Essays on incentives and cooperation in Tullock contests : an experimental approach

Lan, Xiaoqing

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ESSAYS ON INCENTIVES AND COOPERATION IN TULLOCK CONTESTS: AN EXPERIMENTAL APPROACH

LAN XIAOQING
SCHOOL OF SOCIAL SCIENCES
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ESSAYS ON INCENTIVES AND COOPERATION IN TULLOCK CONTESTS: AN EXPERIMENTAL APPROACH

LAN XIAOQING

School of Social Sciences

A thesis submitted to the Nanyang Technological University
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I certify that all work submitted for this thesis is my original work. I declare that no other person's work has been used without due acknowledgement. Except where it is clearly stated that I have used some of this material elsewhere, this work has not been presented by me for assessment in any other institution or University. I certify that the data collected for this project are authentic and the investigations were conducted in accordance with the ethics policies and integrity standards of Nanyang Technological University and that the research data are presented honestly and without prejudice.

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Yohanes Eko Riyanto

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This thesis does not contain any materials from papers published in peer-reviewed journals or from papers accepted at conferences in which I am listed as an author.

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Summary

This thesis consists of three essays that aim to improve our understanding of individual behavior in contests. I use the Tullock contest game to study how far players' behaviors and strategies are from theoretic game models. Specifically, I am interested in the effects of incentives and contest designs on players' behaviors, such as the choice of whether or not to fight and how much effort to expend. In all three essays, I use the Tullock contest game in experimental settings to study players' behaviors in response to various incentives.

Chapter 2 presents an essay on delegation and litigation. I experimentally study the effects of cost structure on strategic delegation in rent-seeking contests. There are two treatments in this experiment. I vary the relative cost of spending between principals and delegates in the two treatments and find that, when the relative cost is higher for principals, they tend to make more delegation choices. This thesis has shown that I can achieve bilateral delegation by changing the cost structure of a game. Hence, mutual cooperative outcomes will occur. As such, this thesis helps to shed light in regard to the growing literature on why delegation can happen endogenously in rent-seeking contest games.

Chapter 3 studies cooperation in an infinitely repeated setting. This chapter also contributes to the empirical research on asymmetry in contests and the destructive aspect of conflict. In this essay, I use a lab experiment to explore the effects of asymmetry on players' abilities and the infinite nature of games in rent-seeking contests. I find that, in line with theoretical predictions, compared to an environment in which players are more equally matched, it is easier to sustain cooperation when players are less equally matched. As a result, total rent-seeking expenditure is lower when the ability difference between contestants is larger. However, although theory predicts equal equilibrium expenditures from strong and weak players, I find a contrasting result in my experiment. Strong players seem to fight more aggressively than their weaker opponents. I also examine a conflictual setting in which conflict is destructive to the prize, while adversaries can peacefully share the whole prize if they cooperate. As predicted, I find that subjects are more likely to cooperate and aggregate expenditures are lower when conflict is destructive.

Finally, in Chapter 4, I present an essay on the effects of winning and losing in a contest. I study the impact of winning and losing on players' performance

in a multi-contest game. More specifically, I examine how winning and losing in previous competitions influence players' behaviors in subsequent contests. I also study the effects of information availability on players' behaviors in a series of competitions. In this essay, I focus on two aspects of these post-conflict effects: willingness to fight and aggressiveness. I designed a novel game called the Contest in Prisoners' Dilemma (CPD) game and employ it to measure people's willingness to fight. Previous and subsequent competitions are introduced using two-stages Tullock contest game. Each stage consists of multiple periods to mimic real-life situations. To study the effects of how players win previous contests on players' behaviors in subsequent contests, I compare contests in which subjects compete using their chosen effort with contests in which subjects compete using computer-generated random effort. I also employ three different designs in the first stage to examine the difference between contests with and without information regarding winning. I find that winning and losing have no effect on people's willingness to fight, neither in treatment in which subjects win through their chosen effort nor in treatment in which winning is random. This is in sharp contrast with previous findings (e.g. Konrad et al. 2009 discovered that there is a "discouragement effect" for losers, while Buser 2016 found that losers aim for more ambitious targets than winners). Winning also has no effect on aggressiveness; I show that it is aggressive people who win more.

Chapter 5 concludes the thesis.

The three essays in this thesis bring together evidence that most of the behaviors of players in contests closely follow standard economic theory predictions. However, theoretical predictions can not fully predict players' actual behaviors in the lab. This thesis provides further evidence of the discrepancies between players' behavior and theoretical predictions. I use Tullock rent-seeking contests in all chapters. Another common aspect among the three essays is that the players all get to choose whether or not to fight before the contests. Despite these similarities, I look at different aspects of contest theory in the three chapters.

1 Chapter 1 Introduction

Conflict is ubiquitous in our society. Political campaigns, sports competitions, patent races and promotions in the workplace are all examples of conflict in society and economic organizations. A common feature among these economic, political or social environments is that they all involve several players exerting costly efforts to compete for a resource. Several models have been proposed to study conflict in an economic setting. The three most prominent models in the extant literature are contests, tournaments, and all-pay auctions (Dechenaux, Kovenock, and Sheremeta 2015).

The Tullock contest model (or rent-seeking model) introduced by Buchanan, Tollison, and Tullock (1980) features prominently in the experimental literature on conflict. It tells a story about n parties competing for an exogenous prize P. The prize varies under different circumstances; it can be a victory in a game, rent from the government, and so on. There are typically two stages in the game. In the first stage, each competing party decides how much to invest in order to win the prize. However, investment is costly and can not be gained back if the party who invests loses the competition. In the second stage, a lottery is conducted to determine the winner of the competition. The probability of each party winning depends on the investments of all competing parties. To be more specific, the success probability is the contest success function:

$$p_i = \frac{x_i^m}{\sum_{j=1}^{n} x_j^m}$$

where p is the probability of winning the competition, x is the investment, and the exponent m is the decisiveness parameter. The decisiveness parameter m, as the name suggests, influences the willingness of each competing party to invest. For instance, if m is large, then according to the above function, the probability of winning the competition increases greatly with investment. If m is small, then a party has to invest a lot more than other parties to win. In extreme cases, if $m = 0$, then the competition has nothing to do with the investment of each party, as every party has an equal probability of winning. If $m = \infty$, the contest becomes an all-pay auction, in which the party with the highest investment wins but all competing parties invest. Hence, compared to the Tullock contest, in which the player who exerts the greatest amount effort does not necessarily win, the player who exerts the greatest amount of effort wins the prize with certainty in all-pay auctions (Nalebuff and Stiglitz 1983; Siegel 2009; Dasgupta 1986).

Lazear and Rosen (1981) proposed to model conflict using rank-order tournament. The model is similar to the Tullock contest model, except that the player with the highest performance (instead of the player who expends the greatest amount of effort) wins the prize. The performance is defined as y_i, and

$$y_i = x_i + \epsilon_i$$

where ϵ_i is a random factor. The random factor can be interpreted as a performance error or just luck. Rosen (1985) also regards it as unknown ability of players. Similar to all-pay auctions, in rank-order tournaments the decisiveness parameter also equals ∞. The difference is that there is noise in determining the winner of the prize. Another difference is that there is usually a pure strategy equilibrium in both Tullock contests and rank-order tournaments, while there is no pure strategy equilibrium in an all-pay auction. There is only a mixed strategy equilibrium.

The three different models have been used extensively in the economic literature. However, they are usually applied in different areas of economic studies of conflict. For example, Tullock contests have been commonly used in rent-seeking and R&D race studies. Economic analyses of contract design usually use rank-order tournaments while all-pay auctions have been studied in literature on auction and lobbying (see Dechenaux, Kovenock, and Sheremeta 2015). I use the Tullock contest in all three chapters for its prediction power and simplicity. Another advantage of the Tullock contest is that there exists a pure strategy Nash equilibrium.

Numerous studies have been conducted on different aspects of Tullock contests: Hirshleifer (1989) looks at the contest success function, Grossman and Kim (1995), Grossman and Kim (1996) and Grossman and Kim (2000) look at the allocation of resources among appropriate and productive activities, and Sheremeta (2011) looks at overbidding. What is common among these different areas of conflict studies using Tullock contests is that there is always a winner and a loser in a contest. Many studies have shown that winning has a positive effect on contestants' subsequent wins in studies conducted with animals (Garcia et al. 2014; Franz et al. 2015; Astor et al. 2013; Apicella, Dreber, and Mollerstrom 2014). Using a large database of professional tennis players, Page and Coates (2017) found a similar winning effect in human species. However, the effect is only significant in men and does not exist among female players. A similar phenomenon called "hot hand" is observed in sports in which athletes who have a winning streak are believed to be more likely to win in subsequent matches. However, there is mixed evidence in empirical studies of the hot hand phenomenon. On one hand, Gilovich, Vallone, and Tversky (1985) dismissed this phenomenon and regarded it as a result of bias in people's subjective judgment. On the other hand, Malueg and Yates (2010) confirmed its existence using professional tennis data.

Much of the literature on conflict focuses on symmetric contests in which all players in the contest are equal (Konrad et al. 2009; Price and Sheremeta 2011). Despite the rich literature on symmetric contests, asymmetry between contestants in conflict is rarely discussed. Asymmetry between players is common in many economic and social environments. In the case of contests, it may stem from varying abilities, different experiences, or different valuations of the prize. The first paper to address the effect of asymmetry between players in conflict is by Harris and Vickers (1985). In their paper, they analyze the strategic consequences of asymmetry using a patent race model. Other studies focus on the prize valuations or effort invested by players in a contest. In order to address the effects of asymmetry in prizes and players' abilities, Baik (2004) theoretically studies how equilibrium effort levels change when the players' valuations of the prize or their abilities change. He showed that the equilibrium effort ratio is equal to the valuation ratio and that the prize dissipation ratios for the players are the same. March and Sahm (2017) provide experimental evidence on the discouragement effect on effort exerted in rent-seeking contest in which players have asymmetric abilities. Compared to symmetric contests, subjects invest the same amount of effort when fighting against a weaker opponent. However, they invest less when facing a stronger opponent - hence, the discouragement effect. Kimbrough, Sheremeta, and Shields (2014) studied asymmetry and willingness to fight. Subjects were provided with a random device to peacefully divide a prize and avoid conflict. In the asymmetric treatment, they varied players' abilities in the experiment so there were both strong and weak players. The results show that the availability of a random device successfully decreased conflict in the symmetric treatment. However, contrary to theory prediction, it also helped to avoid conflict in the asymmetric treatment.

In chapter 2, I study experimentally the effects of asymmetry in cost structure on strategic delegation in rent-seeking contests. There are two treatments in our experiment. I varied the relative cost of spending between principals and delegates in the two treatments. I find that when the relative cost is higher for principals, they tend to choose more delegation choices. The results show that we can achieve bilateral delegation by changing the cost structure of the game. Hence mutual cooperative outcome will occur.

Contests are not only ubiquitous but are also commonly repeated (Aoyagi 2010). Game theory has recognized that repeated interactions may induce punishment and reward schemes that can support cooperation. There is a growing amount of literature on cooperation in infinitely repeated games (Engle-Warnick and Slonim 2006; McBride and Skaperdas 2014; Dal Bó and Fréchette 2011). Dal Bó and Fréchette (2018) provide a survey on how to achieve cooperation in infinitely repeated games. They focus in particular on infinitely repeated prisoner's dilemma games. McBride and Skaperdas (2014) find that, as the future becomes more important, conflict becomes more likely than settlement. They argue that conflict arises despite its costs and risks because it can be considered as an investment in future strength. The winner of the conflict can improve his or her relative strength compared to the loser. Dal Bó and Fréchette (2011), however, argue that cooperation can emerge in repeated settings. They stress the importance of monitoring and punishment in achieving cooperation. A general finding of their analysis is that cooperation from subjects does not necessarily emerge if cooperation is supported in equilibrium. Cooperation will occur only if the parameters of the games are such that they are robust to strategic uncertainty.

In chapter 3, I use a lab experiment to explore the effects of infinity of games and also asymmetry in players' abilities in rent-seeking contests. In contrast with theoretical prediction, players do not cooperate in games with larger continuation probability. I find that in line with theoretical prediction, players cooperate more when they are less equally matched. As a result, the total effort expenditures decrease compared to situations where players are more equal. However, though theory predicts equal equilibrium expenditures from strong and weak players, I find contrasting result in my experiment. The strong players seem to fight more aggressively than their weak opponent.

Another strand of research focuses on the post-contest effect of winning and losing. In practice, players in a contest usually continue to exert effort in subsequent productive or conflict situations. The results of previous contests may affect players' performance in subsequent activities (Bauer, Blattman, et al. 2016; Bauer, Cassar, et al. 2013; Beekman, Cheung, and Levely 2014; Gill, Kissová, et al. 2018). Using a two-stage lab experiment, McGee and McGee (2013) confirm the post-conflict effect of winning. Participants in their experiment first play a competitive tournament game. They then participate in a productive game after the results of the tournament are given. The first stage is set up to induce winning and losing while the second stage serves to measure the effects of winning on players' effort levels. They also differentiate between two kinds of conflict situations, one in which the result of the tournament is determined by participants' performance and the other in which the result is purely random. The results show that losers from the random result treatment exert less effort in the productive stage than losers from the treatment in which the result is determined by performance. Buser (2016) also examined the effect of winning and losing in previous conflicts. He did not, however, focus on effort expenditure; instead, he examined the effects of winning on subjects' willingness to seek further challenges. The results show that losers of previous contests choose more challenging tasks than winners. Furthermore, losers perform worse in subsequent tasks.

In chapter 4, I study the impact of winning and losing on players' performance in a multi-contest game. Specifically, I examine the effects of winning manners as well as winning information in previous competitions on players' behaviors in subsequent contests in a series of competitions. I am interested in two aspects of these post conflict effects: willingness to fight and aggressiveness. I designed a novel game called Contest in Prisoners' Dilemma (CPD) and use it to measure people's willingness to fight. In this chapter, I explore these questions by using two stages Tullock contest game to represent previous and subsequent competitions. Each stage consists of multiple periods to mimic the real life situation. I also employ three different designs in the first stage to examine the difference between contests with and without winning information. I compare contests where subjects compete using their own effort with contests in which subjects compete using computer generated random effort. I find that winning and losing has no effect on people's willingness to fight, neither in treatment where subjects win by own effort nor in treatment where winning is purely random. Winning also has no effect on aggressiveness, on the contrary, it is aggressive people that win more.

2 Chapter 2 An Experimental Investigation of Cost Structure and Delegation in Contests

2.1 Introduction

A contest is a situation in which players compete with one another to win a prize. Players expend non-refundable effort on increasing their probability of winning. Contests are common in many economically relevant situations. Examples include R&D competition, litigation, elections, promotions in firms, competition for government contracts, and so on. There has been extensive research on contests. Examples include the work of Tullock (1980), Dixit (1987), Hirshleifer (1991), and Nitzan (1994). The rent-seeking model introduced by Buchanan, Tollison, and Tullock (1980) features prominently in the literature on conflict. It tells a story about n parties competing for a prize P. The prize varies under different circumstances; it can be a victory in a game, rent from the government, and so on. There are typically two stages in the game. In the first stage, each competing party decides how much to invest to win the prize. However, investment is costly; and cannot be gained back if the party that invests loses the competition. In the second stage, a lottery is conducted to determine the winner of the competition. The probability of each party winning depends on the investments of all competing parties. To be more specific, the success probability is the contest success function:

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where p is the probability of winning the competition, x is the investment, and the exponent m is the decisiveness parameter. The decisiveness parameter m, as the name suggests, influences the willingness of each competing party to invest. For instance, if m is large, then, according to the above function, the probability of winning the competition increases greatly with investment. If m is small, then a party has to invest a lot more than other parties to win. In extreme cases, if m=0, then the competition has nothing to do with the investment of each party, as every party has an equal probability of winning. If $m = \infty$, the contest becomes an all-pay auction, in which the party with the highest investment wins but all competing parties invest. This model has been the work-horse in contest literature since its introduction.

Among the vast literature on conflict, however, contests in which players can choose to hire delegates are rarely studied. One notable exception is Schelling (1980), in which he studied the role of delegates in conflicts and proposed the notion of strategic delegation. I focus on contests in which players have the opportunity to hire a delegate who will expend his effort on winning the prize on behalf of the principal. The aim of this study is to examine players' behaviors in such contests with delegation choices. I am interested in whether or not and when players will hire agents and their effort levels in the contest. Hiring agents is commonly observed in real life. For example, firms hire researchers and university professors to compete in R&D contests for patents, individuals pay lawyers to represent them in court, actors have agents to get contracts, politicians use lobbyists for elections, and so on. I consider a model of litigation in which the probability of winning the prize depends on both players' expenditures. A player can represent herself and expend her own effort in the contest. She can also choose to hire an agent to represent her and the agent will expend his own effort to win the prize on the player's behalf. If an agent is hired, however, the player cannot observe his effort; the player will only observe whether the contest is won or lost. The typical structure of a delegation game consists of two stages. In the first stage, principals decide whether or not to hire delegates. In the second stage, the actual players play the game.

Why do people hire agents to represent them rather than participating themselves in a contest? One intuitive explanation is the existence of asymmetry between principals and agents. For example, if the delegate has more skills or abilities than the principal, then the principal will benefit by hiring the delegate to do the job. This kind of asymmetry between players in contests has also been studied in the literature. As in many economic situations, contestants are rarely symmetric. Usually, they differ in their abilities, access to resources, or preferences. There is a vast literature on asymmetry in rent-seeking contest games. Baik (1994) is the first to examine the effects of asymmetry between players in a rent-seeking contest. He focuses on asymmetry in the valuation of the prize between two players, and considers players' different abilities in regard to converting effort into the probability of winning. He argues that this asymmetry is common in contests. For example, when a government franchise monopoly contract is renewed, the previous contract holder tends to value the franchise contract more than its rivals because it has already invested resources in the particular field. Meanwhile, the previous contract holder has also gained knowledge and experience in the industry. As a result, it may be more able and more efficient than its rivals in competing for the contract. However, there is no delegation in their analysis.

Baik and Kim (1997) conducted a theoretical study including asymmetry in the litigation model. They developed a model in which there are various types of delegates. The delegates are differentiated so that their relative ability to the main players varies. The two players have different valuations of the prize, so the player with the higher valuation is "hungrier" than the other. They also assume that delegates are different in their relative ability to principals. They relax the assumption of compulsory delegation. Each player has two options: to participate in the contest or to choose to hire an agent to do the job. The agent will then expend his own effort to win the prize for the main player. If a player chooses to hire an agent, she needs to pay the agent compensation. There are two parts constituting the compensation: a fixed fee and a contingent fee. Baik and Kim (1997) depicted conditions under which no delegation, unilateral delegation, or bilateral delegation could occur and found that, if the two players value the prize equally, then no delegation and bilateral delegation could happen. If the players value the prize differently but not significantly so, the result is no delegation, bilateral delegation, or unilateral delegation by the player with a higher valuation. Finally, if the players have significantly different valuations of the prize, then no delegation, bilateral delegation, and unilateral delegation by either player are possible. They confirmed that principals choose delegation by buying superior ability.

Baik and Kim (1997) endogenize the decisions regarding whether or not to hire a delegate as I do. However, they also assume that the compensation contract offered to the delegates is exogenously given. In my experiment, I also endogenize the payment contract options so principals can decide the exact amount of payment awarded to their delegates if they win the game. Schoonbeek (2017) gave another explanation for why delegation can happen in rent-seeking contests. Schoonbeek assumes that the principals only know whether the prize is high or low, with given probabilities. However, principals can hire delegates to act on their behalf and the delegates can privately observe the true value of the prize. They find that delegation is possible in equilibrium if the delegates have access to more information about the value of the prize than their principals.

