighting strength and peaceful shares of his opponent. These scenarios underscore the importance of the interaction between the core determinants of conflict in understanding the role of uncertainty regarding peaceability.

In the existing literature, arguably the most important paper for our own is Battigalli et al. (2015), who borrow from psychology. The authors explore behavioral consequences of emotions, specifically frustration and anger expressed through blame and aggression. They look at decision-making by anger-prone individuals when frustration drives anger; where "frustration depends on beliefs about others' choices, and the blame a player attributes to another can depend on his beliefs about others' choices or beliefs" (p. 72). In the game, a player makes inferences about others' intentions.[1] In our paper, peaceability represents a

[1] The solution concept is a generalization of a sequential equilibrium (a solution concept applied to psychological games) (Battigalli et al., 2015).

characteristic of the individual that is *belief-independent* and accounts for proneness to aggression. Importantly, a player holds beliefs about the other player's predisposition (peaceability) and not her intentions.[2] We find that analyzing this distinct problem in a simple Bayesian-Nash setting yields important insight into the role of aggression in conflict.

The paper is organised as follows. The game is described in the next section. In section 4.3, we consider the Bayesian Nash equilibrium with one-sided and two-sided incomplete information and explore various scenarios. Section 4.4 concludes.

4.2 The game

4.2.1 The general setting

We consider a setting with two players, 1 and 2, and incomplete information about types. A players' type is determined by his *peaceability*, as conceived in Chapter 2, and refers to a player's predisposition towards conflict. Peaceability takes the form of a fixed cost, $b_i \geq 0$, $i \in 1, 2$, which is higher for a *more peaceable* player, and thus lower for a player who is *more bellicose* (less peaceable). Player i is said to be *fully bellicose* if he is wholly unpeaceable, i.e. if $b_i = 0$.

In a one-shot game, the players choose to engage in conflict over a common value prize V or to accept an exogenous peaceful sharing arrangement, denoted $G = (g_1, g_2)$. If player i chooses to reject the peaceful sharing arrangement and engage in conflict, he incurs the fixed cost, b_i. Under the peaceful sharing arrangement, player i, $i \in \{1, 2\}$ is offered $g_i = s_i V$, where s_i is player i's exogenous share. No peaceful arrangement allocates the entire prize to one player, so that $s_i > 0\ \forall i$ and there is no waste when the prize is peacefully shared, i.e. $s_1 + s_2 = 1$.

If both players engage in conflict (reject the sharing rule) then fighting ensues. The

[2] Proneness to aggression is discussed in Chapter 1. The concept of peaceability is introduced in Chapter 2.

outcome of fighting is represented by $F = (f_1, f_2)$, where player i, $i = \{1, 2\}$ receives a part of the prize from fighting, $f_i = r_i V$ and bears his fixed cost b_i. The portion of the prize awarded to player i through fighting is r_i, with $r_i \geq 0$. Wastage or destruction from fighting is implied by $r_1 + r_2 < 1$; so that conflict does not simply represent a peaceful renegotiation of the sharing arrangement. The part of a prize secured by a player through fighting is often referred to as his *fighting strength*.

If only one player engages in conflict while the other does not, then the engaging player takes the whole prize in a concession. More formally, if player i chooses to engage in conflict while player j accepts the peaceful arrangement, then player j concedes the entire prize to i, $i \neq j$. Under a concession by player j, player i receives V, but incurs his fixed cost b_i and player j receives nothing, but is spared his fixed cost b_j. It is important to note that player i's incremental gain from forcing a concession, i.e., net of his initial share, is equal to player j's initial share, i.e., $V - g_i = g_j$.

Player i's choice to engage in a fight or not is made simultaneously with player j and is represented by $\epsilon_i \in \{IN, OUT\}$. A player chooses IN to engage in conflict and OUT otherwise. The final payoff for player i is $v_i(\epsilon_i, \epsilon_j)$. The payoffs are summarized in figure 4.1 (figure 2.1 in Chapter 2).

		Player 2	
		IN	OUT
Player 1	IN	$f_1 - b_1, f_2 - b_2$	$V - b_1, 0$
	OUT	$0, V - b_2$	g_1, g_2

Figure 4.1: The game

Clearly, the strengths, shares, and peaceabilities can differ between the players, and there are two distinct configurations that arise.

Configuration 1: $f_i < g_j$ $\forall i$. Consistent with Chapter 2, we refer to player i as *opportunistically inclined* if $f_i < g_j$. For this player, the gain from engaging net of the payoff from not engaging, is greater when his opponent plays OUT over IN. In this configuration, both players are said to be opportunistically inclined.

Configuration 2: $f_i < g_j$ and $f_j > g_i$; $i \neq j$. Consistent with Chapter 2, we refer to player j as *inclined to match* if $f_j > g_i$. For this player, the gain from engaging net of the payoff from not engaging is greater when his opponent plays IN over OUT. In this configuration, player i is opportunistically inclined and player j is inclined to match.

In this game, players have incomplete information about types (peaceabilities). For the solution to the game with complete information, we refer to Chapter 2. The conditions for an equilibrium in pure strategies under complete information are summarized as follows.

Peace. The necessary and sufficient conditions for a peace equilibrium in pure strategies are $g_j - b_i < 0, \forall i \neq j$.

Conflict. The necessary and sufficient conditions for a conflict equilibrium in pure strategies are $f_i - b_i \geq 0, \forall i$

Concession by i. A sufficient condition for a concession equilibrium in pure strategies is $b_i \geq f_i$ and $b_j < g_i$, $i \neq j$.

The game with complete information also admits mixed strategy equilibria that are discussed in Chapter 2.

4.2.2 Information

The players have incomplete information about types as follows. Player i knows the value of his own peaceability, b_i but is uncertain about player j's peaceability, b_j. Rather, players hold a *belief* about each other's peaceability level; these beliefs are represented by a prior probability distribution over a set of possible b_i values, $i = \{1, 2\}$. Beliefs are common knowledge, as are the players' strengths and peaceful shares.

The game with one-sided incomplete information is described in the next section and with two-sided incomplete information in section 4.2.2.2.

4.2.2.1 One-sided incomplete information

In the one-sided incomplete information setting, player 1's peaceability level is perfectly known to both players and takes on any value $b_1 \in [0, +\infty]$. Nature determines player 2's peaceability level: $b_2 = \underline{b}$ with probability ϕ and $b_2 = \bar{b}$ with probability $1 - \phi$. We refer to $\underline{b}$ as a *bellicose* type and $\bar{b}$ as a *peaceable* type.

In this setting, we impose the following inequalities: $\underline{b} < f_2 < g_1 < \bar{b}$, so that $f_1 < g_2$ or $f_1 > g_2$. Before the game begins, player 2 observes her own peaceability level with certainty. Player 1's prior beliefs are that player 2 is bellicose with probability ϕ and peaceable with probability $1 - \phi$.

4.2.2.2 Two-sided, incomplete information

In the two-sided, incomplete information setting, each player is uncertain about the other player's peaceability level. Player j, $j \neq i$, believes that player i's b_i value follows density distribution $d(b_i)$ with $b_i \in [0, +\infty]$, and the associated cumulative distribution $D(b_i)$.[3]

4.3 Bayesian Nash equilibrium

To find a Bayesian Nash equilibrium (BNE) for this game, we need a pair of strategies $(\epsilon_1^*(\cdot), (\epsilon_2^*(\cdot))$ such that $\epsilon_i^*(\cdot)$ maximizes player i's expected payoff $E_{b_j} v_i(\epsilon_i, \epsilon_j^*(b_j), b_i)$, for both players and all types.[4]

[3]To simplify the analysis, we assume that each player has the same distribution function. It would be straightforward to assume that players have different distribution indexed as follows $d_i(b_i)$, $i = 1, 2$, but no new insight would be gained.

[4]The notation and equilibrium derivation procedure are inspired by Fudenberg and Tirole (1991:chapter 6).

Let ρ_j denote the probability that player j chooses IN, given j's equilibrium strategy $\epsilon_j^*(b_j)$ and player i's priors over types b_j. For a player i of type b_i, the expected gain from playing IN is

$$\rho_j(f_i - b_i) + (1 - \rho_j)(V - b_i) \tag{4.1}$$

The expected gain for player i of type b_i from playing OUT is

$$\rho_j(0) + (1 - \rho_j)g_i \tag{4.2}$$

Player i will consequently choose IN if, and only if expression 4.1 is greater than expression 4.2, i.e., if $\rho_j f_i + (1 - \rho_j)V - b_i > (1 - \rho_j)g_i$. There is therefore a *cutoff type* b_i^* who will be indifferent between playing IN or OUT. After rearranging a little, we find that the cutoff type is given by the following equality:

$$\rho_j f_i + (1 - \rho_j)g_j - b_i^* = 0, \quad i \neq j. \tag{4.3}$$

The following terms will be useful in the analysis.

Definition 1: Expected net gain from engaging. Let the expected net gain from engaging $E(NGE)$, denote the expected gain that type b_i of player i makes from engaging, given by the left hand side of expression (4.3), where b_i^* is replaced with b_i.

Definition 2: Cutoff type (b_i^*). Let the cutoff type b_i^* denote the peaceability level that makes the expected net gain from engaging ($E[NGE]$) equal to zero.

If player i is more peaceable than the cutoff type, i.e., $b_i > b_i^*$, then he strictly prefers not to engage. When he doesn't engage, he faces a probability ρ_j of conceding everything and a probability $(1-\rho_j)$ of retaining his peaceful share. Keep in mind that ρ_j denotes the probability that player j chooses IN. On the other hand, if player i is less peaceable than the cutoff type, i.e., $b_i < b_i^*$, then he strictly prefers to engage. When he engages, a conflict occurs with probability ρ_j and a concession by player j occurs with probability $1-\rho_j$. We thus have the monotonicity property for all types: i's best strategy is to play IN when $b_i < b_i^*$.

The following proposition derives directly from expression (4.3):

Proposition 4.1 *Assume that a BNE in pure strategies exists. If $f_i < g_j$, then $f_i < b_i^* < g_j$ and b_i^* decreases with ρ_j. Otherwise, if $g_j < f_i$, then $g_j < b_i^* < f_i$ and b_i^* increases with ρ_j.*

This proposition underscores the fact that the manner in which uncertainty affects the likelihoods of conflict and peace equilibria relies importantly on a comparison of the sharing rule and the fighting abilities, in other words, on whether a player is opportunistically or matching inclined.

In order to gain insight, we first analyze the game in the one-sided incomplete information setting. We then turn our attention to the setting with two-sided incomplete information.

4.3.1 One-sided, incomplete information

In the one-sided setting, player 1's type is known to both players and player 2 is believed by player 1 to be a bellicose type ($b_2 = \underline{b}$) with probability ϕ or a peaceable type ($b_2 = \bar{b}$) with probability $1-\phi$. Player 2 observes his own type.

Proposition 4.2 *A Bayesian Nash equilibrium of the one-sided, incomplete information game is one in which:*

- *Player 1 chooses IN if, and only if, $b_1 < b_1^*$ where $\rho_2 = \phi$;*
- *A bellicose player 2 of type $\underline{b}$ plays IN;*
- *A peaceable player 2 of type $\bar{b}$ plays OUT.*

Proof: From player 1's perspective, player 2 plays IN with probability ϕ and OUT with probability $1-\phi$. Player 1's cutoff type is thus given by expression (4.3) with $\rho_2 = \phi$. Hence, player 1's strategy maximizes his expected payoff. As for player 2, it is easy to verify that IN (OUT) is a dominant strategy when $\underline{b} < f_2 < g_1$ ($\bar{b} > g_1 > f_2$). QED

Conflict as a Bayesian Nash equilibrium: We refer to an equilibrium in which both players choose IN as a *conflict equilibrium.* Conflict is the unique Bayesian Nash equilibrium in pure strategies if and only if $b_1 < b_1^*$ and $b_2 = \underline{b}$.

Peace as a Bayesian Nash equilibrium: We refer to an equilibrium in which neither player engages, i.e. both players choose OUT, as a *peace equilibrium.* Peace is the unique Bayesian Nash equilibrium in pure strategies if and only if $b_1 > b_1^*$ and $b_2 = \bar{b}$.

Concession by i as a Bayesian Nash equilibrium:

a) Assume that $b_2 = \bar{b}$ and $b_1 < b_1^*$. Player 1 chooses IN and player 2 chooses OUT so that concede by 2 is the unique Bayesian Nash equilibrium.

b) Assume that $b_2 = \underline{b}$ and $b_1 > b_1^*$. Player 1 chooses OUT and player 2 chooses IN so that concede by 1 is the unique Bayesian Nash equilibirum.

The properties of the equilibrium are conveniently represented with the help of figure 4.2. Illustrated are the regions associated with peace (*peace*), conflict (*conflict*), a concession by player 1 (*C1*) and a concession by player 2 (*C2*) as a Bayesian Nash equilibrium. The results differ drastically between when $g_2 > f_1$ in *a)* to those with $g_2 < f_1$, in *b).* In case a) of figure 4.2, both players are *opportunistically inclined*; in case b), player 2 is *opportunistically inclined* and player 1 is *inclined to match.* [5]

[5] Note that in the two graphs, the region where b_2 values fall between f_2 and g_1 will never occur as we assumed that $\underline{b} < f_2 < g_1 < \bar{b}$. It is therefore left blank.