I offer another explanation for why delegation can arise in contests by differentiating the cost of participating in the contest between principals and agents. My analysis applies to a case in which two firms compete for a government license. The license can only be awarded to one of them. If a firm wins the license, it gains monopoly position in a given market. In practice, it is possible that the competing firms will not be familiar with the lobbying procedures and the process may cost them a great deal of time and money. Each firm then has the option to hire a professional lobbyist to lobby on its behalf. The professional lobbyist is more experienced in this area. It is also possible that the agent has access to important and private information from the government. Hence, the cost incurred in this process is much lower for the professional lobbyist. However, unlike the firm, which will lose the market if it fails to get the license, the lobbyist has less to lose. Furthermore, the firm cannot observe the efforts of the lobbyist. Hence, it is of interest to explain why delegation can happen endogenously.

Another strand of the literature on delegation focuses on the virtues of delegation, in that it can "shift the blame" (Oexl and Grossman 2013; Bartling and Fischbacher 2011; Hill 2015). Garofalo and Rott (2017) analyze receivers' responses to the delegated communication regarding a negative decision. Their results show that receivers hand out punishments more frequently and more heavily when communication of an unfair decision is delegated. Hamman, Loewenstein, and Weber (2010) found similar results and showed that a principal may hire a delegate to take self-interested or even immoral actions that the principal would reluctantly take by herself. However, these analyses focus on the delegation of a decision. In my study, the delegates have more say in the actions they take; they can choose how much effort they expend, instead of passively following the orders of their principals.

To the best of my knowledge, my research is the first experimental study that considers asymmetry in cost structures in contests with the option of delegation. Several factors differentiate this study from previous work. First, I endogenize the players' decisions on delegation. Instead of compulsory delegation, I give players of the contest the option of spending her own effort or hire a delegate to spend his effort on her behalf. Moreover, I also endogenize the payment scheme in the case where players decide to hire delegates. Second, I include asymmetries in my design. I differentiate principals and agents in my experiment by cost structure. I assume the cost of spending efforts is higher for principals than for agents. This is what usually happens in most economic situations. Agents are usually more experienced and more intelligent than players; thus, I can expect the cost of competing to be relatively lower for them and for them to play in the contest more successfully than their principals.

Although it is straightforward to see why principals hire delegates when there is asymmetry between the two kinds of players, it is less obvious when the game is symmetric. If there is no difference in abilities, information, or experience between principals and agents, will principals still choose to hire delegates? The answer is yes according to my experiment. An intuitive explanation for this is that delegation can serve as a commitment device in this case. That is, a player can benefit by achieving strategic commitments through delegation. That is to say, by hiring an agent, a player can change her opponents' behavior so that the opponent acts in the player's favor, because the objective function of the agent is different from that of the principal. The role of delegates has been discussed extensively since Schelling (1980). Schelling (1980) uses the term strategic delegation and extensively discusses the role of delegates; he notes that it might be to the player's advantage to hire a delegate in a conflictual situation, as a commitment. This notion has been discussed in a substantial amount of literature; strategic delegation may benefit the principal players. Examples include Vickers (1985), Fershtman and Kalai (1997), Fershtman, Judd, and Kalai (1991), Katz (1991), and Reitman (1993). However, a central assumption of the analysis above is that the compensation contract between a principal and a delegate is observable to other players in the game. When the delegate's payment scheme is observable to the other players, it can serve as a commitment device. The observable compensation scheme will manipulate the delegate's strategic behavior so that the outcome of the game can be changed. This assumption is often not realistic. In most economic situations, the delegation contract is unobservable. Principals may hire delegates to play the game on their behalf, but the contract they sign may not be public information. Consider the contract signed between a firm and its manager. Even though the Securities and Exchange Commission requires a firm to publicize the amount of money paid to their managers, this kind of information may be difficult to obtain and, as a result, the other players in the game may not see it. Although the agent could show the contract to the other players, the genuineness of this contract can not be guaranteed, as the firm could have signed a new contract and overridden the previous one displayed.

So the question is whether or not unobservable contracts can serve as precommitments. Katz (1991) says no. He argues that, when the compensation schemes are not common knowledge, it is not possible for delegation to serve as a commitment device. When contracts are unobservable, principals can communicate their own preferences to their agents, making the delegation ineffective. Consequently, in equilibrium, the agents may behave as the principals would do if they themselves were to play. However, Fershtman and Kalai (1997) used a simple ultimatum game to derive the conditions under which unobservable delegation may influence the outcome of the game. In one of their games, the existence of the delegation contract is known to the other party, but the details of the contract remain unknown. They show that beneficial delegation can be obtained even in a one-shot game. Another study on the efficiency of unobservable contracts was conducted by Fershtman and Gneezy (2001). The experiment they used was also an ultimatum game. They compared the outcome of two games, one in which the responder in the ultimatum game signed a publicly observed contract with an agent; in the other game, the responder signed an unobservable contract with the agent. Their results contrast both Katz (1991) and Fershtman and Kalai (1997), in that the responder was worse off using an agent.

In my experiment, I also use unobservable contracts. Principals can choose to sign compensation contracts with an agent, but the details of the contract are not known to other players in the game. My results are consistent with Katz (1991) and I show that, when principals and agents are equal, there is no difference in principals' payoff, whether or not they choose to hire delegates.

Before the commencement of the actual game, players sign contracts with their agents. Fershtman and Kalai (1997) argued that it is crucial to distinguish between two existing types of delegation: incentive delegation and instructive delegation. In incentive delegation, a delegate is given an incentive scheme (e.g. a compensation scheme) and will choose effort to maximize his own payoff. An example of incentive delegation is when firms sign compensation contracts with managers that link the compensation to the firms' profits. In instructive delegation, the agent is given specific instructions regarding his behavior in the game. An example of instructive delegation is a clerk in a store who works for a fixed wage and carries out the instructions (e.g. the prices of goods) he is given. Fershtman and Kalai (1997) show that, when the contract is unobservable, the incentive delegation can be efficient, while beneficial instructive delegation does not exist in the one-shot game.

I use an incentive contract, with the reward to the delegate set as being conditional on the result of the game. The delegate receives compensation from the principal if the delegate wins the game, and nothing otherwise. Similarly, Wärneryd (2000) adopted an incentive payment scheme. They show that, in a two-player contest for an indivisible prize, both players gain from being required to hire delegates. He argued that, if it is compulsory to be represented by a lawyer, litigants will cooperate by using agents, due to moral hazard and limited liability in the litigant-delegate relationship. With the existence of moral hazard, principals cannot observe the agents' effort, only whether the case is won or lost. Wärneryd further assumes that the delegate works under limited liability, in the sense that he is only paid by his principal if he wins the case. Solving the subgame perfect equilibrium of this delegation game, Wärneryd shows that both principals acquire higher payoffs if both hire agents, relative to the case in which both play the contest themselves. The results of Wärneryd (2000) are conditional on the assumption that delegation is compulsory; a game in which players can choose whether or not to hire an agent becomes a prisoner's dilemma. Both players would prefer that both are hiring agents, but not hiring is strictly dominant.

I consider contests in which two players compete for an indivisible prize and the winning probability is determined by the investments of both players. In the contest, each player has two options: expending her own effort in the contest, or hiring a delegate to do the work. The delegate then competes to win the prize on the principal's behalf. If the player chooses to hire a delegate, the player is now a principal and the delegate is an agent. The game has two stages. In the first stage, principals choose whether or not to hire an agent. If a player decides to hire an agent, she will have to reward the agent in the case that the agent wins the contest. In the second stage, principals or agents play the original contest. I vary the relative cost of spending between principals and agents in my experiment. In the Low treatment, the game is symmetric in that the cost of expenditure is the same for principals and agents. In the High treatment which is asymmetric, the cost of spending for principals is three times larger than the cost of spending for agents. I first show under what circumstances that no delegation, unilateral delegation, and bilateral delegation occurs. I find that principals choose more delegation options in treatments with larger relative costs of expenditure between principals and agents.

Hence, there is a significantly higher amount of bilateral delegation in the High treatment compared to the Low treatment. However, I still observe a higher level of cooperation (i.e., mutual delegation) in the Low treatment, compared to other experimental games involving prisoners' dilemma. Next, I find that, in the performance of rent-seeking contests, overbidding occurs relative to the Nash equilibrium prediction in both treatments. However, principals expend less effort under mutual litigation in the High treatment than in the Low treatment. Finally, I establish that, in the Low treatment, compared to choosing delegation, principals obtain a higher payoff by choosing litigation. However, in the High treatment, in which the cost is different for principals and delegates, principals who choose delegation gain more than those who choose litigation.

My results are instructive from policy and social welfare perspectives. One of the major focuses in the literature on conflict is how to reduce the social cost incurred during contests. My study shows that an effective way of achieving this is stressing the different abilities of participants. Moreover, my results illustrate that the simple act of releasing information on participants' heterogeneity may achieve the desired cooperative outcome in a contest.

The rest of the chapter is structured as follows: Section 2.2 describes the theoretical background and the predictions. Section 2.3 shows the design and experiment procedures. I present and discuss the results in Section 2.4. Section 2.5 concludes.

2.2 Theoretical Background and Predictions

I consider contests with two risk-neutral players, i and j, compete for an indivisible prize V in a dispute. Each player has the following two options: expending her own effort, and hiring a delegate. The delegate then expends his effort to win the prize on behalf of the principal. If the player chooses to hire a delegate, the player is now a principal and the delegate his agent. I assume the agent is risk neutral and has a reservation utility of 0. I further assume the game has two stages. In the first stage, principals choose whether to hire an agent or not. If a principal decides to hire an agent, she will have to reward the agent in the case that the agent wins the contest. I denote the positive payment from the principal to her agent as w. In the second stage, principals or agents play the original contest. The principals can not observe the agents' efforts, instead, they only observe whether the contest is won or lost.

There are three possible scenarios in the contest: no delegation, unilateral delegation, and bilateral delegation. If they go to court and let the judge decide the ownership of the prize, the probability that the judge awards the prize to player i is $\frac{x_i}{x_i+x_j}$, where x_i is the expenditure of player i's or the delegate that she hires. The success function was first introduced by Tullock (1980) in his seminal work on rent-seeking contests. It has since been widely used in works on litigation and delegation.

I assume the expected utility of delegate i given the investment of his opponent is

$$\Pi_{ai} = \frac{x_i}{x_i + x_j} w_i - x_i + E, \tag{1}$$

where w_i is the payment from principal **i** should he wins and E is the endowment given to each player. I further assume the expected utility of principal i should she chooses to represent herself is:

$$\Pi_{pi} = \frac{x_i}{x_i + x_j} V - a x_i + E, \tag{2}$$

where a is a cost parameter.

Cost parameter $a \in [1, \infty)$ is the relative cost of principal's expenditure to agent's expenditure. The intuition behind this is that in real life, the cost of participating in the contest is not always the same for principals and lawyers. Usually, the cost is larger for principals than for agents due to agents' superior knowledge over principals or their experience.

2.2.1 No delegation

I first consider the case in which there is no delegation. Both players choose to spend their own efforts in the contest. When one player invests 0, a slightly small expenditure by the other player is sufficient for him to gain the prize with probability 1. Clearly, I can rule out the possibility that there is an equilibrium in which both players invest nothing. Therefore I am looking for an interior equilibrium.

The first-order condition of player i's utility function is

$$\frac{x_j}{(x_i + x_j)^2} V = a. \tag{3}$$

Because the equation must hold symmetrically for both players, there is a unique symmetric Nash equilibrium in which

$$x_i = x_j = \frac{V}{4a}. \tag{4}$$

Prediction 1: In the case in which there is no delegation, the expenditures of principals decrease with cost parameter a.

The equilibrium payoff for both players will then be $\frac{V}{4} + E$. Note that the equilibrium payoff does not depend on the parameter a.

2.2.2 Bilateral delegation

Now I consider the case in which there is bilateral delegation. Suppose player i chooses to hire a lawyer. The expected utility of player i becomes:

$$\Pi_{pi} = \frac{x_i}{x_i + x_j}(V - w_i) + E, \tag{5}$$

where x_i is the expenditure of the lawyer that player i hires and w_i is the fee paid to the lawyer that player i hires if he wins the case.

To solve for a subgame perfect equilibrium of this game with delegation options, I begin from the second stage. Since lawyer i gets the payment w_i only if he wins the case for his client, the expected utility for the lawyer given the expenditure of the other party is:

$$\Pi_{ai} = \frac{x_i}{x_i + x_j} w_i - x_i + E, \tag{6}$$

and his best response is given by the first-order condition:

$$\frac{x_j}{(x_i + x_j)^2} w_i = 1. \tag{7}$$

Since player j also chooses to hire a lawyer, I assume player j pays lawyer j w_2 if he wins the case. Then I have the utility function of lawyer j as:

$$\Pi_{aj} = \frac{x_j}{x_i + x_j} w_j - x_j + E, \tag{8}$$

and the first-order condition is:

$$\frac{x_i}{(x_i + x_j)^2} w_j = 1. \tag{9}$$

Assuming both w_1 and w_j are positive. Solving for the equilibrium expenditures, I have that

$$x_i^* = \frac{w_i^2 w_j}{(w_i + w_j)^2} \tag{10}$$

and

$$x_j^* = \frac{w_j^2 w_i}{(w_i + w_j)^2}. \tag{11}$$

From the equilibrium expenditures of lawyers I can see that for lawyers the expenditures depend on payments from principals only. Given the payments and equilibrium expenditures of the lawyers in the contest, the probability that principal i gets the prize is: $\frac{w_i}{w_i + w_j}$. By backward induction, the optimal payment to lawyers is the one that maximize

$$\frac{x_i}{x_i + x_j}(V - w_i) + E, \tag{12}$$

for which the first-order condition is

$$-w_1^2 - 2w_1 w_2 + w_2 V = 0. \tag{13}$$

Since the condition must hold symmetrically for both principal players, there is a unique symmetric choice of payments such that $w_i = w_j = \frac{V}{3}$. Again, the payments from principals to agents do not depend on parameter a.

In equilibrium, the expected utility for each lawyer is $\frac{V}{12}$. Since the reservation utility of lawyers is 0, it is always optimal for lawyers to accept the offer. For principals, the expected utility of each principal is $\frac{V}{3}$, which is strictly larger than $\frac{V}{4}$ from mutual litigation. Hence both principals gain if they both hire agents.

2.2.3 Unilateral delegation

The last case to consider is the unilateral delegation one. I assume player i chooses to hire a lawyer and player j decides to represent herself in court. The expected utility of the other player j is the same as the mutual litigation case:

$$\Pi_{pj} = \frac{x_j}{x_i + x_j} V - a x_j + E. \tag{14}$$

Since lawyer i gets the payment w_i only if he wins the case for his client, the expected utility for the lawyer given the expenditure of the other party is:

$$\Pi_{ai} = \frac{x_i}{x_i + x_j} w_i - x_i + E, \tag{15}$$

and his best response is given by the first-order condition:

$$\frac{x_j}{(x_i + x_j)^2} w_i = 1. \tag{16}$$

From the first-order conditions of agent i and player j's utility functions, I get the equilibrium expenditures of the two participants in the contest:

$$x_i = \frac{aVw_i^2}{(V + aw_i)^2} \tag{17}$$

and

$$x_j = \frac{V^2 w_i}{(V + aw_i)^2} \tag{18}$$

The expected utility of principal i who hires an agent becomes:

$$\frac{aw_i}{V + aw_i}(V - w_i) + E, \tag{19}$$

for which the first-order condition is:

$$aw_i^2 + 2Vw_i - V^2 = 0. \tag{20}$$

The positive solution to the first-order condition is $w_i = \frac{\sqrt{a+1}-1}{a}V$. Hence the equilibrium expenditure of lawyer i is $x_i = \frac{(\sqrt{a+1}-1)^2}{a(a+1)}V$ while the equilibrium expenditure of player j is $x_j = \frac{\sqrt{a+1}-1}{a(a+1)}V$. In equilibrium, the expected utility of lawyer i is $\frac{(\sqrt{a+1}-1)^3}{a(a+1)}V + E$, the expected utility of player i that hires the lawyer is $\frac{a+2-2\sqrt{a+1}}{a}V + E$. As for the player who chooses to represent herself, the expected payoff is $\frac{V}{a+1} + E$. Hence I have the payoff matrix of the principals as in Table 2.1.

Table 2.1: Payoff matrix of the principals

	Litigation	Delegation
Litigation	$\frac{1}{4}V + E, \frac{1}{4}V + E$	$\frac{V}{a+1} + E, \frac{a+2-2\sqrt{a+1}}{a}V + E$
Delegation	$\frac{a+2-2\sqrt{a+1}}{a}V + E, \frac{1}{a+1}V + E$	$\frac{1}{3}V + E, \frac{1}{3}V + E$

The simplest case is when $a = 1$, in which the cost of expenditures are the same for both principals and agents. In this case, Table 2.1 can be simplified to Table 2.2.

Table 2.2: Payoff matrix in the Low treatment

	Litigation	Delegation
Litigation	$\frac{1}{4}V+E$,$\frac{1}{4}V+E$	$\frac{1}{2}V+E$,$0.17V+E$
Delegation	$0.17V+E$,$\frac{1}{2}V+E$	$\frac{1}{3}V+E$,$\frac{1}{3}V+E$

Without compulsory delegation, players can choose either litigation or delegation. From Table 2.2 I can see that a player gets the highest payoff if she is the only one choosing litigation. The reason is that a lawyer's incentive is the payment he receives from the principal that hires him while the player who chooses to represent herself has a larger incentive, which is the whole prize. The larger the incentive, the larger the expenditure in the contest. Hence the player who chooses to represent herself invests more than the lawyer, leading to a larger winning probability and higher payoff. If both players choose litigation, their individual payoff is lower than the case in which both choose to delegate. The result is a game with a prisoner's-dilemma-like structure. I have four possible outcomes in stage 1: mutual litigation, mutual delegation, player i chooses litigation while player j chooses delegation and player i chooses delegation while player j chooses litigation. Both players wish that both choose to delegate, but litigation is the dominant strategy. Hence the Nash equilibrium in this game is mutual litigation.

Prediction 2: Principals choose litigation in treatment in which $a = 1$.

However, both players will benefit if they both choose delegation, In order to have mutual delegation as the Nash equilibrium in Table 2.1, the following conditions must hold:

$$\frac{a+2-2\sqrt{a+1}}{a}V > \frac{1}{4}V \tag{21}$$

and

$$\frac{1}{3}V > \frac{1}{a+1}V. \tag{22}$$

The solution that satisfies both of the conditions is:

$$a > 2 \tag{23}$$

Hence when the relative cost of expenditure for principals more than double the cost of agents, principals will choose to hire agents instead of representing themselves. If I set a equals to 3, the payoff matrix in the contest becomes Table 2.3, in which the Nash equilibrium is both players choose delegation and each earn payoff $\frac{1}{3}V + E$.

Table 2.3: Payoff matrix in the High treatment

	Litigation	Delegation
Litigation	$\frac{1}{4}V + E, \frac{1}{4}V + E$	$\frac{1}{4}V + E, \frac{1}{3}V + E$
Delegation	$\frac{1}{3}V + E, \frac{1}{4}V + E$	$\frac{1}{3}V + E, \frac{1}{3}V + E$

Prediction 3: Principals choose delegation in treatment in which $a = 3$.