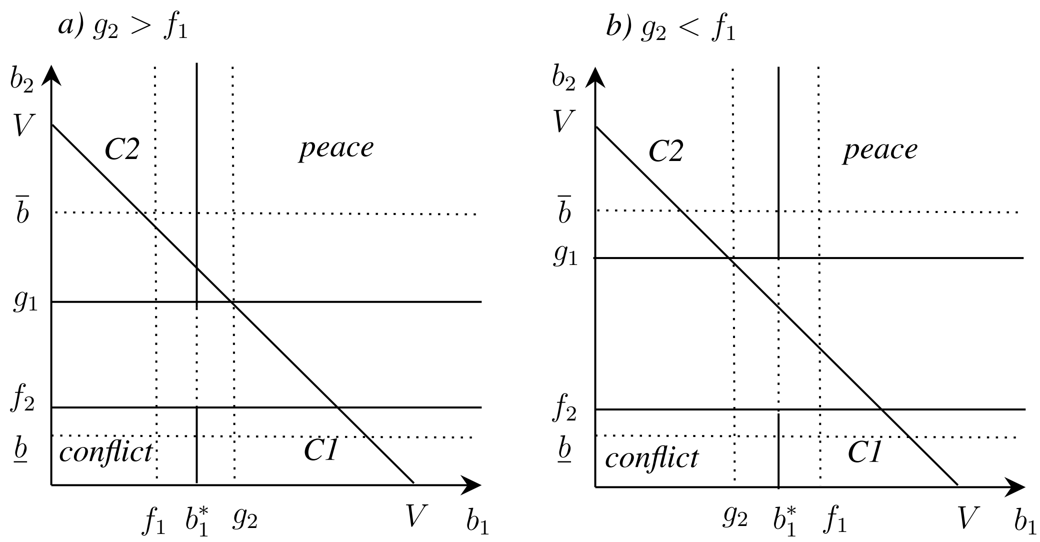

Figure 4.2: BNE with one-sided incomplete information

4.3.1.1 Reduced scopes for peace and conflict ($g_2 < f_1$)

We examine the scopes for peace and conflict compared to the setting with complete information, described in Chapter 2 of this thesis and summarized in section 4.2.1. The scopes for peace and conflict are illustrated in figure 4.3. As we will see, the way in which uncertainty affects the scopes for peace and conflict depends on the configuration of the fighting strengths and peaceful shares. We begin with case b).

In case b) of figure 4.3, $g_2 < f_1$ implies that the cutoff type is a matcher. The points F and G correspond to the configuration of fighting strengths, $F = (f_1, f_2)$ and peaceful shares, $G = (g_1, g_2)$. In this case, uncertainty over player 2's type reduces the scopes for *both* conflict and peace equilibria compared to the results under complete information from Chapter 2, described in section 4.2.1. Let us see why.

Suppose first that player 2's true type is bellicose, i.e., $b_2 = \underline{b}$. If player 1 knew player 2's type with certainty, then he would engage in conflict for all $b_1 < f_1$ and concede otherwise. To understand why, consider player 1's payoffs when player 2 chooses IN, player 1 receives $f_1 - b_1$ if he responds by engaging in conflict with player 2 and 0 if he concedes. However, player 1 is uncertain about player 2's true type, and so conflict occurs only when $b_1 < b_1^*$.

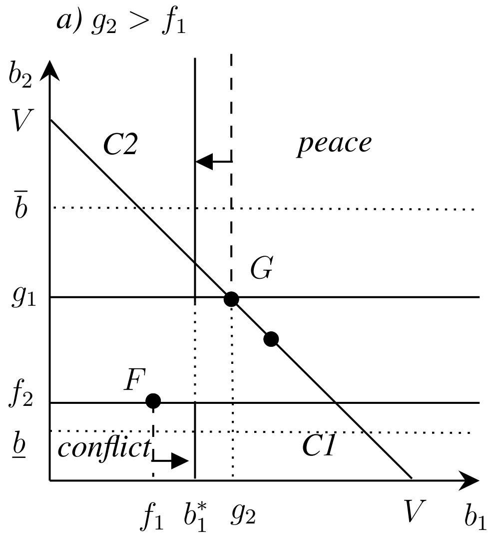

Figure 4.3: Scope for peace and conflict

Since $b_1^* < f_1$, the range of b_1 values for which conflict occurs has been reduced by uncertainty. The following provides an interpretation for this outcome.

Consider the case where player 1's type is such that $b_1 = f_1$. If player 1 knows that $b_2 = \underline{b}$ with certainty ($\phi = 1$), he knows that player 2 will choose IN no matter what. Player 1 is then *indifferent* between IN or OUT, his net gain being zero in both cases. Imagine now that from the perspective of player 1, there is some positive probability that player 2 be of type $\bar{b}$ ($\phi < 1$); this means that player 2 will play OUT with some positive probability. If player 2 chooses OUT, player 1's gains for IN and OUT are $V - b_1$ and g_1, respectively. Now given that $b_1 > g_2$, we have $g_1 > V - b_1$; hence, player 1 *strictly* prefers a peace equilibrium over one where player 2 concedes. Consequently, player 1 is not indifferent anymore, he strictly prefers to play OUT when $\phi < 1$ and $b_1 = f_1$. Player 1 will thus choose to stay OUT for some range of values $b_1 < f_1$ and will end up conceding against a low type $\underline{b}$, though with regrets *ex-post*. That said, further decreases in b_1 raise the attractiveness of a concession by player 2 (C2) relative to peace, we therefore expect to find a value of b_1 for which player 1 will be indifferent between playing IN or OUT.

Consider now the case with $b_1 = g_2$. If $b_2 = \bar{b}$ with certainty ($\phi = 0$), player 2 stays OUT and player 1 is indifferent between playing IN or OUT. Introducing a positive probability that player 2 is of type $\underline{b}$ means that player 1 now expects player 2 to choose IN with positive probability. If player 2 chooses IN, player 1's gains for IN and OUT are $f_1 - g_2$ and 0, respectively. Given that $g_2 < f_1$, player 1 now strictly prefers to play IN when $\phi > 0$. Player 1 will thus choose to play IN for a range of peaceability values $b_1 > g_2$ and will end up forcing player 2 to concede when $b_2 = \bar{b}$ even though he would have strictly preferred to share peacefully. As b_1 increases, however, the attractiveness of playing IN for player 1 diminishes and we expect that he will eventually prefer to stay OUT.

The above discussion suggests the presence of a cutoff value $b_1 \in (g_2, f_1)$ for which player 1 switches from IN to OUT; this value precisely corresponds to b_1^*. It also suggests that the higher the probability that player 2 is of type $\bar{b}$, the higher the range of b_1 values over which player 1 will play IN, and conversely. This is indeed the case when $f_1 > g_2$ in expression (4.3). But as we shall see, things are different with $f_1 < g_2$.

4.3.1.2 Enlarged scopes for peace and conflict ($f_1 < g_2$)

This case is illustrated in part a) of figure 4.3. We see that the presence of uncertainty now has the opposite effect, i.e., it enlarges the scopes for both conflict and peace. The details of the argument are analogous to those made in the previous case, and so we go over them briefly.

In this case, once again suppose that player 2's true type is bellicose, i.e., $b_2 = \underline{b}$. If player 1 knew player 2 is bellicose with certainty, then player 1 would engage in conflict for all $b_1 < f_1$ and concede otherwise. When player 1 is uncertain about player 2's type, he only engages when $b_1 < b_1^*$. So, we see that when $b_1^* > f_1$, the range of values of b_1 for which conflict occurs is increased by uncertainty. Suppose that instead player 2's true type is peaceable, i.e., $b_2 = \bar{b}$. If player 1 knew that player 2 is peaceable with certainty, then player 1 stay OUT for all $b_1 > g_2$ (remember that a peaceable player 2 always chooses OUT and player 1's payoff from choosing IN (OUT) when player 2 chooses OUT is $V - b_1$ (g_1)). When player 1 is uncertain about player 2's type, he chooses OUT only when $b_1 > b_1^*$. So, we see that when $f_1 < g_2$, uncertainty increases the scope for peace.

4.3.1.3 Variations in player 1's (exogenous) belief, ϕ

The above discussion underscores the fact that the presence of uncertainty over peaceable types does not uniformly affect the probabilities of conflict and peace occurring. Indeed, one must also account for its interaction with both the sharing rule and the fighting strengths. The potential for peace and conflict also depend on player 1's beliefs about player 2's type. To better picture this, let us consider the following scenarios.

Scenario 1: Bellicose posturing ($f_1 < g_2$)

Consider a scenario in which players are equal in conflict and the initial peaceful sharing arrangement is egalitarian, i.e. $f_1 = f_2$ and $g_1 = g_2$. In this scenario, $f_i < g_j$, $\forall i \neq j$ due the wastage and destruction associated with conflict. Player 1's peaceability level is $\hat{b_1}$, with $\hat{b_1} < b_1^*$. He believes with probability ϕ that player 2 is bellicose and with probability $1 - \phi$ that player 2 is peaceable. The scenario is illustrated in figure 4.4.

In this scenario, player 1 would engage. If player 2 is peaceable, he concedes everything to player 1, whereas if player 2 is bellicose, a fight ensues. Now, suppose that player 1 acquired new information about player 2's peaceability, so that player 1 now believes with probability ϕ' player 2 is bellicose. We denote the new cutoff type $b_1'^*$, where $b_1'^*$ satisfies expression (4.3) for $\rho_2 = \phi'$. Suppose that under the new information, $b_1'^* < \hat{b_1}$, wherein player 1 now strictly prefers not to engage with player 2. From proposition 4.1, we know that b_1^* decreases with ϕ when $f_1 < g_2$, so it must be the case that $\phi' > \phi$. In other words, player 1 strengthened his belief that player 2 is bellicose.

In this scenario, the stronger belief that player 2 is bellicose deters player 1 from engaging in conflict. When player 1 is deterred, player 2 benefits regardless of his type: the peaceable player 2 retains his initial share g_2 when he previously received nothing. The bellicose player incurs $\underline{b}$ either way, but takes the entire prize V in a concession when player 1 is deterred,

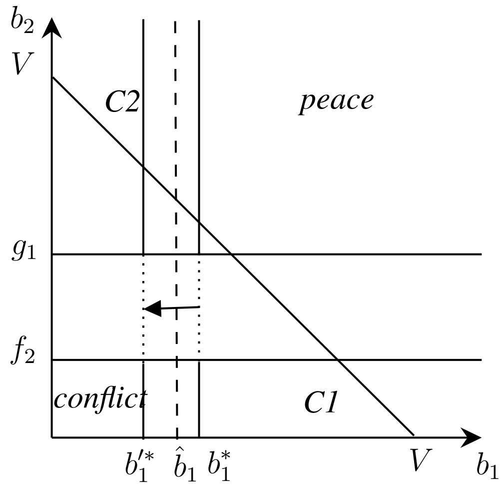

Figure 4.4: Bellicose posturing ($g_2 > f_1$)

compared the portion he would have been granted in conflict, f_2. Clearly, in this scenario, player 2 has an incentive to make player 1 believe that he is bellicose even when he is not.

Scenario 2: Peaceable posturing ($g_2 < f_1$)

Here, player 1 is much stronger than player 2 in conflict, so that $g_2 < f_1$. Player 1 has peaceability level $\hat{b_1}$; he believes with probability ϕ that player 2 is bellicose and with probability $(1 - \phi)$ that player 2 is peaceable. The scenario is illustrated in figure 4.5.

Suppose that player 1 is initially poised to engage with player 2, i.e. $\hat{b_1} < b_1^*$, when new information appears to suggest that player 2 is more likely to be bellicose than initially thought. Let ϕ' denotes player 1's new belief that player 2 is bellicose, with $\phi' > \phi$. The new cutoff type, $b_1'^*$ satisfies expression (4.3) for $\rho_2 = \phi'$. From proposition 4.1, we see that b_1^* increases with ϕ when $g_2 < f_1$, so it must be the case that $b_1'^* > b_1^*$. In this scenario, shown in part a) of figure 4.5, the strengthened belief that player 2 is bellicose does not deter player 1.