Effort levels spent by the players in the contest also deserve attention. The reason is that efforts expended in a rent-seeking contest are interpreted as social costs. For example, both lawyers and principals have to spend resources in a lawsuit to win the case. Hence total efforts measure economic efficiency. I can compare the total effort and rent dissipation in all three scenarios. The total effort in no delegation case is $\frac{V}{2a}$, hence the rent dissipation is $\frac{1}{2a}$. In scenario bilateral delegation, the total effort is $\frac{V}{6}$ while the rent dissipation is $\frac{1}{6}$. Lastly, the total effort in unilateral delegation is $\frac{\sqrt{a+1}-1}{a\sqrt{a+1}}V$ with rent dissipation equals to $\frac{\sqrt{a+1}-1}{a\sqrt{a+1}}$. When I substitute the value of cost parameter a, I can compare the rent dissipation in three scenarios.

Prediction 4: If $a = 1$, the total cost is lowest in bilateral delegation and highest in no delegation case. If $a = 3$, total costs are the same in the three scenarios.

2.3 Experimental Design and Procedures

I have two treatments in my experiment. In one treatment, I set the parameter a to 1. I denote this treatment as the Low treatment, in which the cost of expenditure is the same for both principals and agents. In the other treatment, I set a to 3 in order to have mutual delegation as Nash equilibrium. I call this treatment the High treatment. During the experiment, I use Experimental Currency Units (ECUs) instead of real dollars as a common practice. I set the prize V as 50 ECUs and the endowment E as 20 ECUs. With the values of a specified, I can calculate the equilibrium efforts and payments to agents in both treatments. The results are shown in Table 2.4.

Using Table 2.2 and Table 2.2, I can also get the payoff matrix in the Low treatment (Table 2.5) and the High treatment (Table 2.6).

Table 2.4: Theory Prediction

		$a = 1$	$a = 3$
(L,L)	Effort_principal	12.5	4.2
(D,D)	Effort_agent	4.2	4.2
	Payment	16.7	16.7
(L,D)	Effort_principal	10.4	4.2
	Effort_agent	4.3	4.2
	Payment	20.7	16.7

Table 2.5: Payoff matrix in the Low treatment

	Litigation	Delegation
Litigation	32.5,32.5	45,28.6
Delegation	28.6,45	36.7,36.7

In each treatment, I conducted two independent sessions. Three sessions consist of 24 subjects while one session has 16 subjects. Each session investigated only one treatment, so all comparisons are across subjects.

The experiment was conducted in the experimental economics labs at Nanyang Technological University in April 2019. In total, 88 undergraduates from various disciplines participated in the experiment. Each participant took part in only one session and no participant had experience in similar experiments before. The computerized experimental sessions were run using z-Tree (**F**ischbacher, 2007).

Upon arrival, participants were randomly assigned cubicles in the laboratory. The cubicles do not allow for any visual communication between subjects. During the experiment, verbal communication is also prohibited. Once all the participants were seated, each of them received a written copy of the instructions. The experimenter read the instructions aloud while participants reading their own copies. After reading the instructions, all participants were required to answer several quiz questions regarding the experiment to ensure common knowledge of the procedure in the experiment. Participants were encouraged to raise their hands should they encounter any problem with the instructions. All questions were answered privately by the experimenter. The experiment commenced once all participants passed the quiz.

Table 2.6: Payoff matrix in the High treatment

	Litigation	Delegation
Litigation	32.5,32.5	32.5,36.7
Delegation	36.7,32.5	36.7,36.7

At the start of the experiment, the participants were randomly assigned to groups of four. In each group, there are two principals and each principal is matched with one agent. The roles were also randomly assigned at the beginning of the experiment. I used neutral languages throughout the experiment. So principals are denoted as "type A player" and agents are denoted as "type B player" in the experiment. There are two stages in the experiment: stage 1 and stage 2. They are the same except that in stage 2 the role is reversed. Subjects were told that they would play several periods in each stage and the group composition would change in every period.

At the beginning of each period, each subject was given 20 ECUs as an endowment. Principals simultaneously selected an option from two available options: option 1 and option 2. Option 1 stands for litigation and option 2 stands for delegation. After both principals made their choices, the two agents were notified of the results. The two participants of the contest would then choose expenditures from their endowments to compete for the prize. The prize was worth 50 ECUs. All subjects were informed about the outcomes of the contest and one's own payoff in the period.

At the conclusion of the experiment, two periods were chosen from each of the two stages for payment. I use Experimental Currency Units (ECUs) in my experiment. The earnings were converted into Singapore dollars at the rate of 10 ECUs to S$ 1 . At the end of the experiment, participants were asked to fill up a questionnaire about their social demographics and personal strategies for the experiment.

Each session lasted about one hour and a half inclusive of instructions and payment. On average, each student received 14.9 Singapore dollars from participating, including 2 Singapore dollars show-up fee. Subjects were paid privately and in cash.

2.4 Results and Discussions

I will first look at the choices and payments to delegates (if delegation is chosen) of principals in the first stage. Afterward, I will analyze the efforts invested by the actual participants (principals or delegates) in contest in the second stage. Lastly, I will present the ex-post realized payoffs for principals in all scenarios and overall interpretation of the results.

2.4.1 Delegation decisions of the principal (1st stage)

Theory predicts principals to choose delegation options when the cost of participating in the contest is higher for principals than for delegates, and to choose litigation when the cost is the same. That is, theoretically I would expect principals to choose delegation in the High treatment and to choose litigation in the Low treatment. Figure 2.1 shows for each treatment the percentage of different choice pairs: mutual litigation, mutual delegation, unilateral litigation/delegation. The result is not very straightforward. I observe a large number of unilateral litigation/delegation in both treatments. For the High treatment, I also have a significant amount of mutual delegation, so the data seems to support the theory in the High treatment. To obtain a detailed analysis of the data, I look at choices of principals on the individual level. Figure 2.2 shows the individual choices of principals in the two treatments. In line with the theory, I observe a significant amount of delegation choices in the

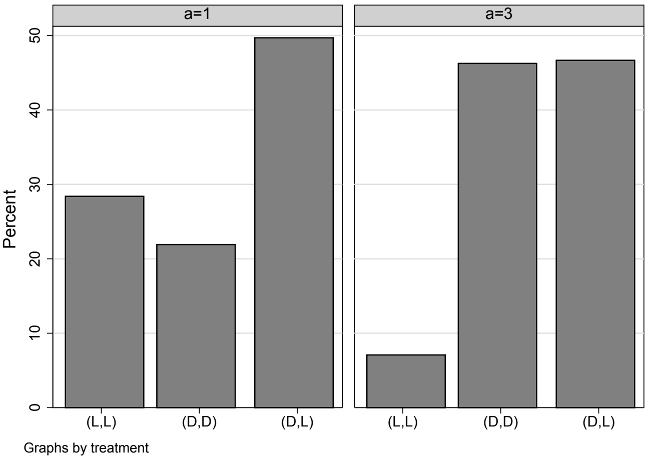

Figure 2.1: Litigation and delegation results, by treatment

High treatment. In my experiment, 69.6 percent of principals in the High treatment choose delegation. On the contrary, I have mixed results in the Low treatment. The percentage of litigation choices and delegation choices in the Low treatment is almost half-and-half. I have 53.2 percent of principals choosing litigation and 46.8 percent choosing delegation.

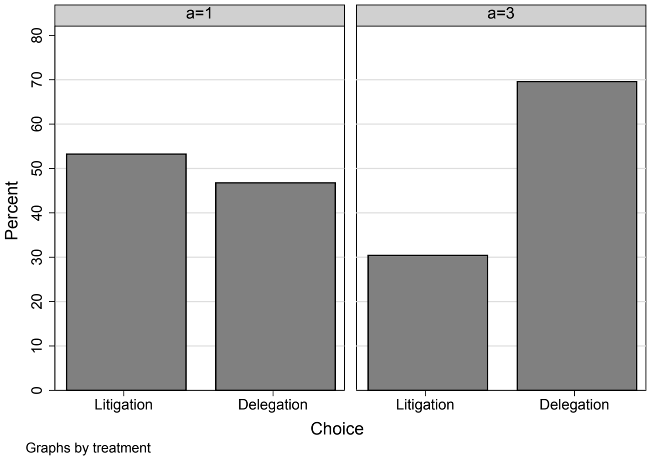

Figure 2.2: Choice of principals, by treatment

Figure 2.3 displays the percentage of principals' delegation choice decisions in two treatments. In both treatments, the games start with roughly half of the principals choosing delegation. As time goes by, principals in the High treatment choose more and more delegation choices while principals in the Low treatment choose slightly less delegation but the percentage still remains at around 40%. Figure 2.4 and Figure 2.5 show the choice pairs of principals in the Low treatment and the High treatment respectively. I see mutual delegation is quite stable in the Low treatment while it is increasing in the High treatment. I also observe a sharp decline of mutual litigation in the High treatment in which the percentage almost drops to zero from period 5. It is possible that players in the High treatment eventually learn the higher cost of representing themselves compared to hiring an agent. Hence participants learn to choose the equilibrium choice over time. With regard to the absolute frequency of delegation choices between the two treatments, I conducted statistical tests on the number of delegation choices by individuals over the whole course of the experiment, the result indicates that the difference is significant. [1]

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[1] Applying a two-tailed Mann-Whitney U test I get the following P-levels: P=0.0000 (Low treatment vs. High treatment).

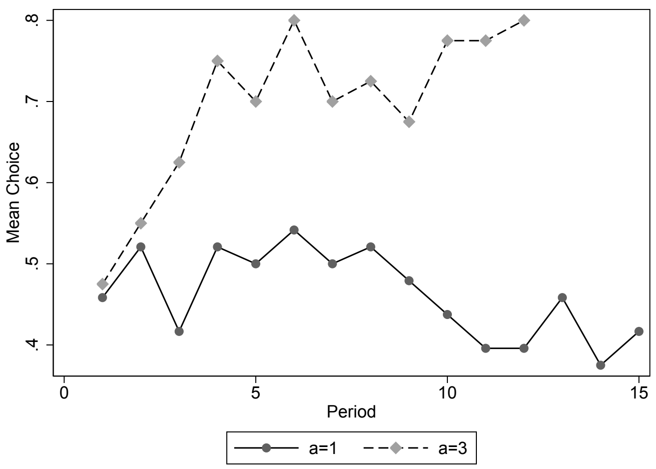

Figure 2.3: Percentage of delegation choice over the time, by treatment

Result 1: Higher relative cost of principals to delegates leads to more delegation choices from principals.

Result 2: Principals choose more delegation options in the High treatment than in the Low treatment.

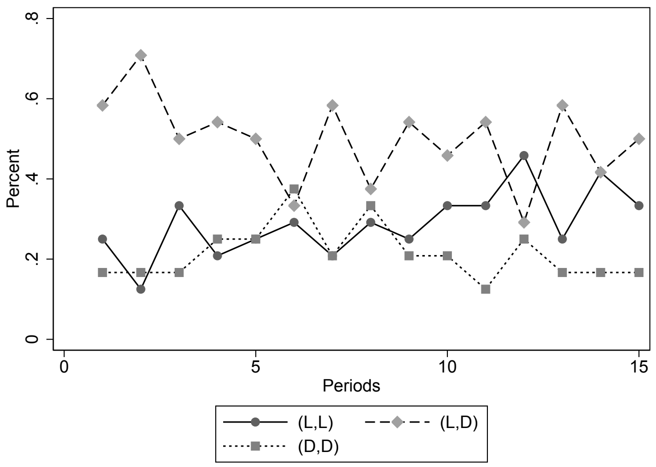

Figure 2.4: Choice pairs over time in the Low treatment

2.4.2 Contracts of the principals (1st stage)

Next, I look at the contracts offered by principals in the case of delegation. In my setting, the details of the contact are not observable to other players in the

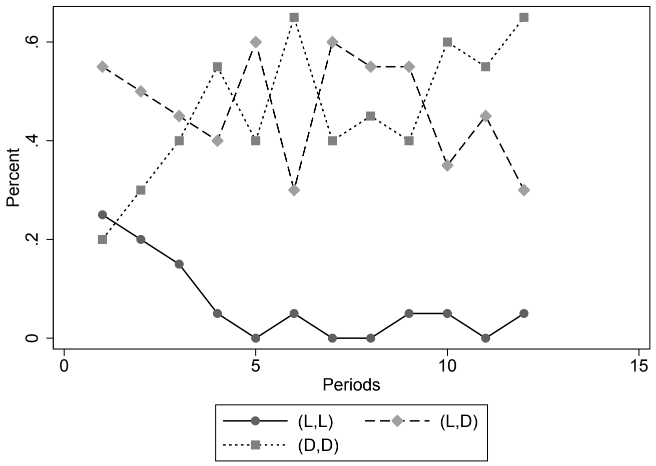

Figure 2.5: Choice pairs over time in the High treatment

game. Principal chooses the payment to her delegate if he wins the contest for her. Delegates do not have a say in this process and serve as passive receivers. Table 2.7 shows that theory predicts average payment from principals in the case of delegation quite well. In both treatments, the amounts of compensation specified by principals fit the prediction. One thing to note is that under bilateral delegation, the payments proposed by principals are the same in both treatments.

Table 2.7: Payments from principals who choose delegation (standard deviation and number of observations in parentheses)

		Low Treatment		High Treatment	
		Theory	Experiment	Theory	Experiment
(D,D)	Payment	16.7	19.2 (8.2, N=142)	16.7	18.2 (9.3, N=222)
(L,D)	Payment	20.7	19.4 (8.6, N=161)	16.7	15.7 (9.3, N=112)

Result 3: Principals' payments to delegates if they win fit the theory prediction.

2.4.3 Efforts in the contest (2nd stage)

After principals make their choices on delegation or litigation, the contestants (principals or/and delegates) will participate in the rent-seeking contest. If a principal chooses litigation, she will participate in the contest herself. If a principal chooses delegation, the delegate that she hires will take part in the contest on her behalf. Table 2.8 displays summary statistics on the distribution of efforts by treatment. I see there are overbidding in the expenditures of both principals and agents in the Low treatment. Though the observed efforts are larger than predicted, the predicted effort levels are still within one standard deviation (S.D.) of the actual mean. In the High treatment, I only observe overbidding in principals under mutual litigation. In the rest of the scenarios, the efforts of players (both principals and delegates) seem to fit the prediction. Overbidding is commonly observed in experiments on rent-seeking contest (e.g. Price and Sheremeta 2011; Fonseca 2009; Sheremeta, Masters, and Cason 2013; Sääksvuori, Mappes, and Puurtinen 2011; Abbink et al. 2010; Anderson and Freeborn 2010).

Table 2.8: Average effort levels in contest (standard deviation and number of observations in parentheses)

		Low Treatment		High Treatment	
		Theory	Experiment	Theory	Experiment
(L,L)	Effort_principal	12.5	14.4 (5.2, N=184)	4.2	10.1 (5.2, N=34)
(D,D)	Effort_agent	4.2	9.4 (6.6, N=142)	4.2	8.8 (5.8, N=222)
(L,D)	Effort_principal	10.4	14 (5.1, N=161)	4.2	7.3 (4.9, N=112)
	Effort_agent	4.3	9 (6.5, N=161)	4.2	8 (5.9, N=112)

Result 4: There are overbidding from both principals and delegates in the Low treatment while the efforts in the High treatment fit the theory prediction except for the efforts of principals under mutual litigation.

Under mutual litigation, though there are overbidding in both treatments, the effort levels are still significantly lower in the High treatment than in the Low treatment (p=0.0000, Rank-sum test). It seems that despite the overbidding, players do realize the higher cost incurred with their efforts in the High treatment. Hence principals decrease their expenditures in the High treatment compared to the Low treatment.

Result 5: Principals' expenditures under mutual litigation are lower in the High treatment than in the Low treatment.

Table 2.9 displays the total cost and rent dissipation under different scenarios in both treatments. Theory predicts when cost parameter a equals to one, the rent dissipation is smallest under mutual delegation and largest under mutual litigation. I observe the same pattern in my data. When cost parameter a equals to three, I are expected to have the same rent dissipation under all three scenarios. Inspecting my data, I have the lowest rent dissipation under unilateral delegation while the highest is under bilateral litigation. Overall, I have lower rent dissipation in the High treatment compared to the Low treatment. I can safely conclude that by increasing the relative cost of principals to delegates, I can achieve a lower rent dissipation rate in the rent-seeking contest.

Table 2.9: Total costs and rent dissipation in both treatments

	Low Treatment		High Treatment	
	Total costs	Rent dissipation	Total costs	Rent dissipation
(L,L)	28.8	0.576	20.2	0.4
(D,D)	18.8	0.376	17.6	0.352
(L,D)	23	0.46	15.3	0.306

2.4.4 Payoffs of the principals

Figure 2.6 shows the average payoff of principals in no delegation, bilateral delegation and unilateral delegation with different cost parameter a. In a mutual litigation case, the expected payoffs for principals are the same according to theory prediction (32.5 ECUs). However, my data shows that there is a significant difference in the payoffs of principals between the two treatments. In the Low treatment, the payoff of principals is close to my theory prediction. However, principals earn significantly less in the High treatment. This may due to the overspending of principals in the High treatment under no delegation. According to Table 2.8, the mean expenditures of principals in mutual litigation is 10.1 while the equilibrium expenditure is only 4.2.

Result 6: Principals earn significantly less in the High treatment than in the Low treatment under no delegation.

Under unilateral delegation, the payoffs of principals are different when they choose delegation compared to when they choose litigation. In the Low treatment,

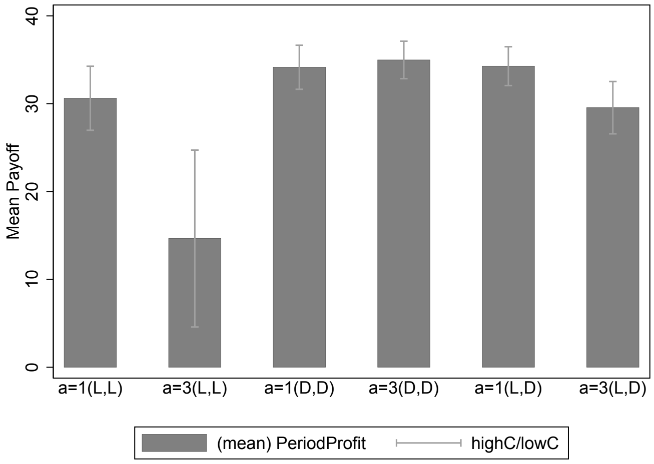

Figure 2.6: Mean payoff of principals

principals earn more when they choose litigation, whereas in the High treatment, principals earn more if they choose delegation. This is because in the Low treatment, principals earn more if they are the only principal who chooses to litigate. As when they are competing against another agent, they have a larger incentive than the lawyers. Hence they invest more than their opponents. Larger expenditures lead to larger winning probability. Hence they get higher payoff.

Overall, in the High treatment, principals earn significantly less when they represent themselves than when they hire delegates (p=0.0000, rank-sum test). This is mainly due to the larger costs principals suffer compared to delegates in the rent-seeking contest. A similar pattern can be observed in the world of law. When asked to comment on the increase of litigants in person (LIPs) in courts, Sir John Thomas, Lord Chief Justice of England and Wales from 2013 to 2017 said "*The saving you get by not having lawyers has to be counter-balanced by the increase you have to have in court time.*"[2]

Result 7: When the cost in participating in the contest is higher for principals than delegates. Principals earn significantly less when they compete by themselves than hiring delegates.