Suppose instead that player 1 had a higher initial peaceability level, $\hat{b_1}'$, where $b_1^* < \hat{b_1}' < b_1'^*$ (not shown). In which case, the stronger belief that player 2 is bellicose leads player 1 to engage when he previously wouldn't have. Under these conditions, player 2 stood to

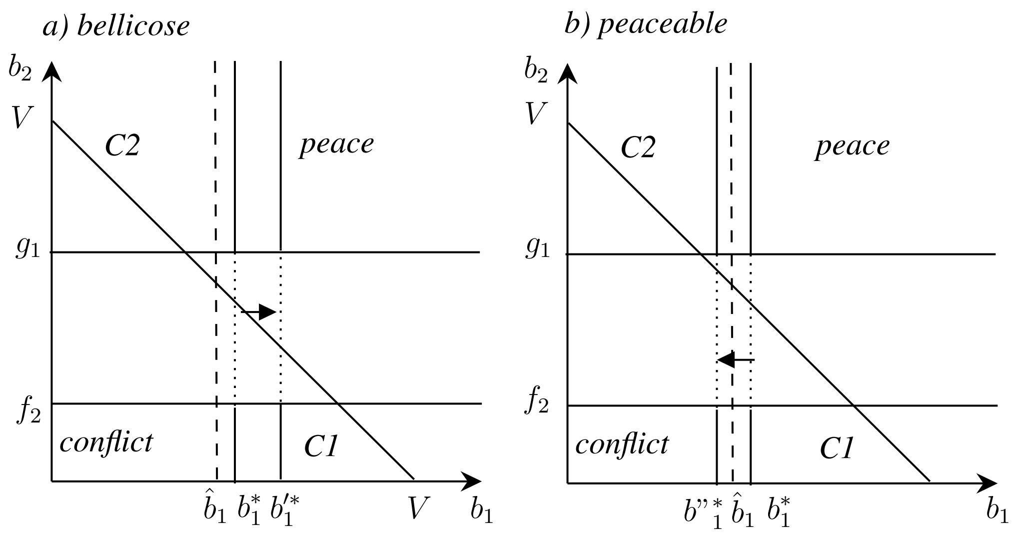

Figure 4.5: Bellicose vs peaceable posturing ($g_2 < f_1$)

receive his initial share when facing player 1 of type $\hat{b_1}'$ before the new information appeared, compared to nothing when player 1's beliefs changed. A bellicose player 2 stood to gain $V-\underline{b}$ when facing the same player 1 before the new information, but only $f_2-\underline{b}$ afterward. Clearly, bellicose posturing is not always good for player 2!

In this scenario, Player 2 is better off portraying himself of as peaceable, regardless of his true nature. Consider Part b) of figure 4.5, where player 1 prefers not to engage when the cutoff type is $b_1''^*$, where $b_1''^* < b_1^*$. If $b_1''^*$ satisfies expression (4.3) for $\rho_2 = \phi''$, then from proposition 4.1, we know we must have $\phi'' < \phi$. In other words, player 1 no longer wishes to engage with player 2 when his belief that player 2 is bellicose is weakened.

4.3.2 Two-sided, incomplete information

We now turn our attention to the setting with two-sided incomplete information, described in section 4.2.2.2. In this setting, both players have incomplete information about the other's type. Player i's peaceability level is drawn from the density distribution $d(b_i)$ where $b_i \in [0, +\infty]$; the associated cumulative distribution is $D(b_i)$. The distribution from which player i's type is drawn is known by player j, $i \neq j$.

In accordance with expression (4.3), if b_j^* is the cutoff type for player j, then the probability ρ_j that she will play IN is equal to $D(b_j^*)$. Given the fighting strengths f_i and sharing rule g_i, $i = 1, 2$, the two cutoff types b_1^* and b_2^* are thus defined by the following set of two equations:

$$D(b_2^*)f_1 + (1 - D(b_2^*))g_2 - b_1^* = 0 \tag{4.4}$$

$$D(b_1^*)f_2 + (1 - D(b_1^*))g_1 - b_2^* = 0 \tag{4.5}$$

Proposition 4.3 *A Bayesian Nash equilibrium of the two-sided, incomplete information game described above is one in which player i chooses IN if, and only if,* $b_i < b_i^*$, $i = \{1, 2\}$.

Proof: When player 2 plays IN with probability $D(b_2^*)$ and OUT with probability $1 - D(b_2^*)$, player 1's cutoff type is given by expression (4.4). When player 1 plays IN with probability $D(b_1^*)$ and OUT with probability $1 - D(b_1^*)$, player 2's cutoff type is thus given by expression (4.5). Hence, player 1 and 2's strategies each maximize their respective expected payoffs. QED

From proposition 4.3, we find the probability of conflict is given by $D(b_1^*)D(b_2^*)$ while the probability of peace is given by $(1 - D(b_1^*))(1 - D(b_2^*))$. For given peaceability distributions $d(b_i)$, we are now in a position to analyse the effects of variations in the sharing rule and fighting strengths.

4.3.2.1 Variations in the sharing rule

Let us analyse the effect of increasing the peaceful share g_1 of player 1. Through implicit differentiation, and using the fact that $g_2 = V - g_1$, we have

$$\frac{db_1^*}{dg_1} = \frac{-(1 - D(b_2^*)) + (1 - D(b_1^*))d(b_2^*)(f_1 - g_2)}{\Delta}, \tag{4.6}$$

$$\frac{db_2^*}{dg_1} = \frac{(1 - D(b_1^*)) - (1 - D(b_2^*))d(b_1^*)(f_2 - g_1)}{\Delta}, \tag{4.7}$$

where $\Delta = 1 - d(b_1^*)d(b_2^*)(f_1 - g_2)(f_2 - g_1)$. Expressions (4.8) and (4.9) underscore the presence of a complex nexus between the sharing rule, the fighting strengths, and the distribution over peaceability in the manner in which it affects the likelihood of conflict. While it is not possible to provide some general results, we can shed some light on the forces at work by considering various scenarios.

Scenario 1 Suppose that there is symmetry in the fighting strengths and peaceful shares, i.e., $f_1 = f_2$, $g_1 = g_2 = 0.5V$. Note that this necessarily implies that both players are opportunistically inclined, i.e., $f_1 < g_2$ and $f_2 < g_1$, in which case the sign of the denominator Δ is ambiguous. One can however draw some conclusions in terms of the conflict's *destructiveness*.

Suppose that the conflict involves very little waste and destruction.[6] At the limit of a non-destructive conflict, we have $f_1 - g_2 \approx 0$ and $f_2 - g_1 \approx 0$, such that $\Delta \approx 1$. By inspection of expressions (4.8) and (4.9), we then have $db_1^*/dg_1 < 0$ and $db_2^*/dg_1 > 0$. *Under symmetrical strengths and shares, and a non-destructive conflict, increasing the share of player 1 will lower the probability that player 1 engages and increase that of player 2.*

If, on the other hand, the conflict is highly wasteful and destructive, then we may have $\Delta < 0$, in which case increasing the peaceful share of player 1 will now increase the probability that player 1 engages and reduce that of player 2.

Scenario 2 Suppose we have $f_1 > g_2$ and $f_2 < g_1$. In this scenario, player 1 is inclined to match and player 2 is opportunistically inclined. This implies that $\Delta > 0$ and $db_2^*/dg_1 > 0$. The sign of $db_1^*/dg_1 > 0$ is, however, indeterminate. In other words, increasing the share of player 1 increases the probability that the opportunistically inclined player 2 engages, but the effect on the likelihood of conflict is ambiguous.

[6]This would be the case, for instance, when a conflict success function is not very *decisive*. (See Hirshleifer, 1995.)

4.3.2.2 Variations in the fighting strengths

Let us now analyse the effect of increasing the fighting strength f_1 of player 1, while f_2 remains unchanged. We have,

$$\frac{db_1^*}{df_1} = \frac{D(b_2^*)}{\Delta}, \tag{4.8}$$

$$\frac{db_2^*}{df_1} = \frac{d(b_1^*)(f_2 - g_1)}{\Delta}. \tag{4.9}$$

Scenario 1 Suppose that there is symmetry in the fighting strengths and peaceful shares, i.e., $f_1 = f_2$, $g_1 = g_2 = 0.5V$. This implies that both players are opportunistically inclined, i.e., $f_1 < g_2$ and $f_2 < g_1$. At the limit of a non-destructive conflict, we have $\Delta \approx 1$. This gives $db_1^*/df_1 > 0$ and $db_2^*/df_1 < 0$. An increase in player 1's fighting strength increases the probability that player 1 engages and reduces that of player 2. Or, in other words, player 2 believes the relatively stronger player 1 is now more likely to engage, whereas player 1 believes the relatively weaker player 2 is less likely to engage. The increased strength of player 1 thus has an ambiguous effect on the likelihood of conflict.

Scenario 2 Suppose we have $f_1 > g_2$ and $f_2 < g_1$; player 1 is inclined to match and player 2 is opportunistically inclined. This implies that $\Delta > 0$ and again $db_1^*/df_1 > 0$ and $db_2^*/df_1 < 0$. The increase in player 1's fighting strength once again increases the probability that player 1 engages and reduces the probability of engagement by player 2. Increasing the strength of the matching-inclined player 1 has an ambiguous effect on the likelihoods of conflict and peace.

Scenario 3 Suppose we have $f_1 < g_2$ and $f_2 > g_1$. This implies that $\Delta > 0$, $db_1^*/df_1 > 0$ and $db_2^*/df_1 > 0$. In this scenario, player 2 is inclined to match and player 1 is opportunistically inclined. Here, an increase in player 1's fighting strength increases the probability that both players engage. To see why this is the case, consider that player 2's net gain from engaging over not engaging is greater when player 1 engages, i.e. $f_2 > g_1$. So when player

2 believes that the relatively stronger player 1 is now more likely to engage, the probability that player 2 will engage also increases, illustrating the inclination of player 2 to match with player 1. *When a opportunistically inclined player faces a matching inclined player, increasing the strength of the opportunistically inclined player increases the likelihood of conflict.*

From these scenarios, we see that an increase in one player's strength can have an ambiguous effect on the likelihood of conflict. However, when an opportunistically inclined player faces a matching inclined player an increase in the strength of the opportunistically inclined player unambiguously increases the likelihood of conflict. These illustrations emphasize the importance of a comparison of the fighting strengths and peaceful shares.

4.4 Conclusion

The purpose of this paper has been to analyze the role of uncertainty in a two player model of conflict in which players have incomplete information about peaceabilities. We have identified the Bayesian Nash equilibrium in pure strategies when there is uncertainty about the players' true peaceable nature in a one-sided and two-sided incomplete information setting.

In the one-sided incomplete information setting, in which the peaceable nature of one player is common knowledge and the peaceability of the other player is known only to himself, we have shown that when players are equal in fighting abilities and the sharing rule, the uncertainty over the player's true nature enlarges the scope for peace and conflict; whereas, when the fighting abilities or the sharing rule are sufficiently unequal, the uncertainty reduces the scope for peace and conflict. In the same information setting, we also illustrate scenarios in which a player who's true type is unknown to his opponent has the incentive to portray himself as bellicose for some configurations of the peaceful shares and fighting strengths and peaceable for other configurations.

In the two-sided incomplete information setting, we saw how variations in the initial shares and fighting strengths affect the probability for peace and conflict in different scenarios. When players were evenly matched in conflict and equally endowed in peace, we saw that an increase in the initial share of a player increases (decreases) the probability that he engages and decreases (increases) the probability that his opponent engages in conflict at the limit of destructive (non-destructive) conflict. In another scenario, when one player is opportunistically inclined and the other is inclined to match, we saw an increase in the strength of the opportunistically inclined player increased the likelihood of conflict.

Our analysis contributes the understanding of conflict when there is uncertainty about the true quarrelsome nature of contending parties. Further research could include signaling peaceability or extending the model to allow for bargaining over shares when there is uncertainty about the players' predispositions towards conflict.

General Conclusion

This thesis has contributed to the analysis of conflict through four essays. In the first essay, we considered the literature on emotions and other aspects of psychology in conflict economics. In the second essay, we developed a theory of the three-way interaction between fighting strengths, initial shares and peaceabilities in conflict. In the third essay, we proposed a theory of resource use and conflict motivated by blame. Finally, in the fourth essay, we explored uncertainty over peaceability as a potential source of conflict.

Here are some interesting results. In the first chapter, we argued that emotions and other aspects from psychology are deserving of further exploration in the economic analysis of conflict. In Chapter 2, we found that the way peaceability affects conflict and peace depends of the configuration of fighting strengths and peaceful shares. In Chapter 3, we found that the threat of blame-driven punishment can explain the peaceful cooperative use of a common resource. In Chapter 4, we saw that in some instances an individual has the incentive to misrepresent his true predisposition towards conflict.

This thesis contributes to the economic analysis of conflict by incorporating aspects from psychology in explanations for conflict and cooperation, characterizing the role of asymmetries and exploring uncertainty as a potential source of conflict. We also contribute more broadly to the analysis of emotions from an economics perspective.

This thesis also provides two additional distinct contributions. First, we have considered settings in which *both* players can choose to engage or not in conflict; this is a departure from the literature in which *one-sided* punishment is common. Second, we have identified that the configuration of peaceful shares and fighting strengths in a standard conflict setting admit tendencies for either *opportunism* or *matching behaviour*. An observation that, as far as we can tell, had not previously been made.

Bibliography

Akerlof, R. (2016). Anger and enforcement. *Journal of Economic Behavior & Organization*, 126:110–124.

Allen, D. (2000). Transaction costs. In Bouckaert, B. and Geest, G. D., editors, *Encyclopedia of Law and Economics*, pages 893–926. Edward Elgar Publishing, Cheltenham.

Anderson, C. A. and Bushman, B. J. (2002). Human aggression. *Annual Review of Psychology*, 53(1):27–51.