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[2] https://www.lawgazette.co.uk/law/litigants-in-person-putting-pressure-on-courts-system–lcj/5040663.article

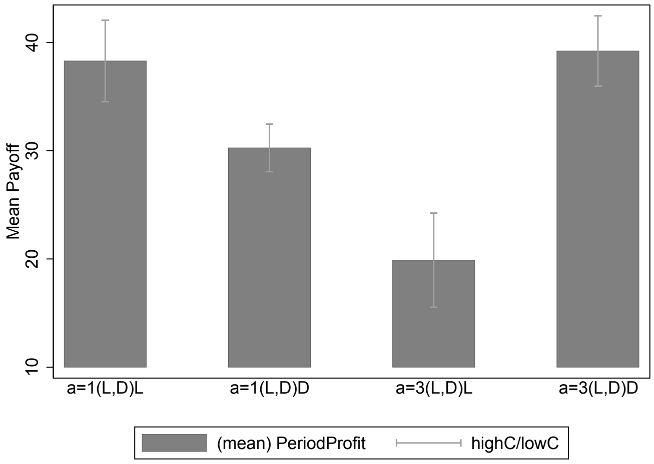


Figure 2.7: Mean payoff of principals in (Litigation, Delegation)

2.4.5 Overall interpretation

In the High treatment where the relative cost of investing is higher for principals than for delegates, the Nash equilibrium choice pair is bilateral delegation. I did observe a significant amount of mutual delegation in my experiment, hence my result shows that asymmetric cost functions in contest game are effective for the theory of strategic delegation to be successful.

The game in the Low treatment has features of a prisoners' dilemma for the principals. Both principals gain from mutual delegation while the dominant strategy is to choose litigation. Theory predicts that principals choose litigation in this treatment yet I still observe almost 50 percent of delegation choices in my experiment. Although research has shown that subjects can cooperate-to some level-in this kind of two persons prisoners' dilemma experiments. Is it possible that my data can solely be explained by this propensity to cooperate? As far as I know the answer is partial yes but the propensity alone cannot fully explain the results.

Table 2.10: Realized payoff matrix in the Low treatment

	Litigation	Delegation
Litigation	30.6,30.6	38.3,30.3
Delegation	30.3,38.3	34.1,34.1

Cooper et al. (1996) found that 22 percent of the subjects cooperate in prisoners'

Table 2.11: Realized payoff matrix in the High treatment

	Litigation	Delegation
Litigation	14.6,14.6	19.9,39.2
Delegation	39.2,19.9	35.0,35.0

dilemma experiment with random matching. Compared to his figure, I observed higher cooperation rates in my experiment. The non-equilibrium choice "delegation" is chosen with a high frequency of 46.8%, which more than doubles the ratio from Cooper et al. (1996). Hence I conclude that while cooperation alone may explain my results to some extent, something else is going on here.

Table 2.10 and Table 2.11 show the (ex-post) realized payoffs of principals resulting from the actual behavior of principals and delegates in the contest in the Low treatment and the High treatment respectively. When I focus on Table 2.10, I can see it is very different from the predicted one in Table 2.5. The main difference is that principals earn a lot less than predicted if they choose litigation in unilateral litigation scenarios. As is evident from Figure 2.3, principals start by a relatively high proportion (roughly 45%) of cooperation choices (i.e. delegation) and the usual propensity of experimental participants to cooperate in prisoners' dilemma might explain this. However, the crucial difference lies in the fact that the players who deviate from mutual delegation do not earn more (there is no significant difference between 38.3 and 34.1). This is because principals tend to overbid when they participate in the contest themselves. Thus, cooperation rates do not decline dramatically as they usually do in cooperation experiments. On the contrary, I observe a small increasing trend of cooperation during the middle of the experiment.

My analysis focus on a symmetric trial environment rather than a pre-trial negotiation and settlements. I assume that the parties in such a case can influence the merits of their case and their probability of winning by hiring legal services. As I see in my analysis, my experiment enables me to examine how rational litigants respond to incentives created by the availability of legal services. Hence it helps to shed light on the debate about the virtues and disadvantages of "litigation in person" in the society of law.

2.5 Conclusions

Suppose that a player in an economic setting has the option of hiring an agent to represent her. The agent then spends his own effort to do her work. In return, the agent gets a fixed payment from the principal if he successfully finishes the work. In this setting, will the principal choose to hire an agent? Does the agent behave differently in the task from the principals? And is the payoff higher for the principal if she chooses to hire an agent? I use a laboratory experiment to investigate these questions. The game I use is Tullock's rent-seeking contest. In my setting, the game has two stages: In the first stage, principals choose whether to hire an agent or not. If a player decides to hire an agent, she will have to reward the agent in the case that the agent wins the contest. In the second stage, principals or agents play a standard Tullock' rent-seeking contest game. I have two treatments in the experiment: In the Low treatment, the cost of spending effort is the same for principal and agent; In the High treatment, the cost of spending for principal is three times the cost for agents.

The main results show that what matters for the principal's choice is the cost structure. If the cost of expenditure is too high for principals, they tend to choose delegation more often. During the experiment, I also observe a substantial level of overbidding compared to Nash predictions. This observation is in line with previous research of Tullock contests, tournaments and all-pay auctions (Dechenaux, Kovenock, and Sheremeta 2015; Abbink 2012; Anderson and Freeborn 2010). Nevertheless, my theory seems to predict well the qualitative impact of changes in relative cost on expenditure in contest. If both principals choose to participate in the contest themselves, their efforts are relatively lower in the High treatment than in the Low treatment. Moreover, agents do invest less in effort than principals in either treatment.

Much of the existing literature on experiments of delegation has appropriately focused on the blame-shifting and responsibility attributions of delegation (examples are Hamman, Loewenstein, and Weber 2010; Garofalo and Rott 2017; Bartling and Fischbacher 2011; Charness et al. 2012). But it is also important to understand how features of cost structure influence the choice of delegation. My experiment fills this gap by providing evidence regarding when and why do players in a contest setting choose delegation.

In the real world, my experiment may model a client–agent setting. When firms compete in R&D contests for patents, they can either use their own employees or hire researchers or university professors. In the latter case, the firm becomes the client and researchers the agents. Usually, researchers and professors are equipped with more adequate skills or superior information, my study thereby shows that it is in the interest of firms to hire professionals for R&D contests.

A limitation of my study is that I only focus on principal-agent relationship in which there is only one kind of contract. Specifically, in my analysis principals only offer fixed payments to agents regardless of agents' behavior. In real-world economic environments, there are many other kinds of possible contract, for example, a contingent fee contract. Different contracts may provide varying incentives for the agents. It would be worth exploring how players' behavior and the outcomes of the game change when I use different kinds of contracts.

2.6 Appendix

2.6.1 A Example of Experimental Instruction: Treatment Low

General Information

You are now taking part in an interactive study on decision making. **Please pay attention to the information provided here and make your decisions carefully**. If at any time you have questions to ask, please raise your hand and we will attend to you in private.

Please note that unauthorized communication is prohibited. Failure to adhere to this rule would force us to stop the experiment and you may be held liable for the cost incurred in this experiment. You have the right to withdraw from the experiment at any point, and if you decide to do so your payments earned during this study will be forfeited.

By participating in this study, you will be able to earn a considerable amount of money. The amount depends on the decisions you and others make.

At the end of this session, this money will be paid to you privately and in cash. It would be contained in an envelope which is indicated with your unique user ID. You will need to sign a receipt form to acknowledge that you have been given the correct payment amount.

General Instructions

Each of you will be given a unique user ID at the beginning of the experiment. Your **anonymity will be preserved** for the study. You will **never be aware of** the personal identities of other players **during or after** the study. Similarly, other players will also **never be aware of** your personal identities **during or after** the study. You will only be identified by your user ID in my data collection. All information collected will **strictly be kept confidential** for the sole purpose of this study.

Your earnings in the experiment are denominated by "**Experimental Currency Unit(s)**" or "**ECU(s)**". At the end of the experiment, they will be converted into

Singapore Dollars at the rate of

1 ECU = 0.1 SGD

The real-dollar equivalent of your final earnings will be added to your **show-up fee** and paid to you in cash at the end of the experiment.

You will participate in **three** stages, the specific instructions for each stage are explained below.

Specific Instructions

Stage 1

There are two types of players in the experiment: **Type A** and **Type B**. Half of the players will be randomly assigned as Type A players and the other half as Type B players.

There are several periods in this stage. At the beginning of each period, each player will be given an endowment. The endowment is denoted by **E**, which is equal to **20 ECUs**.

E = 20 ECUs

In each period, every **Type A** player will be randomly matched with a **Type B** player.

Type A player will face a contest to win a monetary prize against another **Type A** player. The prize is denoted by **V**, which is equal to **50 ECUs**.

V = 50 ECUs

To get the prize, each **Type A** player has two options: **Option 1** and **Option 2**.

Option 1: He or she decides to take part in the contest himself or herself.

Option 2: He or she can hire the **Type B** player who is matched with him or her in this period to take part in the contest on his or her behalf:

1) If the **Type B** player wins the contest, the **Type A** player gets the prize **V** but needs to pay the **Type B** player a positive amount **W**

2) If the **Type B** player loses the contest, the **Type A** player does not need to pay the **Type B** player

We denote the two Type A players in a contest as **Player A1** and **Player A2**. Similarly, we denote the Type B player who is matched with respectively **Player A1** and **Player A2** as **Player B1** and **Player B2**.

Since there are two Type A players and each one has two options, we have the following four possible outcomes:

1) Both **Player A1** and **Player A2** choose **Option 1**

2) **Player A1** chooses **Option 1** and **Player A2** chooses **Option 2**

3) **Player A1** chooses **Option 2** and **Player A2** chooses **Option 1**

4) Both **Player A1** and **Player A2** choose **Option 2**

After both **Type A** players have made their choices, the contest starts. The two players who participate in the contest need to determine how much of their endowments to spend to win the contest. The expenditure is denoted by **S**. **Note that the expenditure should be round numbers (integers)**.

Let me denote the expenditures of the two contestants by S_1 and S_2. The probability of winning the contest will depend on both S_1 and S_2.

The probability that contestant 1 wins the contest is:

$$\frac{S_1}{S_1 + S_2}$$

The probability that contestant 2 wins the contest is:

$$\frac{S_2}{S_1 + S_2}$$

The earnings of the players depend on three factors:

1) **Type A** players' choices between Option 1 and Option 2

2) The result of the contest

3) The players' types

Specifically, the earnings for both **Type A** and **Type B** players are calculated as follows:

1) Both **Player A1** and **Player A2** choose **Option 1**

Both **Type A** players will participate in the contest while both **Type B** players will not participate in the contest.

If Player A1 wins the contest and Player A2 loses the contest.

Player A1's earning is: **E**+**V**-S_1

Player A2's earning is: **E**-S_2

Player B1's earning is: **E**

Player B2's earning is: **E**

2) **Player A1** chooses **Option 1** and **Player A2** chooses **Option 2**

The contest will be played between **Player A1** and **Player B2**. Player B1 and Player A2 will not participate in the contest.

2.1) If **Player A1** wins the contest and **Player B2** loses the contest.

Player A1's earning is: **E**+**V**-S_1

Player A2's earning is: **E**

Player B1's earning is: **E**

Player B2's earning is: **E**-S_2

2.2) If **Player A1** loses the contest and **Player B2** wins the contest.

Player A1's earning is: **E**-S_1

Player A2's earning is: **E+V-W**

Player B1's earning is: **E**

Player B2's earning is: **E+W**-S_2

3) **Player A1** chooses **Option 2** and **Player A2** chooses **Option 1**

The contest will be played between **Player B1** and **Player A2**. Player A1 and Player B2 will not participate in the contest.

3.1) If **Player B1** wins the contest and **Player A2** loses the contest.

Player A1's earning is: **E+V-W**

Player A2's earning is: **E**-S_2

Player B1's earning is: **E+W**-S_1

Player B2's earning is: **E**

3.2) If **Player B1** loses the contest and **Player A2** wins the contest.

Player A1's earning is: **E**

Player A2's earning is: **E+V**-S_2

Player B1's earning is: **E**-S_1

Player B2's earning is: **E**

4) Both **Player A1** and **Player A2** choose **Option 2**

Both **Type B** players will participate in the contest while both **Type A** players will not participate in the contest.

If **Player B1** wins the contest and **Player B2** loses the contest.

Player A1's earning is: **E+V-W**

Player A2's earning is: **E**

Player B1's earning is: **E+W-**S_1

Player B2's earning is: **E-**S_2

This is the end of the decision making process for one period. You will play several periods in this stage. Your type remains the same but the players you are interacting with are different in each period.

At the end of each game, **two periods** will be randomly selected as binding periods to determine your actual payment.

Stage 2

Stage 2 and stage 1 are the same except that your type is **reversed**. For example, if your type is **Type A** in stage 1, then your type will change to **Type B** in stage 2. Similarly, if your type is **Type B** in stage 1, then your type will change to **Type A** in stage 2.

Stage 3

In this part of the experiment you will be asked to make a series of choices. How much you receive will depend partly on chance and partly on the choices you make. The decision problems are not designed to test you. What we want to know is what choices you would make in them. The only right answer is what you really would choose.

For each line in the table on the computer screen, please state whether you prefer **Option L** or **Option R**. Notice that there are a total of ten lines in the table but **just one line** will be randomly selected for payment. You do not know which line will be paid when you make your choices. Hence you should pay attention to the choice you make in every line. After you have completed all your choices, the computer will randomly generate a number, which determines which line is going to be paid.

Your earnings for the selected line depend on which option you chose: If you chose **Option L** in that line, you will receive **20 ECUs**. If you chose **Option R** in that line, you will receive either **40 ECUs or 0**. To determine your earnings in the case you chose Option R, there will be a second random draw. The computer will randomly determine if your payoff is 40 ECUs or 0, with the **chances stated in Option R**.

This is the end of the specific instructions for each stage.

For your reference, your total payoff in this experiment would be sum of the following parts:

(1) Show-up fee

(2) Total earnings of **two randomly chosen binding periods** in Stage 1

(3) Total earnings of **two randomly chosen binding periods** in Stage 2

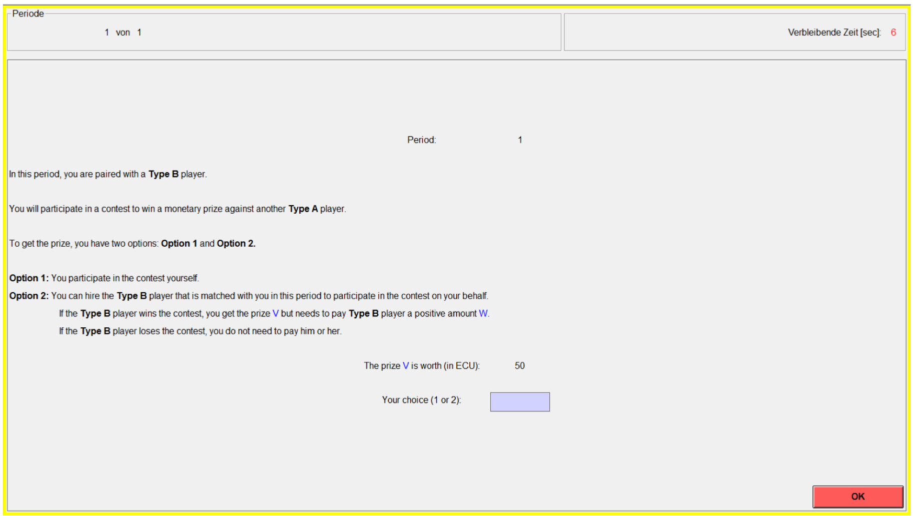
(4) Payoff from Stage 3

Thus, your total earning in this experiment equals to:

(1) + 0.1*(2) + (3) + (4),

where 0.1 is the exchange rate.

2.6.2 Screenshots of the Experiment



Period: 1

In this period, you are paired with a **Type B** player.

You will participate in a contest to win a monetary prize against another **Type A** player.

To get the prize, you have two options: **Option 1** and **Option 2.**

Option 1: You participate in the contest yourself.

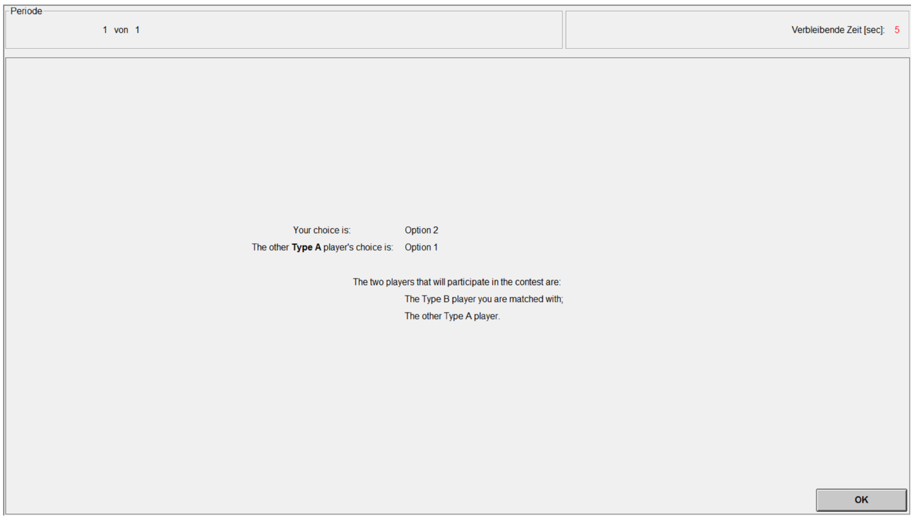
Option 2: You can hire the **Type B** player that is matched with you in this period to participate in the contest on your behalf.

If the **Type B** player wins the contest, you get the prize V but needs to pay **Type B** player a positive amount W.

If the **Type B** player loses the contest, you do not need to pay him or her.

The prize V is worth (in ECU): 50

Your choice (1 or 2):



Your choice is: Option 2

The other **Type A** player's choice is: Option 1

The two players that will participate in the contest are:

The Type B player you are matched with;

The other Type A player.

3 Chapter 3 Asymmetry, Destruction, and Cooperation in Tullock Contests Under the Shadow of the Future

3.1 Introduction

In a standard rent-seeking contest, two players invest costly efforts in order to win a prize. The prize can be regarded as a scarce resource. In the contest, a greater amount of effort expended equates to higher probability of winning. However, effort invested by either party can not be recovered. First proposed by Tullock (1980), this model has been used to address a large variety of social, political, and economic problems.

Despite the simplicity of the model's predictions, it is not easy to conduct an empirical analysis of the rent-seeking model with real data. Data such as the time and resources invested in rent-seeking activities are usually not observable. Even if they are available, they are difficult to collect and may not be free from confounding factors. Furthermore, some parameters, such as the individual value of the prize or the different abilities of players, are difficult to measure and are not available. This makes it difficult to employ empirical estimations using real-life data.

Experimental economics has been proven to be useful in this kind of situation. It has been used widely to study Tullock contests (Sheremeta 2010; Ke, Konrad, and Morath 2013). The lab provides a controlled environment and enables experimenters to isolate all factors that are not relevant in the decision making process. Hence, one can use incentive structures in this controlled environment to study the strategic aspects of the theory.

Much of the literature focuses on symmetric contests, in which all players in the contest are equal (Konrad et al. 2009; Price and Sheremeta 2011). However, the perfect symmetric case is unlikely to happen in the field. Asymmetry between players may stem from varying abilities, different experiences, or different valuations of the prize in the case of contests. For example, people living in different locations receive different economic impacts from the building of a local supermarket; hence, their valuations for the project may differ. In an R&D contest, a firm that has won the contest before may have more experience than its rivals, it may also have gained more knowledge in the relevant field, which results in a larger probability of winning. It is also possible that the previous patent holder values the prize more than new entrants do.

To the best of my knowledge, the first paper to address the effect of asymmetry between players is by Harris and Vickers (1985), who analyze the strategic consequences of asymmetry in a patent race model. Other studies focus on the efforts invested by players in an asymmetric contest. It is of great interest to economists because efforts expended by players can be seen as their engagement in the game. In other scenarios, effort stands for the revenue or tax collected by certain organizations. In a rent-seeking contest, efforts are seen as the social costs incurred in the process; hence, ways to decrease total efforts expended in a rent-seeking contest have been widely studied in the literature. Baik (2004) theoretically studies the effect of asymmetric valuations. He measured the changes in equilibrium effort levels when players value the prize differently or when their relative abilities are different. March and Sahm (2017) provide experimental evidence on the discouragement effect on efforts expended in rent-seeking contests with asymmetric abilities. The results show that, compared to a contest in which players have symmetric abilities, players decrease their efforts in an asymmetric contest in which they are paired with a stronger competitor. However, they invest the same level of effort when fighting against a weak competent in an asymmetric contest. Similarly, Fonseca (2009) also considers the effects of asymmetry on the abilities of players in a rent-seeking contest, finding that the behaviors of players qualitatively fit the predictions of the theory. However, he also observe a high level of overbidding in the experiment. I adopt a similar strategy in my experiment. There are two types of players in the contest: "strong" players and "weak" players. They differ in their relative abilities in the contest, which is reflected in their respective probabilities of winning in the contest.

Conflicts not only come with social costs in the form of wasted resources expended in the contests, they can also be destructive (Chang and Luo 2013; Voors et al. 2012; Flannery and Marcus 2003). A typical example of this is the damage that war does. The two world wars have caused human casualties and the destruction of infrastructure and natural resources. They have also had negative effects on economic transactions and trade. According to Collier (2006), an economy is 15% poorer after a typical conflict, compared to its original state before the conflict. In the literature on the destructive aspects of conflict, destruction can be endogenous or exogenous. Chang, Sanders, and Walia (2015) analyzed a situation in which war has a destructive effect on consumable resources. They studied the best choice between conflict and settlement under this circumstance. Smith et al. (2014) experimentally compared the total costs in conflict between two scenarios: one in which the destruction is endogenous in that it is arms-dependent, another in which they use an exogenously set destruction parameter. They found that, when the destruction of conflict is dependent on competing parties' efforts, conflict is costlier; hence, cooperation in this case is more likely. Applying the standard equilibrium analysis to the model presented by Smith et al. (2014), Chang, Sanders, and Walia (2015) gave different results. They argue that endogenously-destructive conflict reduces the marginal benefit of arming; hence, total arming may decrease in this case. For the sake of simplicity, I use the exogenous destruction parameter in my experiment.

Contests are not only ubiquitous but are also commonly repeated. For example, individuals and institutions apply for research grants or government contracts on a yearly basis. More often it is the same group of applicants participating in a contest. Game theory has recognized that (finitely or infinitely) repeated interactions may induce reward and punishment schemes that support cooperation. In an infinitely repeated game in which there is always a future, the threat of retaliation from the future represents "the shadow of the future" and has the potential to support cooperation.

In the last decade, there has been a growing literature on cooperation in infinitely repeated games (Engle-Warnick and Slonim 2006; McBride and Skaperdas 2014; Dal Bó and Fréchette 2011). McBride and Skaperdas (2014) find that conflict emerges more easily than settlement when the future is more important. They argue that the reason why conflict arises, despite its costs and risks, is that it can be considered as an investment in future strength. Winners of a contest can improve its relative strength. Dal Bó and Fréchette (2011), however, argue that cooperation can emerge in repeated settings. They also note the importance of monitoring and punishment in achieving cooperation. Dal Bó and Fréchette (2018) provide a survey of the literature, especially in regard to infinitely repeated prisoner's dilemma games. A general finding of their analysis is that experimenters do not necessarily observe cooperative behavior from subjects in the experiment, even if cooperation is supported in equilibrium. It is only possible to achieve cooperation when the parameters of the games are set in such a way that cooperation is the equilibrium, regardless of the uncertainties. According to Dal Bó and Fréchette (2018), it is important for subjects to be able to participate in several super-games using the same set of parameters. In this way, subjects can gain experience and become familiar with the experiment. In my experiment, I let subjects play each super-game twice under the same parameters. Dal Bó and Fréchette (2018) also suggest that, during the experiment, payment should not be based on a randomly selected period, which I followed in my experiment by paying for a randomly selected super-game instead. Another guideline is that subjects should change pairs across super-games to avoid interacting with the same partners in different super-games. I shuffle the subjects across super-games.

To create an infinitely repeated game environment in the experimental lab, a common practice is to use a random termination period, in which subjects are all aware of the continuation probability, which is the probability that the current game will continue for another period. The experimenter can set the discount factor or the continuation probability in advance. The subjects then play each super-game without knowing which period is the last. The method was first used by Roth and Murnighan (1978) and has been widely adopted. With the discount factor, I can determine conditions for cooperation in my experiment. Several strategies account for the behaviors of subjects. According to Dal Bó and Fréchette (2018), always defect (AD), grim trigger, tit-for-tat (TFT) are three strategies that cover the majority of strategies observed in the lab. I use Friedman (1971)'s trigger strategy to characterize the Tullock repeated rent-seeking contest. The grim trigger equilibrium is convenient for my analysis here because it is subgame perfect (Shaffer and Shogren 2008). Following grim trigger strategy, a player cooperates in the first period and continues cooperating until the other player defects. After that, the player defects forever. It provides a harsh punishment for defection. Engle-Warnick and Slonim (2006) provide evidence on trigger strategy being used in repeated games. They develop a strategy model and inference procedure to infer strategies from both finite and indefinite trust games. In the indefinite game, they use a continuation probability of 0.8. They find that, consistent with equilibrium strategies, players use grim trigger strategies in the game.

In my experiment, I have three discount factors: 0.3, 0.6, and 0.9. I hope to capture different degrees of "the shadow of the future" by increasing or decreasing the discount factor in my experiment. There is also one game in which the discount factor is set to zero. A match lasts only for one period if the discount factor is equal to zero, so I can compare an infinitely repeated game with a one-shot game. The asymmetry of players' abilities is reflected in players' probability of winning. Suppose, for example, that the expenditure of the strong player is x_s and the expenditure of the weak player is x_w. The winning probability of the strong player is $\frac{ax_s}{ax_s+x_w}$, while the winning probability of the weak player is $\frac{x_w}{ax_s+x_w}$. Parameter $a > 1$ is the ability parameter, which captures the fact that, with the same amount of effort, a strong player is more effective at turning the effort into winning probability than the weak player. The values of the ability parameters that I use in the experiment are 2 and 4. When $a = 2$, the strong and weak players are relatively equal. However, the strong player is much more effective at expending effort than the weak player when a equals 4. I also vary the destructiveness of conflict between treatments. In treatments in which conflict is not destructive, the prize that players fight for is the same as the prize that players peacefully share under cooperation. In treatments in which conflict is destructive, the value of the prize shrinks to half of the original value if both players choose to fight.

My findings can be summarized as follows. First, I found that, in line with theoretical predictions, I observe more cooperation when players are less equally matched in the asymmetric contest. As a result, the total rent-seeking effort levels are lower than in the contest in which players are more equally paired. However, although theory predicts equal equilibrium expenditures from strong and weak players, I find contrasting results in my experiment. The strong players seem to fight more aggressively than their weak opponents. As for the effect of the destructiveness of conflict, I find that subjects are more likely to cooperate and aggregate expenditures are lower when conflict is destructive, as predicted.

The rest of the chapter is structured as follows: Section 3.2 describes the experimental design and the predictions. Section 3.3 shows the experiment procedures. I present and discuss the results in Section 3.4. Section 3.5 concludes.

3.2 Theoretical Background and Predictions

I consider a two-player game in my setting. The two players decide the allocation of a prize V. Both have two options to choose. The two options represent two different ways to allocate the prize between the two players. One option is to cooperate and the other is to defect. More specifically, if both players choose to cooperate, each player gets a proportion of the prize; if both players choose to defect, both players have to participate in a contest game in which the winner gets the whole prize and the loser gets nothing. However, if one of the players chooses to cooperate while the other player chooses to defect, the one who chooses cooperation will get nothing while the other player gets the whole prize. The payoff has a prisoner's dilemma game structure in that both players benefit from cooperating and the Nash equilibrium is to defect. Table 3.1 shows the payoff in each scenario.

Table 3.1: Payoff matrix

	Cooperate	Defect
Cooperate	Each player gets a share of the prize	0,V
Defect	V,0	Both players play a contest game and winner gets the whole prize

3.2.1 Asymmetry in contest

First, I consider the case in which both players choose to defect and participate in a contest game to determine the allocation of the prize. The contest in this scenario is a standard Tullock contest. I consider a two-player game in my experiment, in which each player invests his or her effort X_i from the endowment E in order to get the prize V. The expected payoff for each player in the contest is given by the following equation

$$\Pi_i = p_i V - X_i + E, \qquad i = 1, 2 \tag{24}$$

where p_i is the probability of winning the prize in the contest for player i and is defined as

$$p_1 = \frac{X_1}{X_1 + aX_2} \tag{25}$$

$$p_2 = \frac{aX_2}{X_1 + aX_2}. \tag{26}$$

The a parameter captures the ability difference between the two players. It represents the relative "ability" of player 2 with regard to player 1. If a equals to 1, the game is symmetric. So for either player, each unit of effort invested will result in the same increase of winning probability in the contest. If a is larger than 1, the game is asymmetric; player 2 has a higher ability than player 1. Therefore, to get the same winning probability in the contest, player 1 must invest a times the effort of player 2. Player 1 is called the weak player and player 2 the strong player in my analysis here.

I get the Nash equilibrium when both parties are using strategies that are best responses to the other opponent's strategies. It means both players will maximize their expected payoffs based on their payoff functions of the contest game. Hence I can get the reaction functions of both players:

$$X_1 = (aVX_2)^{1/2} - aX_2 \tag{27}$$

$$X_2 = \frac{(aVX_1)^{1/2} - X_1}{a}. \tag{28}$$

I get the unique Nash equilibrium solution by solving the two equations simultaneously:

$$X_1^* = X_2^* = \frac{aV}{(1+a)^2}, \tag{29}$$

It is worth noting that both players invest the same level of effort in equilibrium regardless of the values of ability parameter a. To understand the logic behind this, I first consider the symmetric case in which a equals to one. In this simple case, the two players enjoy the same abilities in converting effort into winning probabilities. For either player, one unit increase in effort results in the same increase in chances of winning. Now suppose the ability parameter a is larger than 1, which means for the strong player, he or she needs a lower effort to enjoy the same level of winning probability than before. Hence the strong player will decrease his or her effort expenditure. However the reverse applies for the weak player, hence the weak player will lower his or her effort to maximize the payoff in the contest. As a result, both players decrease their effort expenditures when the ability parameter a increases from one. Another conclusion I can get from the analysis here is that the Nash equilibrium effort, as well as the total rent-seeking expenditure, reach the highest value when the game is symmetric.

Hypothesis 1: Strong and weak players invest the same effort in all treatments.

I can calculate the derivative with respect to a of the Nash equilibrium effort accordingly. From Equation 29, the derivative is $\frac{1-a^2}{(1+a)^4}V$. For $a > 1$, it is a negative value. Since the Nash equilibrium is the same for strong and weak players, the effect is uniform for these two types of players. Hence I have the following hypothesis:

Hypothesis 2: Both strong and weak players' effort decrease when the ability difference between the two types of players gets larger.

If both players choose to cooperate, then each player gets a share s_i of the prize V. More specifically, the share is defined as

$$s_1 = \frac{X_1}{X_1 + aX_2} \tag{30}$$

$$s_2 = \frac{aX_2}{X_1 + aX_2}. \tag{31}$$

Note that the shares functions are the same as the winning probabilities formula in the case that both players choose defection and play a contest game. The difference between the two cases is that in the mutual cooperation scenario, each player gets a share of the prize for sure, whilst in the contest case, only one player will get the prize with the stated probability and the other player will get nothing.

3.2.2 Destruction in contest

I now further assume there is destruction to the prize if both choose to defect. The intuition behind this that during conflict, damage is inevitable. For example, war will lead to casualties and reduce human capital; There are also physical damages to the resources of involved countries. I use parameter θ to capture the damages induced by conflict. Hence, in the case of mutual defection, the value of the prize V shrink to $(1-\theta)V$.

The expected payoff of player i in this case becomes

$$\Pi_i = p_i(1-\theta)V - X_i + E, \qquad i = 1, 2 \tag{32}$$

where p_i is the probability of winning the prize in the contest for player i. The winning probabilities are the same as before, namely:

$$p_1 = \frac{X_1}{X_1 + aX_2} \tag{33}$$

$$p_2 = \frac{aX_2}{X_1 + aX_2}. \tag{34}$$

The first-order condition for player i and player j are:

$$\frac{aX_2}{(X_1 + aX_2)^2}(1-\theta)V = 1 \tag{35}$$

$$\frac{aX_1}{(X_1 + aX_2)^2}(1-\theta)V = 1 \tag{36}$$

Solving these two equations simultaneously I get the equilibrium efforts for both players:

$$X_1^* = X_2^* = \frac{\alpha(1-\theta)}{(1+\alpha)^2}V \tag{37}$$

I can see that strong and weak players still invest the same effort in equilibrium. Their equilibrium efforts decrease with destruction parameter θ, so the more destructive the conflict is, the less the efforts.

Hypothesis 3: Total expenditures decrease with destruction parameter θ.

While both players invest the same during the conflict, their winning probabilities are different due to the dissimilarity in abilities. Hence the equilibrium payoff for weak player 1 is $\frac{(1-\theta)V}{(1+\alpha)^2}$ while the equilibrium payoff for the strong player is $\frac{(1-\theta)\alpha^2 V}{(1+\alpha)^2}$. I have the payoff matrix as in Table 3.2. The Nash equilibrium is still (Defection, Defection).

3.2.3 Infinitely repeated games

Now I turn to infinitely repeated games in the contest environment. In economic theory, infinitely repeated games are represented by a series of games in which the

Table 3.2: Payoff matrix of strong player and weak player with destruction to prize

	Cooperate	Defect
Cooperate	$\frac{\alpha}{1+\alpha}V, \frac{1}{1+\alpha}V$	0,V
Defect	V,0	$\frac{(1-\theta)\alpha^2 V}{(1+\alpha)^2}, \frac{(1-\theta)V}{(1+\alpha)^2}$

payoff from each period is discounted. Usually, the discount factor is exogenous and can be set by researchers. The exogenous discount factor represents the reality that people usually give less weight to things happen in the future. What is more, with a positive discount factor I can solve for many decision problems under infinitely repeated games. In practice, the discount factor may vary across individuals and time. However, I adopt the standard assumption in literature and use fixed discount factor δ here for the sake of simplicity in the analysis.

Without loss of generality, I employ Friedman's (1971) grim trigger strategy to characterize the game: both players cooperate in the first period. After that, either player will choose to punish the defector by reverting to the Nash equilibrium forever. A simulation by Linster (1992) shows that Grim Trigger is the most successful automation strategy. It is also appealing for its simplicity.

Under the grim trigger strategy, I can calculate the payoff of a deviator over the infinite horizon. At first, both players get the cooperative payoff, then the deviator gets hold of the entire prize by defecting. The other player responds by choosing the Nash equilibrium forever. Hence the payoff of deviation is the one-time payoff of the whole prize V plus a discounted infinite sequence of Nash payoff:

$$\pi_{D1} = V + \delta(\frac{1}{(1+\alpha)^2}V) + \delta^2(\frac{1}{(1+\alpha)^2}V) + \ldots = V + \frac{1}{(1+\alpha)^2}V\frac{\delta}{1-\delta}. \tag{38}$$

Using the grim trigger strategy, the payoff of cooperation for each player is defined as:

$$\pi_{C1} = \frac{1}{1+\alpha}V + \delta(\frac{1}{1+\alpha}V) + \delta^2(\frac{1}{1+\alpha}V) + \ldots = \frac{1}{1+\alpha}V\frac{1}{1-\delta}. \tag{39}$$

Equations (38) and (39) imply that the weak player (player 1) will cooperate if $\pi_{C1} \geq \pi_{D1}$, or if:

$$\delta > \frac{\alpha+1}{\alpha+2}. \tag{40}$$

Similarly, for the strong player (player 2), he or she will cooperate as long as

$\pi_{C2} \geq \pi_{D2}$, or if:

$$\delta > \frac{\alpha+1}{2\alpha+1} \tag{41}$$

From equations (40) and (41) I get the conclusion cooperation can be sustained with a large enough discount factor under grim trigger strategy. A large δ here means the future payoffs are not steeply discounted. The intuition behind this is that when the future is not too steeply discounted, the punishment by reverting to Nash equilibrium action seems more severe compared to the case in which the future punishment is largely discounted.

Another finding is that for $a > 1$, the cooperation threshold is smaller for the strong player than for the weak player. It implies that it is more easy for the weak player to defect. The reason behind this is that the payoff of one-time deviation is the same for both weak and strong players, but the loss after deviation is different among the two types of players. The loss can be represented by the difference in payoff between mutual cooperation and mutual defection. From the analysis above I can see that the loss is larger for strong players as it is proportional to ability parameter a.

When there is destruction to the prize in the contest scenario, I can calculate the cooperation threshold for weak and strong players respectively following the same procedure. For the weak player, the payoff of defection is:

$$\pi_{Dw} = V + \delta(\frac{1-\theta}{(1+\alpha)^2}V) + \delta^2(\frac{1-\theta}{(1+\alpha)^2}V) + \ldots = V + \frac{1-\theta}{(1+\alpha)^2}V\frac{\delta}{1-\delta} \tag{42}$$

The payoff of cooperation is:

$$\pi_{Cw} = \frac{1}{1+\alpha}V + \delta(\frac{1}{1+\alpha}V) + \delta^2(\frac{1}{1+\alpha}V) + \ldots = \frac{1}{1+\alpha}V\frac{1}{1-\delta} \tag{43}$$

So weak player will cooperate if $\pi_{Cw} > \pi_{Dw}$, which is $\delta > \frac{\alpha^2+\alpha}{\alpha^2+2\alpha-\theta}$, which is bigger than $\frac{\alpha+1}{\alpha+2} = \frac{\alpha^2+\alpha}{\alpha^2+2\alpha}$ in the no destruction case.

For the strong player, the payoff from defection is:

$$\pi_{Ds} = V + \delta(\frac{(1-\theta)\alpha^2}{(1+\alpha)^2}V) + \delta^2(\frac{(1-\theta)\alpha^2}{(1+\alpha)^2}V) + \ldots = V + \frac{(1-\theta)\alpha^2}{(1+\alpha)^2}V\frac{\delta}{1-\delta} \tag{44}$$

The payoff from cooperation is:

$$\pi_{Cs} = \frac{\alpha}{1+\alpha}V + \delta(\frac{\alpha}{1+\alpha}V) + \delta^2(\frac{\alpha}{1+\alpha}V) + \ldots = \frac{\alpha}{1+\alpha}V\frac{1}{1-\delta} \tag{45}$$

So strong player will cooperate when $\pi_{Cs} > \pi_{Ds}$. The solution is $\delta > \frac{\alpha+1}{\theta\alpha^2+2\alpha+1}$, which is smaller than $\frac{\alpha+1}{2\alpha+1}$ in the no destruction case.