Anderton, C. H. and Carter, J. R. (2009). *Principles of conflict economics : A primer for social scientists*. Cambridge University Press, Cambridge; New York.

Attanasi, G. and Nagel, R. (2008). A survey of psychological games: theoretical findings and experimental evidence. LERNA Working Papers 08.07.251, LERNA, University of Toulouse.

Aumann, R. J. (1985). What is game theory trying to accomplish? In Arrow, K. and Honkapohja, S., editors, *Frontiers of Economics*, pages 5–46. Basil Blackwell, Oxford.

Axelrod, R. and Hamilton, W. D. (1981). The evolution of cooperation. *science*, 211(4489):1390–1396.

Baliga, B. and Sjöström, T. (2015). The strategy of conflict and the technology of war. Working paper, Northwestern University.

Baliga, S. and Sjöström, T. (2004). Arms races and negotiations. *The Review of Economic Studies*, 71(2):351–369.

Baliga, S. and Sjöström, T. (2012). The strategy of manipulating conflict. *American Economic Review*, 102(6):2897–2922.

Baron, R. A. and Richardson, D. R. (1994). *Human aggression*. Perspectives in social psychology. Plenum Press, New York, 2nd ed. edition.

Battigalli, P. and Dufwenberg, M. (2007). Guilt in games. *American Economic Review*, 97(2):170–176.

Battigalli, P. and Dufwenberg, M. (2009). Dynamic psychological games. *Journal of Economic Theory*, 144(1):1–35.

Battigalli, P., Dufwenberg, M., and Smith, A. (March 30, 2015). Frustration and anger in games. Cesifo working paper series no. 5258.

Benjamin, A. J. (2016). Aggression. In *Encyclopedia of Mental Health*, pages 33–39. Elsevier Inc., 2nd edition.

Boland, L. A. (1997). *Critical economic methodology: a personal odyssey*. Routledge. London, 1st edition.

Boland, L. A. (2003). *The foundations of economic method: a Popperian perspective*. Routledge. London, 2nd edition.

Boulding, K. E. (1962). *Conflict and defense: A general theory*. New York: Harper & Brothers.

Bowles, S. and Gintis, H. (2003). Origins of human cooperation. *Genetic and cultural evolution of cooperation*, 2003:429–43.

Bowles, S. and Gintis, H. (2013). *A cooperative species: Human reciprocity and its evolution.* Princeton University Press, Princeton, New Jersey.

Brito, D. L. and Intriligator, M. D. (1985). Conflict, war, and redistribution. *American Political Science Review*, 79(4):943–957.

Çelen, B., Schotter, A., and Blanco, M. (2017). On blame and reciprocity: Theory and experiments. *Journal of Economic Theory*, 169:62–92.

Cheung, S. N. S. (1970). The structure of a contract and the theory of a non-exclusive resource. *The Journal of Law and Economics*, 13(1):49–70.

Cohen, R. A. (2018). Arousal. In Kreutzer, Jeffrey S.and DeLuca, J. and Caplan, B., editors, *Encyclopedia of Clinical Neuropsychology*, pages 339–342. Springer International Publishing, Cham.

Cosmides, L. and Tooby, J. (2000). Evolutionary psychology and the emotions. In Haviland-Jones, M. L. . J. M., editor, *Handbook of emotions*, number 2, pages 91–115. Guilford, New York, 2 edition.

Cubitt, R., Gächter, S., and Quercia, S. (2017). Conditional cooperation and betrayal aversion. *Journal of Economic Behavior & Organization*, 141:110–121.

Danielsen, A. L. (1975). A theory of exchange, philanthropy and appropriation. *Public Choice*, 24(1):13–26.

Doyle, M. W. (1983). Kant, liberal legacies, and foreign affairs. *Philosophy and Public Affairs*, 12(3):205–235.

Dube, O. and Harish, S. (2017). Queens. NBER Working Paper 23337, National Bureau of Economic Research, Inc.

Dufwenberg, M. (2002). Marital investments, time consistency and emotions. *Journal of Economic Behavior & Organization*, 48(1):57–69.

Dufwenberg, M. and Kirchsteiger, G. (2004). A theory of sequential reciprocity. *Games and economic behavior*, 47(2):268–298.

Ellingsen, T. and Miettinen, T. (2008). Commitment and conflict in bilateral bargaining. *American Economic Review*, 98(4):1629–35.

Elster, J. (1998). Emotions and economic theory. *Journal of economic literature*, 36(1):47–74.

Encyclopaedia Britannica, . (April 14, 2018). Kin selection. In *Encyclopaedia Britannica*. Encyclopaedia Britannica, inc.

Encyclopaedia Britannica, . (August 09, 2019a). Ronald reagan. In *Encyclopaedia Britannica*. Encyclopaedia Britannica, inc.

Encyclopaedia Britannica, . (November 03, 2019b). United states world war ii. In *Encyclopaedia Britannica*. Encyclopaedia Britannica, inc.

Falk, A., Fehr, E., and Fischbacher, U. (2003). Reasons for conflict: lessons from bargaining experiments. *Journal of Institutional and Theoretical Economics JITE*, 159(1):171–187.

Falk, A., Fehr, E., and Fischbacher, U. (May 2001). Appropriating the commons a theoretical explanation. Working paper no. 55: Cesifo working paper series no. 474, Institute for Empirical Research in Economics.

Falk, A. and Fischbacher, U. (2006). A theory of reciprocity. *Games and economic behavior*, 54(2):293–315.

Fearon, J. D. (1995). Rationalist explanations for war. *International organization*, 49(3):379–414.

Fearon, J. D. (August 30-September 2, 2007). Fighting rather than bargaining. In *2007 Annual Meetings of the American Political Science Association*, Chicago.

Fehr, E. and Fischbacher, U. (2002). Why social preferences matter–the impact of non-selfish motives on competition, cooperation and incentives. *The economic journal*, 112(478):C1–C33.

Fehr, E. and Gachter, S. (2000). Fairness and retaliation: The economics of reciprocity. *Journal of Economic Perspectives*, 14(3):159–181.

Fehr, E. and Gächter, S. (2002). Altruistic punishment in humans. *Nature*, 415(6868):137 – 140.

Frank, R. (2008). Cooperation through moral commitment. In Novartis Foundation, G. B. and Goode, J., editors, *Empathy and Fairness*, pages 197–215. John Wiley & Sons, Ltd.

Frank, R. H. (1988). *Passions within reason: the strategic role of the emotions.* WW Norton & Co, New York, New York.

Frank, R. H. (2011). The strategic role of the emotions. *Emotion Review*, 3(3):252–254.