With destruction, the weak player will cooperate if:

$$\delta > \frac{\alpha^2+\alpha}{\alpha^2+2\alpha-\frac{1}{2}} \tag{46}$$

Similarly, for the strong player, he or she will cooperate if:

$$\delta > \frac{\alpha+1}{\frac{1}{2}\alpha^2+2\alpha+1} \tag{47}$$

Comparing the cooperation threshold for weak players (equations (40) and (41)), I find that the cooperation threshold is larger in the case in which there is destruction to the prize in the contest, it implies that it is less likely for the weak player to cooperate if there is destruction. However I get the opposite result for the strong player, they cooperate more easily if there is destruction to the prize in the case of contest.

Hypothesis 4: It is more difficult for weak players to cooperate if the conflict is destructive.

Hypothesis 5: Strong players cooperate more easily when conflict is destructive.

3.3 Experimental Design and Procedures

To capture the different abilities of strong and weak players, I have two values of ability parameter a in my experiment: $a = 2$ where the gap between the relative abilities of the two players is not so large and $a = 4$ where the strong player is a lot more able than the weak player.

Another treatment variable is whether there is destruction of the prize in the case of a contest. I have introduced the model without destruction in which the prize in the contest is the same as the prize in other scenarios. In the other variant, if both players choose defection and they have to play the contest game, the prize in the contest will shrink compared to the other three cases. In my experiment, I set the shrinkage rate to one half. I have two treatment variables and each treatment variable has two values, hence I have four treatments in total.

Following the current literature, I use the probability of continuation as a measure of the discount rate. I use four different continuation probabilities in my experiment: 0, 0.3, 0.6 and 0.9. For continuation probability 0, it is equivalent to a one-shot game. The exact number of periods in a given match is determined by the computer based on the continuation probability. In my case, the expected number of periods is 1.4 when the discount factor equals 0.3. It is 2.5 under 0.6 and 10 under 0.9. The values of continuation probabilities were chosen because, first, they reflect different degrees and evenly distributed of "shadows of future", and, second, they allow for sharp predictions.

Using the parameter values I have in my experiment, I can calculate the threshold for different situations in the experiment setting. Table 3.3 outlines the predicted choices for both strong and weak players in each treatment.

In the one-shot game, the Nash equilibrium is both players choosing defection. Table 3.4 outlines the four different treatments as well as the equilibrium options and efforts for each one.

I are able to establish several testable predictions based on the Nash equilibrium predictions.

Prediction 1. In treatment 2N, the average effort will be 11.11; In treatment 2D, the average effort will be 5.55; In treatment 4N, the average effort will be 8; In treatment 4D, the average effort will be 4.

Prediction 2. Under the same ability difference parameter, the average effort in treatment with destruction is half of the average effort in treatment without destruction.

Prediction 3. Players behave more cooperatively (choose less fight options) in treatments with destruction than in treatments without destruction.

Prediction 4. When the continuation probability is 0, both strong and weak

Table 3.3: Choice predictions

Treatments	Continuation probability	Choice (Weak,Strong)
2N	C=0	(D,D)
	C=0.3	(D,D)
	C=0.6	(D,D)
	C=0.9	(C,C)
2D	C=0	(D,D)
	C=0.3	(D,D)
	C=0.6	(D,C)
	C=0.9	(C,C)
4N	C=0	(D,D)
	C=0.3	(D,D)
	C=0.6	(D,C)
	C=0.9	(C,C)
4D	C=0	(D,D)
	C=0.3	(D,C)
	C=0.6	(D,C)
	C=0.9	(C,C)

Table 3.4: Treatments and predictions in one-shot game

Treatment name	a	Destruction	Equilibrium choice	equilibrium effort
2N	2	No destruction	(Defect,Defect)	(11.11,11.11)
2D	2	With destruction	(Defect,Defect)	(5.55,5.55)
4N	4	No destruction	(Defect,Defect)	(8,8)
4D	4	With destruction	(Defect,Defect)	(4,4)

players choose fight options; when the continuation probability is 0.9, both strong and weak players choose to cooperate.

The experiment was programmed and conducted using the software z-Tree (Fischbacher, 2007). Four experimental sessions with 10 to 12 subjects in each session were run for each treatment. Each participant took part in only one session and no participant had experience in similar experiments before. Table 3.5 summarizes the information for each treatment.

Upon arrival, participants were randomly assigned cubicles in the experimental economics laboratory. The cubicles did not allow for any visual communication between participants. During the experiment, verbal communication is also prohibited. Once all the participants were seated, each of them is given a written copy of the instructions. The experimenter read the instructions aloud while participants reading their own copies. After reading the instructions, all participants were required to answer 5 quiz questions to ensure common knowledge of the experimental conditions. Participants were encouraged to raise their hands should they encounter any problem with the instructions. All questions were answered privately by the experimenter. The experiment commenced once all participants passed the quiz.

At the start of the experiment, the participants were randomly assigned roles. I used neutral language such as "type 1 player" and "type 2 player" instead of "weak player" and "strong player" throughout the experiment's instructions. Subjects retained their roles throughout the experiment. They were told that they would participate in a series of games, each game would last several periods. The game was played in pairs and subjects were randomly assigned to pairs with one type 1 player and one type 2 player in each pair. The pair composition remained the same during each game but subjects were re-matched for a different game.

Table 3.5: Session summary

	2N	**2D**	**4N**	**4D**
No. of sessions	4	4	4	4
No. of participants	48	48	40	48

Each game lasted several periods. The number of periods was determined by the continuation probability used in each game. The continuation probability represents the probability that the game continues to period 2, the probability that period 3 is reached given you are in period 2, and so on. Subjects were also told that different games had different continuation probabilities. There were four values of the continuation probability in this experiment: 0, 0.3, 0.6, and 0.9. The continuation probability was shown to the subjects at the beginning of each game.

At the start of each period, subjects were given 20 Experimental Currency Units(ECUs) as endowment. The value of the prize is 50 ECUs. In the end, subjects were paid by four randomly chosen games. One ECU was worth S$0.05.

At the end of the experiment, all participants were required to fill up a questionnaire about their social demographics and personal strategies for the experiment.

I conducted 16 experimental sessions in December 2018 in the behavioral and experimental economics labs of Nanyang Technological University (NTU), Singapore. Each session lasted about one hour and a half. On average, each student received 19.6 Singapore dollars from participating, including 2 Singapore dollars show-up fee. Subjects were paid privately and in cash. A total of 184 undergraduates (86 males and 98 females) from various disciplines participated in the study.

3.4 Results and Discussions

Table 3.6 describes the general data from the experiment. In total, I have 184 participants in my study. All the participants were randomly allocated to four treatments. Kruskal-Wallis test shows no significant difference on risk averse value among the treatments. When I focus on the efforts of players, I see that in general players spend less in treatment with destruction compared to treatment without destruction (treatment 2N versus treatment 2D; treatment 4N versus treatment 4D).

Also, average contest expenditures are lower when the ability difference between strong and weak players is larger (treatment 2N versus treatment 4N; treatment 2D versus treatment 4D). Another thing worth noting in Table 3.6 is that a significant number of subjects choose to fight in the experiment, the percentage of players who choosing fighting options is above 90 percent in all four treatments. Table 3.6 also breaks down the contest expenditures and choice percentages into strong and weak players. In general, strong players invest higher effort than weak players. As far as the choice percentage is concerned, there is no difference between strong and weak players.

Table 3.6: Breaks down of experiment data into strong and weak players

	2N	**2D**	**4N**	**4D**
Variable means:				
Risk averse	6.5	7.1	6.3	7.4
Effort (overall)	13.2	9.3	9.6	6.6
Effort (strong)	13.7	10.4	12.4	6.8
Effort (weak)	12.7	8.3	6.9	6.4
Choice (overall)	0.97	0.93	0.94	0.90
Choice (strong)	0.98	0.94	0.98	0.93
Choice (weak)	0.96	0.93	0.91	0.87

Note. Defection: Choice = 1; Cooperation: Choice = 0

3.4.1 Efforts in contest

According to my model, the equilibrium efforts for strong and weak players if they both choose defection are shown in column 2 of Table 3.7. The expected effort in treatment without destruction is twice the expected value in treatment with destruction. The reason is that in my model, the equilibrium effort is proportional to the value of the prize. In treatment with destruction, the value of the prize shrinks to half of the value of the prize in treatment without destruction. Hence, the expected effort decrease by one half accordingly. As for treatments in which I vary players' ability difference, the equilibrium effort is lower in treatment where players' ability difference is larger.

The third column of Table 3.7 and Figure 3.1 show the average efforts under four

Table 3.7: Predicted and observed efforts of players (in ECUs)

Treatment	Nash equilibrium effort	Mean effort	t-statistic
2N	11.11	13.20	8.2718
2D	5.55	9.33	20.4311
4N	8	9.63	6.8360
4D	4	6.57	12.9248

different continuation probabilities in all treatments. Comparing column two and column three in Table 3.7, I can see that there is overbidding in each treatment. The last column in Table 3.7 provides the t-statistic. I test for the null hypothesis that the mean effort level is equal to the Nash equilibrium effort level. In each treatment, I observe significantly larger effort than the theory prediction at the 1 percent level.

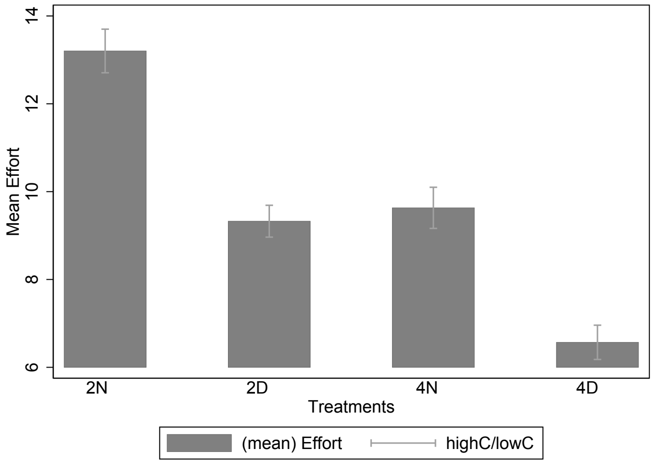


Figure 3.1: Average Effort over treatments

Finding 1. The average efforts are higher than Nash equilibrium efforts in all treatments.

When I focus on the effect of destruction on players' efforts, it is obvious that when the ability difference parameter is the same, players invest lower efforts in treatments with destruction. However, I also observe that players' efforts do not decrease proportionally to the predicted effort levels when the prize shrinks in treatment with destruction. For example, comparing treatment 2N with treatment 2D, effort is predicted to be 50 percent lower in treatment 2D but is actually only 29.3

percent lower. Similarly, the observed effort is only 31.8 percent lower in treatment 4D when compared with treatment 4N, but the prediction is 50 percent lower.

Table 3.8 shows the regression table in treatments in which the ability parameter is equal to 2. Table 3.9 displays the regression table in treatment 4N and treatment 4D. It is obvious that destruction has a negative effect on a player's effort under both values of ability parameter. For example, in treatment 2D, observed effort decrease by 3.6 ECUs compared to treatment 2N. The magnitude of the decrease is quite similar in treatment in which the ability parameter equals to 4. The effort drops by approximately 4.1 ECUs in treatment 4D compared to treatment 4N.

Finding 2. Under the same ability parameter, the average effort in treatments with destruction is significantly lower than the average effort in treatment without destruction. But the magnitude of the decrease is smaller than predicted.

Turning now to the effect of ability difference on players' effort. From Figure 3.1, it is obvious that the average effort is lower in treatment in which the ability parameter equals to 4 compared to treatment in which the ability parameter is 2. Table 3.10 shows the regression table in treatment 2N and treatment 4N, Table 3.11 shows the regression table in treatment 2D and treatment 4D. In both tables, the effect of the ability parameter is significant. One unit increase in the ability difference parameter decreases both types of players' effort by 1.5 units in treatment without destruction and 1.9 units in treatment with destruction.

Finding 3. The increase of ability difference parameter will decrease both strong and weak players' efforts.

Theory predicts that strong and weak players invest the same level of effort when they fight in a contest. Figure 3.2 displays the realized efforts of both strong and weak players in my experiment. According to my analysis, the efforts of strong and weak players should be the same despite their different abilities. However, I observe significantly higher efforts from strong players than weak players in all treatments except treatment 2N. The z-statistics and p-value from Mann-Whitney test are shown in the last column of Table 3.12. The null hypothesis is strong and weak players spend the same level of effort. It is significant at the 1 percent level in all treatments except treatment 2N.

Table 3.8: OLS regressions in treatment 2N and 2D (Dependent Variable: Effort)

	(1)	(2)	(3)	(4)
destruction	-3.847***	-4.026***	-4.043***	-3.564***
	(0.590)	(0.791)	(0.856)	(1.016)
continue	-0.0719	-0.241	-0.241	-0.0490
	(0.560)	(0.390)	(0.390)	(0.472)
destruction*continue		0.288	0.284	0.249
		(0.990)	(0.990)	(0.959)
Gender			-0.176	-0.477
			(1.190)	(1.173)
Strong			1.587**	1.548**
			(0.512)	(0.546)
Period				-0.0619
				(0.0415)
Risk				-0.404
				(0.350)
Constant	13.01***	13.11***	12.43***	15.72***
	(0.675)	(0.663)	(1.246)	(2.778)
Observations	2136	2136	2136	2136
Adjusted R^2	0.073	0.073	0.085	0.098

Note. Robust standard errors are in parentheses.

*, **, and *** denote significance at the 10%, 5%, and 1% level, respectively.

Table 3.9: OLS regressions in treatment 4N and 4D (Dependent Variable: Effort)

	(1)	(2)	(3)	(4)
destruction	-3.168***	-4.214**	-4.048**	-4.056**
	(0.872)	(1.249)	(1.286)	(1.175)
continue	0.320	-0.510	-0.535	-0.331
	(0.591)	(1.037)	(1.024)	(0.944)
destruction*continue		1.502	1.527	1.252
		(1.100)	(1.085)	(1.000)
Gender			0.940	0.937
			(1.016)	(1.001)
Strong			3.089**	3.069**
			(1.114)	(1.120)
Period				-0.0581
				(0.0309)
Risk				0.0739
				(0.168)
Constant	9.244***	9.856***	7.871***	8.000***
	(0.747)	(1.042)	(1.304)	(2.040)
Observations	1920	1920	1920	1920
Adjusted R^2	0.061	0.062	0.120	0.123

Note. Robust standard errors are in parentheses.

*, **, and *** denote significance at the 10%, 5%, and 1% level, respectively.

Table 3.10: OLS regressions in treatment 2N and 4N (Dependent Variable: Effort)

	(1)	(2)	(3)	(4)
ability parameter	-1.720***	-1.629**	-1.544**	-1.513*
	(0.372)	(0.618)	(0.621)	(0.655)
continue	-0.377	0.0273	0.0608	0.188
	(0.562)	(1.298)	(1.291)	(1.331)
ability parameter*continue		-0.134	-0.151	-0.120
		(0.554)	(0.549)	(0.519)
Gender			1.243	1.274
			(1.416)	(1.315)
Strong			3.404**	3.411**
			(1.092)	(1.123)
Period				-0.0611
				(0.0454)
Risk				-0.302
				(0.224)
Constant	16.64***	16.37***	13.75***	16.09***
	(1.222)	(1.687)	(2.290)	(3.197)
Observations	1848	1848	1848	1848
Adjusted R^2	0.055	0.055	0.117	0.126

Note. Robust standard errors are in parentheses.

*, **, and *** denote significance at the 10%, 5%, and 1% level, respectively.

Table 3.11: OLS regressions in treatment 2D and 4D (Dependent Variable: Effort)

	(1)	(2)	(3)	(4)
ability parameter	-1.420***	-1.723***	-1.806***	-1.846***
	(0.372)	(0.406)	(0.371)	(0.364)
continue	0.489	-0.900	-0.931	-0.622
	(0.547)	(1.856)	(1.862)	(1.663)
ability parameter*continue		0.473	0.481	0.385
		(0.490)	(0.492)	(0.442)
Gender			-0.761	-0.700
			(0.692)	(0.677)
Strong			1.164*	1.164*
			(0.593)	(0.583)
Period				-0.0592
				(0.0322)
Risk				0.114
				(0.349)
Constant	11.65***	12.53***	12.50***	12.48***
	(0.801)	(1.103)	(1.001)	(2.268)
Observations	2208	2208	2208	2208
Adjusted R^2	0.054	0.055	0.067	0.072

Note. Robust standard errors are in parentheses.

*, **, and *** denote significance at the 10%, 5%, and 1% level, respectively.

My result is in line with the finding of March and Sahm (2017). In their experiment, they examine players' effort in a rent-seeking experiment in which the abilities between players differ. Similar to me, they found that weak players do invest fewer efforts than strong players. However, this effect is only significant when the prize is relatively high. The contest game they studied is a finite repeated game in that the future does not play a part in their experiment. Fonseca (2009) also studied asymmetric rent-seeking experiments in both simultaneous and sequential move environments. They showed that in the simultaneous move, there is no significant difference in effort levels between strong and weak players. It is worth noticing that they only focus on the last third of the experiment while I examined players' choice of efforts throughout the whole experiment.

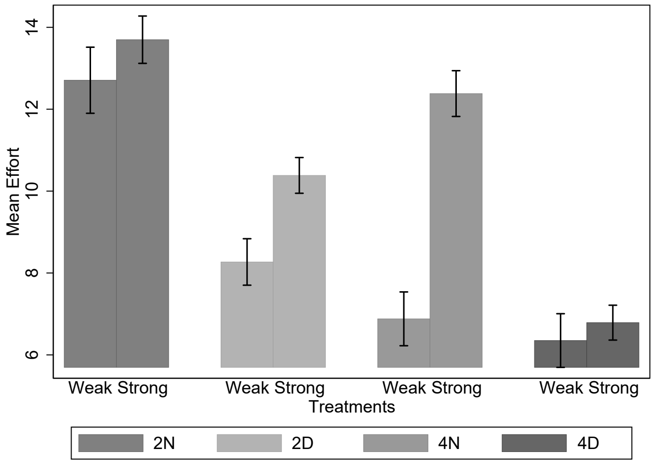


Figure 3.2: Efforts of strong and weak players over treatments

Finding 4. Strong and weak players do not spend the same efforts. More specifically, strong players invest higher effort than weak players in all treatments except treatment 2N.

3.4.2 Individual choices

Figure 3.3 shows the mean choice of players in all treatments. There is a significant amount of fighting in my experiment. In all treatment, the percentage of players choosing to fight is larger than 90 percent though there is a difference between treatments. From Figure 3.4 I can see that there is almost no cooperation in the

Table 3.12: Efforts of strong and weak players

Treatment	Nash equilibrium effort	Strong	Weak	Z-statistics from Mann-Whitney test (p-value)
2N	11.11	13.7	12.7	-0.701 (0.4836)
2D	5.55	10.4	8.3	-6.123^{***} (0.0000)
4N	8	12.4	6.9	-12.009^{***} (0.0000)
4D	4	6.8	6.4	-4.391^{***} (0.0000)

Note: The last column tests the prediction: $Effort_{weak} = Effort_{strong}$

four treatments. Since the Nash equilibrium is (D,D) in all treatments, this result comes as no surprise.

Finding 5. Subjects choose a significant amount of fighting options in the experiment.

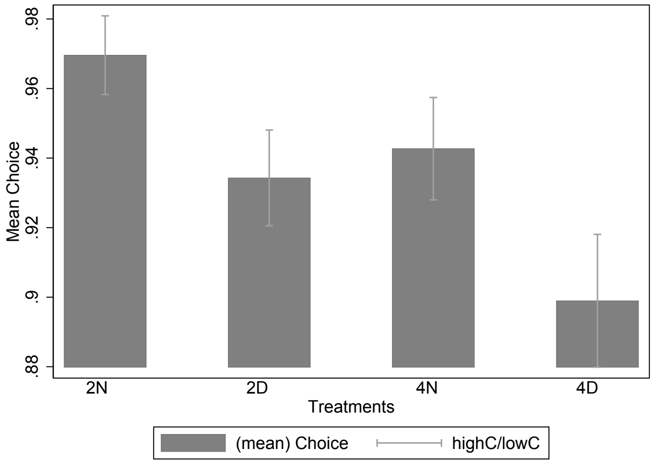


Figure 3.3: Choice over treatments

Figure 3.5 displays individual choices of both strong and weak players in my experiment. In general, strong players are more aggressive than weak players in that they tend to choose more fighting options. From my analysis in Table 3.3, I should expect different behaviors on choices between strong and weak players.

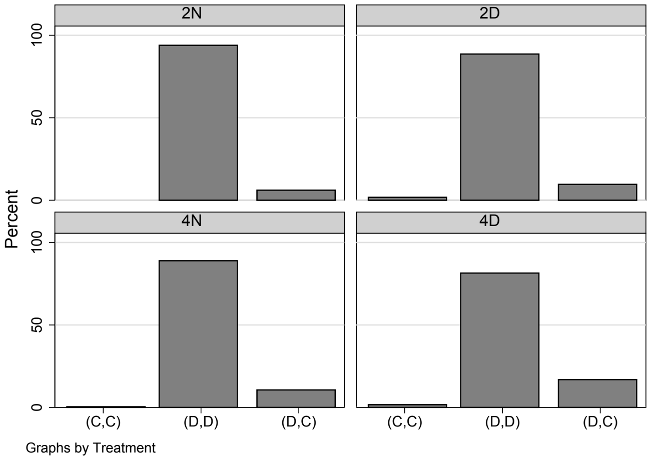


Figure 3.4: (C,C) (C,D) (D,D) over treatments

However, I did not observe a significant difference in choices between strong and weak player.

Finding 6. There is no significant difference in choices between strong and weak players.

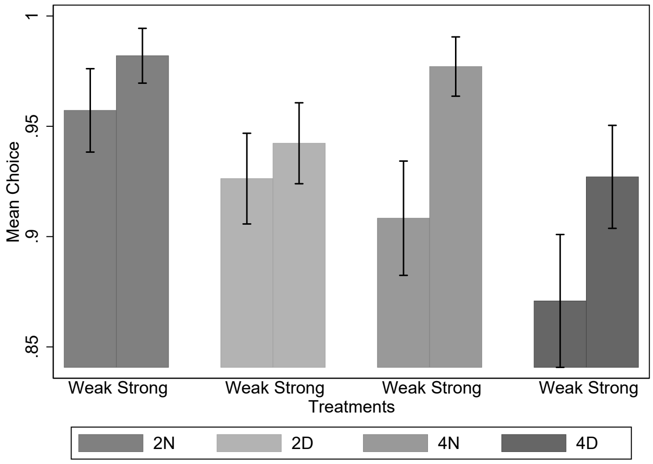


Figure 3.5: Choice of strong and weak players over treatments

3.4.3 Payoff

Based on theory prediction, the equilibrium payoff of strong and weak players are shown in Table 3.13. Strong players get higher expected payoff than the weak

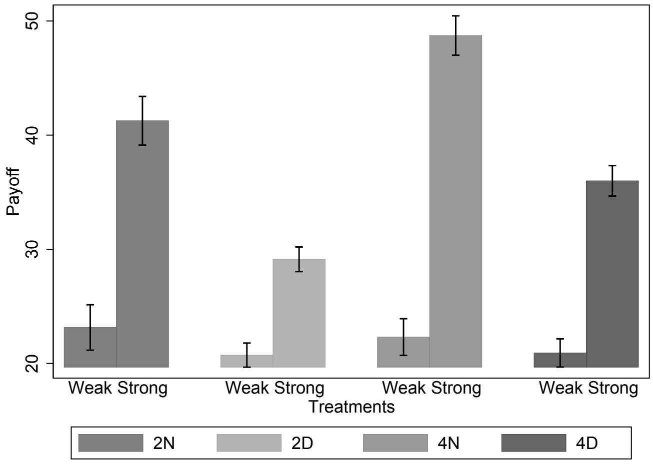


Figure 3.6: Payoff of strong and weak players in four treatments

players in all treatments. Comparing treatment in which conflict is destructive with treatment in which conflict is not destructive, both strong and weak players earn less in the former case. Figure 3.6 shows the realized payoffs in my experiment. The payoffs of both strong and weak players are not significantly different from theory predictions. Another thing to note is that there is a significant difference in payoffs between strong and weak players in that strong players earn much more than weak players. This result comes as no surprise as strong players enjoy higher winning probabilities than weak players given the same expenditure. On top of that, strong players do invest higher effort than weak players in my experiment. Combining these two factors, I have strong players enjoying higher payoffs than weak players in my experiment.

Finding 7. Strong players get higher payoffs than weak players in all treatments.

Table 3.13: Equilibrium payoffs of strong and weak players (in ECUs)

Treatment	Strong Player	Weak Player
2N	42.22	25.55
2D	31.11	22.77
4N	52	22
4D	36	21

3.5 Conclusions

This chapter seeks to shed light on the impact of asymmetries in players' ability and destruction of contest prize on players' behaviors in Tullock contests. I also consider different scenarios in which the length of the contest is varied. Specifically, I are interested in the players' effort and cooperation level in the contest game. I varied players' abilities in that given the level of expenditures, strong players have higher winning probabilities than weak players. I also vary the value of the prize across treatments. In treatments in which there is destruction to the prize if both players choose to fight, the value of the prize is only half of that in treatments without destruction.

One of my observations is that there is a high level of overbidding compared to risk-neutral Nash predictions. The result is in line with a substantial number of studies of Tullock contests, tournaments as well as all-pay auctions. However, the theory does predict well about the qualitative impact of destruction on players' contest expenditure. Players do decrease their expenditures when there is destruction to the prize, though the drop in efforts is not proportional to theory prediction. It is also confirmed that when the asymmetries increase between the strong player and the weak player, both players' expenditures decrease. However, I do not find a significant difference in fighting choices between strong and weak players. Both types are quite aggressive in that more than 90 percent of them choose to fight in all treatments.

My results have several implications from a policy perspective. A significant amount of discussion in the contest literature focuses on rent-seeking expenditures in the contest. They are often regarded as the social costs incurred during the conflict. Discouragement effect has long been thought to be helpful in reducing expenditures. The intuition is that if the differences between players are highlighted in the contest, it may help to discourage the less able players and reduce effort expenditures. My model proves that such a policy may indeed be effective. The experiment results show that releasing information on participants' heterogeneity can decrease total expenditures in a contest. Moreover, my results illustrate that informing players about the destructive aspect of a contest could also help in reducing effort levels.

3.6 Appendix

3.6.1 A Sample of Experimental Instruction: Treatment 2N

General Information

You are now taking part in an interactive study on decision making. **Please pay attention to the information provided here and make your decisions carefully**. If at any time you have questions to ask, please raise your hand and we will attend to you in private.

Please note that unauthorized communication is prohibited. Failure to adhere to this rule would force us to stop the experiment and you may be held liable for the cost incurred in this experiment. You have the right to withdraw from the experiment at any point, and if you decide to do so your payments earned during this study will be forfeited.

By participating in this study, you will be able to earn a considerable amount of money. The amount depends on the decisions you and others make.

At the end of this session, this money will be paid to you privately and in cash. It would be contained in an envelope which is indicated with your unique user ID. You will need to sign a receipt form to acknowledge that you have been given the correct payment amount.

General Instructions

Each of you will be given a unique user ID at the beginning of the experiment. Your **anonymity will be preserved** for the study. You will **never be aware of** the personal identities of other players **during or after** the study. Similarly, other players will also **never be aware of** your personal identities **during or after** the study. You will only be identified by your user ID in our data collection. All information collected will **strictly be kept confidential** for the sole purpose of this study.

At the beginning of the experiment, we will randomly divide you into **two** groups: **Group A** and **Group B**. Each group consists of **half of the players in the lab**.

Group composition will **remain the same** throughout the experiment. **You will only interact with players from your own group**.

In each group, there are **two** types of players: **Type 1** and **Type 2**. Your type is randomly assigned to you at the beginning of the experiment. Once assigned, **your type will remain the same** throughout the experiment. Players will only interact with players of a **different** type in the **same** group.

Your earnings in the experiment are denominated by "**Experimental Currency Unit(s)**" or "**ECU(s)**". At the end of the experiment, they will be converted into Singapore Dollars at the rate of

1 ECU = 0.05 SGD

The real-dollar equivalent of your final earnings will be added to your **show-up fee** and paid to you in cash at the end of the experiment.

You will participate in **two** stages, the specific instructions for each stage are explained below.

Specific Instructions

Stage 1

In this stage, you will form a pair with a **different type** of player **from your own group**. Players in each pair will interact with each other for several matches. Your earnings will depend on the decisions you and the other player make.

Your pair composition is **fixed** during the match. **But you will be randomly re-matched with another player in every match**.

Each match will last several periods. The number of periods is determined by the continuation probability.

The continuation probability is the probability that the match continues to period 2, the probability that period 3 is reached given you are in period 2, and so on.

Suppose the continuation probability is 0.6 in one of the matches. This probability means that there will be a 60% chance of another period occurring after period 1. With remaining 40% chance, the current period will be the last period of this match. If period 2 is reached, then there will be a 60% chance of another period occurring after period 2. If period 3 is reached, then there will be a 60% chance of another period occurring after period 3. And so on. A computer program will determine the total number of periods for each match using this continuation probability.

Different matches may have different continuation probabilities. There are four values of the continuation probability in this experiment: **0, 0.3, 0.6, and 0.9**. The continuation probability will be shown to you at the beginning of each match.

At the beginning of every period in each match, you and the other player will both be given an endowment. The endowment is denoted by **E**, which is equal to **20 ECUs**.

$$\mathbf{E = 20\ ECUs}$$

You and the other player will spend this endowment to get a prize in each period. The prize is denoted by **V**, which is equal to **50 ECUs**.

$$\mathbf{V = 50\ ECUs}$$

Your spending is denoted by **S**, which is represented by the amount of ECU you would like to spend out of your endowment to get the prize. **Note that the amount you allocate as your spending should be round numbers (integers)**.

You will have to pay this amount. Whatever remains in your endowment will be given to you as a part of your earning at the end of the period. You and the other player have to choose your spending simultaneously.

After you and the other player have chosen the spending, both of your spending will be shown to you. You and the other player will then be asked to choose an option to determine the allocation of the prize from two available options: **Option A** and **Option B**. Your allocation of the prize in each period depends on your and the other player's options.

Specifically, you and the other player's allocations of the prize are calculated as follows:

1. If both of you choose Option A:

Each of you will get a proportion of the prize **V**.

The proportion is based on your type and your spending.

Suppose S_1 is the spending of **type 1** player and S_2 is the spending of **type 2** player.

1.1 If you are type 1 player:

The proportion **P** of the prize **V** you will get is:

$$\frac{S_1}{S_1 + 2S_2}$$

Your earning is: $P * V + (E - S_1)$.

1.2 If you are type 2 player:

The proportion **P** of the prize **V** you will get is:

$$\frac{2S_2}{S_1 + 2S_2}$$

Your earning is: $P * V + (E - S_2)$.

2. If both of you choose Option B:

One of you will get the whole prize **V** and the other player will get nothing.

The probability of getting the whole prize **V** is based on your type and your spending.

Suppose S_1 is the spending of **type 1** player and S_2 is the spending of **type 2** player.

2.1 If you are type 1 player:

The probability **P** that you get the whole prize **V** is:

$$\frac{S_1}{S_1 + 2S_2}$$

Your earning in this case is: $V + (E - S_1)$.

The probability that you do NOT get the whole prize **V** is:

$$1 - P$$

Your earning in this case is: $0 + (E - S_1)$.

2.2 If you are type 2 player:

The probability **P** that you get the whole prize **V** is:

$$\frac{2S_2}{S_1 + 2S_2}$$

Your earning in this case is: $V + (E - S_2)$.

The probability that you do NOT get the whole prize **V** is:

$$1 - P$$

Your earning in this case is: $0 + (E - S_2)$.

3. If one of you choose Option A and the other player chooses Option B:

The one who choose **Option A** will get nothing.

His or her earning is: $0 + (E - S)$.

The one who choose **Option B** will get the whole prize **V**.

His or her earning is: $V + (E - S)$.

This is the end of the decision making process for one period. After this, the computer will determine whether there is a new period after the current period based on the continuation probability.

Your earning in each match is the **sum** of all earnings in each period of the match.

You will play as many matches as possible during the experiment.

At the end of each game, **four matches** (with each of the four continuation probabilities) will be randomly selected as binding matches to determine your actual payment.

Stage 2

In this part of the experiment you will be asked to make a series of choices. How much you receive will depend partly on chance and partly on the choices you make. The decision problems are not designed to test you. What we want to know is what choices you would make in them. The only right answer is what you really would choose.

For each line in the table on the computer screen, please state whether you prefer **Option L** or **Option R**. Notice that there are a total of ten lines in the table but **just one line** will be randomly selected for payment. You do not know which line will be paid when you make your choices. Hence you should pay attention to the choice you make in every line. After you have completed all your choices, the computer will randomly generate a number, which determines which line is going to be paid.

Your earnings for the selected line depend on which option you chose: If you chose **Option L** in that line, you will receive **20 ECUs**. If you chose **Option R** in that line, you will receive either **60 ECUs or 0**. To determine your earnings in the case you chose Option R, there will be a second random draw. The computer will randomly determine if your payoff is 60 ECUs or 0, with the **chances stated in Option R**.

This is the end of the specific instructions for each stage.

For your reference, your total payoff in this experiment would be the sum of following parts:

(1) Show-up fee: 4 dollars

(2) Total earnings of **four randomly chosen binding matches** in Stage 1

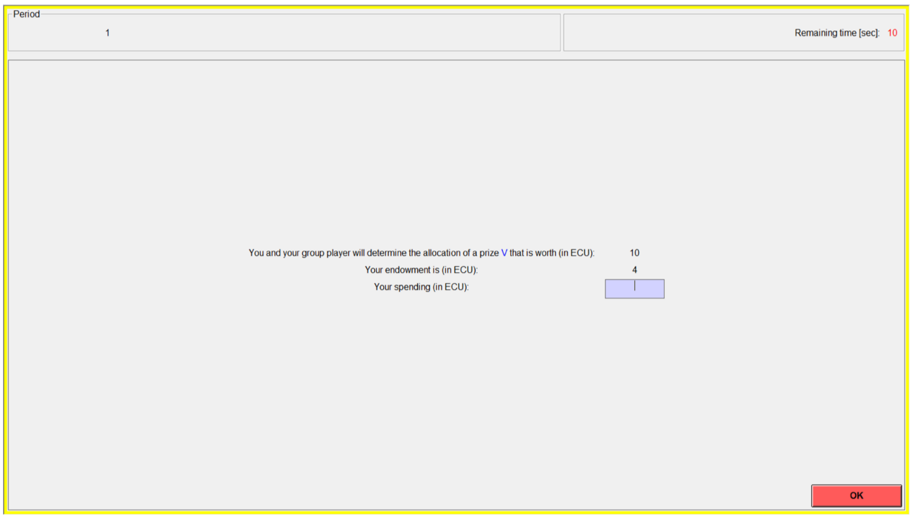
(3) Payoff from Stage 2

Thus, your total earning in this experiment equals to:

(1) + 0.05*(2) + (3),

where 0.05 is the exchange rate.

3.6.2 Screenshots of the Experiment



Period 1

Remaining time [sec]: 10

You and your group player will determine the allocation of a prize V that is worth (in ECU): 10

Your endowment is (in ECU): 4

Your spending (in ECU):

4 Chapter 4 An Experimental Investigation of the Impact of Winning on Willingness to Fight and Aggressiveness

4.1 Introduction

Contests happen in many economic, political, and social environments. A common feature of these environments is that contestants expend costly efforts in order to compete for a prize. As individuals in society, we will encounter various kinds of competitions in our lives. For example, employees compete for promotions or better salaries, and students participate in various contests to win prizes or to compete for admission to a higher education institution. On the world level, there is trade competition among regions or countries. Peace is a luxury in some areas of the globe, while fighting is a common scene in other places. As a result, it comes as no surprise that there has been a substantial number of studies conducted on various aspects of contest. Contest has been studied using various economic analysis models, such as Tullock contests, all-pay auctions, and rank-order tournaments (Durfee, Lesser, and Corkill 1987; Hirshleifer 1989; Rao et al. 2011).

However, the contests we experience in real life are often not singular experiences. In reality, prizes are usually won through a series of competitions, instead of just one contest. For example, professional sports players have to win a range of tournaments before entering the finale. After students successfully beat other competitors in college entrance exams and are enrolled in their dream schools, there are always more competitions in the university to win prizes and seek job opportunities. Because of this, winners at the beginning may not have the last laugh; meanwhile, underdogs in competitions are not doomed for life, as there are always second chances for them to prove themselves. The question is: which party is more willing to fight again? Will the winners choose to fight again more often than losers because they want to strike while the iron is hot? Or will losers be more willing to fight again in the hope that they can have a second chance to prove themselves?

Another issue worth studying is that, while all contests involve conflict among competitors, there exist different kinds of contests in the world. One simple and widely observed difference among contests lies in how the result of the contest is determined. For instance, winning and losing in a college entrance exam is largely determined by students' own effort; on the other hand, in an environment in which the relative performance of contestants are disregarded, the results of competitions may not purely depend on each competing party's own effort - hence, winning and losing become random. What I am interested in is how people's willingness to fight and aggressiveness are linked to previous conflict experience.

Among all other subjects, experimental economics has proven itself to be a useful tool to use in studying human behavior in a controlled contest environment. Although it has a comparatively short history, experimental economics has contributed a great deal to studies on human behavior by testing theories and predicting human behavior in a controlled environment. Many studies have contributed to the exploration of post-conflict behavior as well (see Sheremeta 2015 for a review of experimental research of behavior in contests).

I use a laboratory experiment to measure the impact of previous conflict on people's willingness to fight again and their aggressiveness. Participants all play a standard Tullock contest game in pairs in the first stage of the experiment. The rent-seeking Tullock game, developed by Tullock (1980), has been widely used in the study of contest. The aim of this stage is to provide a contest environment. In the second stage of the experiment, all participants are randomly paired again to play a revised prisoners' dilemma game. I use this new game to measure people's willingness to fight again and their aggressiveness. The two given options in the prisoners' dilemma game are "peace" and "fight". "Peace" leads to a peaceful solution in determining the winner of a prize, in which each member gets half of the prize. If both members choose "fight", however, they will need to fight to determine who gets the prize. More specifically, they will need to play one round of Tullock contest game as in Stage 1. Winner of this contest gets the whole prize. The loser in this scenario gets nothing. I use this stage to quantitatively measure subjects' willingness to fight by the proportion of "fight" options in all periods of the second stage. Aggressiveness is represented by the effort each participant invests in the contest game; greater fighting effort equates to higher levels of aggressiveness.