Friedman, D. and Singh, N. (2009). Equilibrium vengeance. *Games and Economic Behavior*, 66(2):813–829.

Garfinkel, M. and Skaperdas, S. (2007). Economics of conflict: An overview. In Hartley, K. and Sandler, T., editors, *Handbook of Defense Economics*, volume 2, chapter 22, pages 649–709. Elsevier, 1 edition.

Garfinkel, M. R. and Skaperdas, S. (2000). Conflict without misperceptions or incomplete information: how the future matters. *Journal of conflict resolution*, 44(6):793–807.

Geanakoplos, J., Pearce, D., and Stacchetti, E. (1989). Psychological games and sequential rationality. *Games and economic Behavior*, 1(1):60–79.

Gray, J. and Silverberg, J. P. (1992). *Aggression and peacefulness in humans and other primates.* Oxford University Press on Demand.

Gretlein, R., Hamilton, J., and Slutsky, S. (1996). To fight or not to fight? that is the question. *Mathematical Social Sciences*, 31(2):85–114.

Hardin, G. (1968). The tragedy of the commons. *Science*, 162(3859):1243–1248.

Herbst, L., Konrad, K. A., and Morath, F. (2017). Balance of power and the propensity of conflict. *Games and Economic Behavior*, 103:168–184.

Hirshleifer, J. (1987). On the emotions as guarantors of threats and promises. In *The Dark Side of the Force*, pages 198–219.

Hirshleifer, J. (1991a). The paradox of power. *Economics & Politics*, 3(3):177–200.

Hirshleifer, J. (1991b). The technology of conflict as an economic activity. *The American Economic Review*, 81(2):130–134.

Hirshleifer, J. (1993). The affections and the passions: Their economic logic. *Rationality and Society*, 5(2):185–202.

Hirshleifer, J. (1995). Theorizing about conflict. In *The Handbook of defense economics*, volume 1, pages 165–189. Elsevier.

Hirshleifer, J. (2001). *The dark side of the force: Economic foundations of conflict theory*. Cambridge University Press.

Hughes, J. W. (2018). Affect. In Kreutzer, Jeffrey S.and DeLuca, J. and Caplan, B., editors, *Encyclopedia of Clinical Neuropsychology*, pages 67–68. Springer International Publishing, Cham.

Jackson, M. and Morelli, M. (2009). Strategic militarization, deterrence and wars. *Quarterly Journal of Political Science*, 4(4):279–313.

Konrad, K. A. (1990). Passions within Reason: The Strategic Role of Emotions. *The Economic Journal*, 100(403):1339–1341.

Levy, J. S. (2011). Theories and causes of war. In *The Handbook on the political economy of war*, pages 13–33. Edward Elgar Publishing, Cheltenham.

Levy, J. S. (2013). Psychology and foreign policy decision-making. In Leonie Huddy, D. O. S. and Levy, J. S., editors, *The Oxford handbook of political psychology*. 2nd edition.

Loewenstein, G. (2000). Emotions in economic theory and economic behavior. *American economic review*, 90(2):426–432.

Mattes, M. and Vonnahme, G. (2010). Contracting for peace: Do nonaggression pacts reduce conflict? *The Journal of Politics*, 72(4):925–938.

Percy, H. R. (1964). Literature and the law. *Chitty's Law Journal*, 2.

Pillutla, M. M. and Murnighan, J. K. (1996). Unfairness, anger, and spite: Emotional rejections of ultimatum offers. *Organizational behavior and human decision processes*, 68(3):208–224.

Powell, R. (2002). Bargaining theory and international conflict. *Annual Review of Political Science*, 5(1):1–30.

Powell, R. (2006). War as a commitment problem. *International organization*, 60(1):169–203.

Rabin, M. (1993). Incorporating fairness into game theory and economics. *The American economic review*, 83:1281–1302.

Rabin, M. (1998). Psychology and economics. *Journal of Economic Literature*, 36(1):11–46.

Rick, S. and Loewenstein, G. (2004). The role of emotion in economic behavior. In Michael Lewis, J. M. H.-J. and Barrett, L. F., editors, *The Handbook of Emotion*, chapter 9, pages 138–158. Guilford Press, third edition.

Rohner, D., Thoenig, M., and Zilibotti, F. (2013). War signals: A theory of trade, trust, and conflict. *The Review of Economic Studies*, 80(3):1114–1147.

Rotemberg, J. J. (2008). Behavioral aspects of price setting, and their policy implications. Nber working papers 14222, National Bureau of Economic Research, Inc.

Schelling, T. C. (1960). *The strategy of conflict.* Oxford, England: Harvard university press.

Sell, A., Tooby, J., and Cosmides, L. (2009). Formidability and the logic of human anger. In *Proceedings of the National Academy of Sciences*, volume 106, pages 15073–15078. National Academy of Sciences.

Sheremeta, R. M. (2015). Behavioral dimensions of contests. In Congleton, R. and Hillman, A., editors, *Companion to the political economy of rent seeking*, chapter 10, pages 150–164. Edward Elgar Publishing, Cheltenham.

Skaperdas, S. (1992). Cooperation, conflict, and power in the absence of property rights. *The American Economic Review*, 82(4):720–739.

Skaperdas, S. (2006). Bargaining versus fighting. *Defence and Peace Economics*, 17(6):657–676.

Tedeschi, J. T. and Felson, R. B. (1994). *Violence, aggression, and coercive actions.* American Psychological Association, Washington DC.

Trivers, R. (2006). Reciprocal altruism: 30 years later. In Kappeler P.M., v. S. C., editor, *Cooperation in primates and humans*, pages 67–83. Springer, Berlin, Heidelberg.

Trivers, R. L. (1971). The evolution of reciprocal altruism. *The Quarterly review of biology*, 46(1):35–57.

Tullock, G. (1974). *The social dilemma: The economics of war and revolution.* Blacksburg: Center for Study of Public Choice.

Umbeck, J. (1981). Might makes rights: A theory of the formation and initial distribution of property rights. *Economic Inquiry*, 19(1):38–59.

Velez, M. A., Stranlund, J. K., and Murphy, J. J. (2009). What motivates common pool resource users? experimental evidence from the field. *Journal of Economic Behavior & Organization*, 70(3):485–497.

Wrzus, C. and Luong, G. (2016). Negative affect. In Zeigler-Hill, V. and Shackelford, T. K., editors, *Encyclopedia of Personality and Individual Differences*, pages 1–4. Springer International Publishing, Cham.

Xiao, E. and Houser, D. (2005). Emotion expression in human punishment behavior. *Proceedings of the National Academy of Sciences*, 102(20):7398–7401.