In the first stage of the experiment, I use three treatments to represent three kinds of contest environments: a control treatment, a feedback treatment, and a feedback_luck treatment. The difference between the three treatments in Stage 1 is that, in the control treatment, no result is shown until the very end of the experiment, while, in the feedback treatment participants receive immediate feedback on the result of the contest. Contest result information is also provided in the feedback_luck treatment; however, participants cannot choose their own effort level in this treatment, as the computer will randomly choose the fighting effort for them. Hence, the control treatment acts as a baseline treatment regarding how subjects behave in a contest game without being influenced by additional information on winning and losing. The feedback treatment refers to a standard and more prevalent situation in which people compete using their own effort and are given immediate feedback. Finally, the feedback_luck treatment stands for an extreme case of a payment scheme because winners are randomly decided by luck instead of relative effort.

Many studies have been conducted on the effects of winning and losing in a competition on subsequent human behaviors (Berger and Pope 2011; Brown 2011; Cummins, Nadorff, and Kelly 2009; Dreber et al. 2008). Buser (2016) studied the effect of previous competition results (winning and losing) on players' willingness to attempt further challenges. He also employed a two-stage design in the experiment. In the first stage, participants only use real effort for an arithmetic task; in the second stage, participants are given the opportunity to choose a personal target before competing in the arithmetic task again. Compared to winners, losers in the first stage seek a more challenging target but actually display worse performance in the second task. Gill and Prowse (2014) used a slider task in their experiment and varied the scale of the prize. They found that there is a gender difference in response to losing. More specifically, losing is detrimental to productivity for women. However, for men, the effect only exists when the prize is large. Decamps, Ke, Page, et al. (2018) identified the causal effect of winning by using a best-of-three dynamic game. They show that winning has a positive effect on subsequent performance. The difference between their experiment and ours is that my experimental design is not a strategic setup. Unlike a best-of-three game, winning a previous period in my experiment has no influence on the probability of winning in the subsequent period. Each period is independent of each other in my design; hence, my experiment observations are the effects of winning and losing.

Most relevant to this chapter is McGee and McGee (2013)'s study, which also examines the effect of competition on players' subsequent performance. They also employ a treatment in which the result of the competition is determined by players' effort and a treatment in which the competition result is arbitrary. My study is different from theirs in several areas. First, McGee and McGee (2013) asked their subjects to participate in a production stage after the competition, so as to focus on their effort in productive activities. I allow subjects to choose whether to cooperate or fight after the first stage of the competition. In this way, I am able to measure subjects' willingness to fight, as well as their effort levels in case they choose to fight. Second, in the treatment in which the winner is determined arbitrarily, players do not know that their effort is disregarded until the end of the tournament in McGee and McGee (2013)'s study, while I inform subjects on how the result is determined at the start of the experiment.

I found that participants invest more in fighting in the second stage, in which they get to choose whether or not to fight. In treatments with winning and losing information (the feedback treatment and the feedback_luck treatment), winning has no effect on people's willingness to fight or on aggressiveness. Rather, I find that aggressive people win more in the first stage, choose to expend greater amounts of effort in Stage 2, and eventually win more in Stage 2. As for the comparison among different contests in the first stage, I find that participants from the feedback_luck treatment in the first stage choose more fighting options than participants from the other two treatments. Again, this is only observed in male subjects.

My contribution to the previous literature is the study of the effect of feedback information and outcome transparency on subsequent behavior in contests. More specifically, I tested the post-conflict effects of previous contest experience on people's willingness to fight and their aggressiveness.

The rest of the chapter is structured as follows: Section 4.2 describes the experimental design and the predictions. Section 4.3 describes the experiment procedures. I present and discuss the results in Section 4.4. Section 4.5 concludes.

4.2 Experimental Design and Predictions

I use a standard Tullock contest game in my experiment. At the beginning of each period, subjects were given an endowment E. They were told to invest in effort using their endowments to win a prize V. The probability of winning the contest is

$$p_i = \frac{x_i}{\sum_{j=1}^{2} x_j} \qquad (i = 1, 2),$$

where p_i is the probability of winning the competition for subject i; x_i is the investment of subject i. All invested effort is lost, regardless of the result of the contest. So subjects were required to invest carefully because the larger the invested effort, the higher the probability to win the prize but the larger the loss if they did not win the contest game. After one round of the contest, the winner gets the prize and his or her remaining endowment while the loser only gets the remaining endowment. No endowment is carried over to the next round.

Based on the probability of winning and the rules of the Tullock contest game, I can get the expected payoff:

$$\Pi_i = p_i V - x_i \qquad (i = 1, 2).$$

Hence I can get the equilibrium fighting effort from the expected payoff equation as follows,

$$x_i^* = \frac{V}{4} \qquad (i = 1, 2).$$

I can further calculate the equilibrium payoff: $\Pi_i * = \frac{V}{4} \qquad (i = 1, 2)$.

To study the effects of different kinds of contests, I have three treatments in stage 1: the control treatment, the feedback treatment, and the feedback_luck treatment. In the control treatment, after subjects invested effort in the contest game, they were only shown their own effort and their group members' result. They would not know the results of each contest game in this stage until the very end of the experiment. The difference between the feedback treatment and the control treatment is that in the feedback treatment, subjects were shown the effort and the result of the contest game after each round. This way I can study the effect of providing information about contest result (e.g. winning and losing) on post-conflict behavior. Specifically, I are interested in contestants' behavior of willingness to fight and their aggressiveness. In the feedback_luck treatment, subjects cannot choose

Table 4.1: Treatments summary

		Control	**Feedback**	**Feedback_luck**
Stage 1	Endowment	E	E	E
	Prize	V	V	V
	Players	Pairwise	Pairwise	Pairwise
	Expected effort	$\frac{V}{4}$	$\frac{V}{4}$	random
	Expected profit	$\frac{V}{4}+E$	$\frac{V}{4}+E$	random
	Effort choice	Subjects	Subjects	Computer
	Show contest result	No	Yes	Yes
Stage 2	Endowment	E	E	E
	Prize	V	V	V
	Players	Pairwise	Pairwise	Pairwise
	Effort choice	Subjects	Subjects	Subjects
	Show contest result	Yes	Yes	Yes

effort levels by themselves, instead, the computer would choose for them. In this way, if a subject wins in the contest game, it is due to pure luck instead of his or her chosen effort, so I can compare the difference between winning by pure luck and winning by effort. In both feedback and feedback_luck treatment, all subjects were shown a summary of their winning history in all twenty periods, they also got to see their rank among all subjects in the same session. Table 4.1 summarizes properties of different treatments.

After that, they play a game called Contest in Prisoner's Dilemma (CPD) in stage 2 of the game. I designed this game to study subjects' post-conflict behavior, especially the subjects' willingness to fight. CPD is a combination of Tullock contest game and prisoner's dilemma game. The prize in the game denoted by V. Like a prisoner's dilemma game, subjects face two options: B (FIGHT) and A (PEACE). Choice B represents fighting so that if both players choose B, they will have to play a contest game to determine who wins the prize. The contest game is similar to the one played in stage 1, each player gets an endowment E, and the result is shown immediately after the contest. As I have shown earlier, the expected payoff for each player in this scenario is $\Pi_i* = \frac{V}{4}$. Choice A stands for peace, in the case that both players choose A, the prize will be divided peacefully among the two and each player gets half of the prize, which is $\frac{V}{2}$. Suppose one player chooses option B

Table 4.2: Expected payoff matrix of CPD game

	Peace	Fight
Peace	$\frac{V}{2}+E,\frac{V}{2}+E$	E,V+E
Fight	V+E,E	$\frac{V}{4}+E,\frac{V}{4}+E$

and the other player chooses option A, then the player who chooses option B gets the whole prize while the other player gets nothing. The expected payoff matrix of CPD game is shown in Table 4.2, I can easily see the Nash equilibrium strategy is (FIGHT, FIGHT).

4.3 Experimental Procedures

I conducted 24 experimental sessions in August 2017 in the behavioral and experimental economics labs at Nanyang Technological University (NTU), Singapore. A total of 286 undergraduates from various disciplines participated in the study. The experiment was programmed and conducted using z-Tree software (Fischbacher 2007). I have 8 sessions for each of the three treatments. Each session lasted approximately 90 minutes. There are 8, 10 or 12 subjects in each session [3]. Table 4.5 summarizes the information for each treatment.

Upon arrival, participants were randomly assigned to groups. Each group consists of two participants and group members change in each period. At the beginning of the experiment, I informed participants that there would be several stages in the experiment and the instructions for each stage will only be given after they finished the previous stage. Printed copies of the instructions were given out to participants and they were read aloud by the experimenter to ensure common knowledge.

There are four stages in the experiment. The first two stages are the main experiment whereas the last two stages are conducted to elicit participants' risk preference and to measure their quantitative ability. In the first stage, subjects played 20 rounds of standard Tullock contest game in pairs and they were re-paired randomly after each round. The subjects were told that only two rounds out of the

---

[3] the number of subjects in each session is determined by the actual show-up of registered participants. In specific, I have 2 sessions with 8 subjects, 6 sessions with 10 subjects and 16 sessions with 12 subjects.

Table 4.3: Expected payoff matrix of CPD game (in ECUs)

	Peace	Fight
Peace	125,125	50,200
Fight	200,50	87.5,87.5

Table 4.4: Treatments summary

		Control	**Feedback**	**Feedback_luck**
Stage 1	Endowment (in ECU)	50	50	50
	Prize (in ECU)	150	150	150
	Players	Pairwise	Pairwise	Pairwise
	Expected effort	37.5	37.5	random
	Expected profit	87.5	87.5	random
	Effort choosing	Subjects	Subjects	Computer
	Show contest result	No	Yes	Yes
Stage 2	Endowment (in ECU)	50	50	50
	Prize (in ECU)	150	150	150
	Players	Pairwise	Pairwise	Pairwise
	Effort choosing	Subjects	Subjects	Subjects
	Show contest result	Yes	Yes	Yes

twenty rounds would be chosen to determine their payoff and each round has equal probability to be chosen. In each round, every subject received an endowment of 50 Experimental Currency Units (ECUs) and the prize of the contest equals to 150 ECUs. In stage 2, subjects play 20 periods of CPD games. The endowment and prize are the same as in stage 1.

Since the prize in my experiment is 150 ECUs, the equilibrium fighting effort in my experiment is 37.5 ECUs. I can further calculate the equilibrium payoffs under different circumstances. The payoff matrix in my experiment is shown in Table 4.3. Table 4.4 summarizes the properties of different treatments.

Prediction 1. The equilibrium effort is the same in the control and the feedback treatments and equals to 37.5 ECUs.

At the end of the experiment, participants were asked to fill up a questionnaire

Table 4.5: Sessions summary

	Control	**Feedback**	**Feedback_luck**
No. of sessions	8	8	8
No. of participants	88	88	92
Female	47	48	41
Male	41	40	51
Average earnings	19.8	18.7	20.2

about their social demographics and personal strategies they adopted in the experiment. On average, each student received 19.6 Singapore dollars from participating, including 2 Singapore dollars show-up fee. Subjects were paid privately and in cash.

4.4 Results and Discussions

Table 4.6 describes the data and sample. In total, I have 268 participants (136 males and 132 females) participating in my study, all of whom are undergraduate students from various disciplines of NTU. All participants were randomly allocated to the three treatments. Kruskal-Wallis test shows no significant difference in risk-aversion and the quantitative ability among participants in the three treatments. In stage 1, on average subjects invest lower than the equilibrium effort amount (37.5 ECUs) in both control and feedback treatment. They increase their effort in the contest game in the second stage with the mean effort value exceeding the equilibrium effort value in all three treatments. The lowest effort participants invested is 0 ECU and the highest is 50 ECUs.

Result 1: Participants invest more in fighting effort when they choose to fight themselves.

Figure 4.1 shows the average effort level in both stage 1 and stage 2 across three groups. One obvious finding is that participants invest more in fighting effort in stage 2 than in stage 1. I use Wilcoxon matched-pairs signed-ranks test to test the difference between effort in two stages and find significant results for all three treatments ($p<0.0001$ in all three treatments). In stage 1 of the control and the feedback treatment in which participants are allowed to choose their own effort,

Table 4.6: Data

	Control	**Feedback**	**Feedback_luck**
Observations:			
Men	41	40	51
Women	47	48	41
Total	88	88	92
Variable means:			
Risk averse	6.5	6.1	5.9
Quantitative score	6.8	7.1	6.5
Effort in stage 1	34.2	36.5	25.3
Choice in stage 2	0.88	0.90	0.93
Effort in stage 2	42.11	39.36	38.13

Note. Choice = 1: Fight; Choice = 0: Peace

the average effort level is 34.2 ECUs in the control group and 36.5 in the feedback group, both of which are below the equilibrium effort level (37.5 ECUs) but they do not differ from each other (p=0.617; rank-sum test). When it comes to the second stage, all participants invest more than the equilibrium effort value. The highest effort comes from the control group in which participants invest 42.11 ECUs on average. It seems that participants in the control group significantly increase their effort in the second stage compared to participants in the feedback treatment, the rank-sum test on the effort difference between these two treatments confirms my finding (p=0.0123).

There is no significant difference in the average fighting effort in stage 2 between the control and the feedback treatments (p=0.1363; rank-sum test), nor there any significant difference in the average fighting effort between the feedback and the feedback_luck treatments (p=0.1026; rank-sum test). However, it seems that on average, participants in the control treatment invest significantly more on the second stage fighting effort than participants in the feedback_luck treatment (p=0.0018; rank-sum test).

My main focus lies on the second stage of the game as I are interested in the difference in subjects' willingness to fight and the aggressiveness behavior after they have experienced different types of conflicts in the first stage. First, I look at the

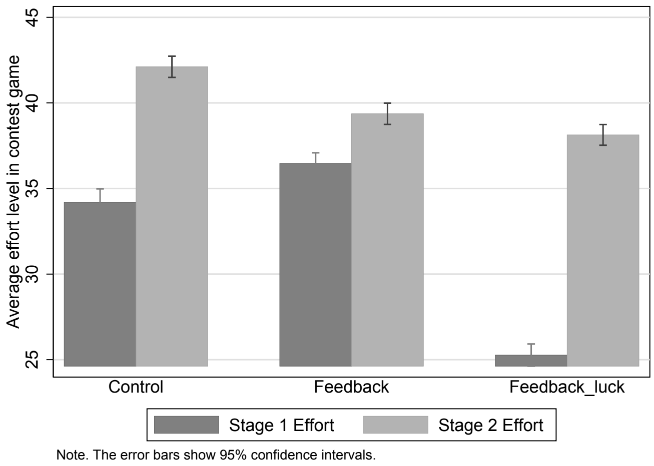


Figure 4.1: Average Effort in Two Stages by Treatment

post-conflict effect on people's willingness to fight. In my experiment, willingness to fight is measured by the the percentage that each contestant chooses the FIGHT option in the second stage.

Result 2: There is a positive treatment effect on people's willingness to fight in the feedback_luck treatment.

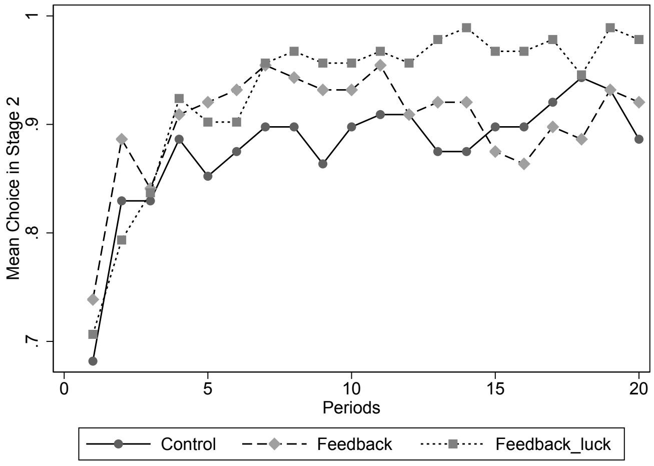


Figure 4.2: FIGHT Choice across periods

As shown by Figure 4.2, subjects quickly converge to (FIGHT, FIGHT) situations in stage 2 in all treatments. The percentage of subjects who choose FIGHT option jump from around 70 percent in the first period to about 90 percent at period 5 and remains at high levels. It seems that even though some subjects try to cooperate at the beginning, they soon realized that their opponents tend not to cooperate and switched to the FIGHT option ever since. This is confirmed when I look at subjects' ex-post rationales, one subject wrote "I started off with the choice that will best benefit both parties but after a few rounds, I realized that people are much more competitive and that is why I became competitive too." Another subject stated that "I wanted to be nice and use option A but resulted to use B cos everyone used B".

Though most of the time subjects are competitive in all treatments, from Figure 4.2 it seems that subjects in the feedback_luck treatment are more competitive than subjects in the other two treatments. Figure 4.3 shows the percentage of participants who choose the FIGHT option in the second stage across treatments. Participants in the feedback treatment, who choose their own effort in stage 1 contest game, choose the FIGHT option 90.3 percent of the time in the CPD game, while those in the control group only choose the FIGHT option 87.8 percent of the time, though the difference is not significant (p=0.2941; rank-sum test). Participants in the feedback_luck treatment, whose effort in stage 1 is chosen by the computer, choose FIGHT option 93.1 percent of the time, which is significantly higher than those in the control group (p=0.0896; rank-sum test). Focusing on the two treatments with feedback, I find that there is no significant difference in the incentive to choose FIGHT option between the feedback and the feedback_luck treatment (p=0.5342; rank-sum test).

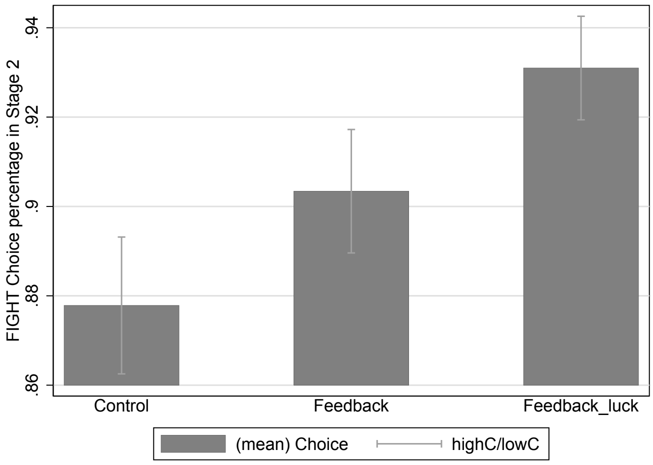


Figure 4.3: FIGHT Choice Percentage by Treatment

Table 4.7: OLS Regressions (Dependent Variable: Percentage of FIGHT option in second stage)

	(1) FIGHT Choice	(2) FIGHT Choice	(3) FIGHT Choice
Feedback	0.0256	0.0278	0.0239
	(0.0288)	(0.0281)	(0.0274)
Feedback_luck	0.0531^{**}	0.0483^{**}	0.0436^{**}
	(0.0233)	(0.0221)	(0.0214)
Male		0.00773	0.00264
		(0.0204)	(0.0206)
Quant		-0.00132	-0.00178
		(0.00405)	(0.00400)
Experiment experience		0.0790^{***}	0.0788^{***}
		(0.0301)	(0.0300)
Game theory experience		0.00939	0.00849
		(0.0218)	(0.0217)
Risk averseness			-0.00878^{**}
			(0.00393)
Constant	0.878^{***}	0.822^{***}	0.886^{***}
	(0.0203)	(0.0394)	(0.0473)
Observations	268	268	268
Adjusted R^2	0.009	0.038	0.050

Note. Robust standard errors are in parentheses.

*, **, and *** denote significance at the 10%, 5%, and 1% level, respectively.

In Table 4.7, I test these results more formally using ordinary least squares (OLS) regressions. In column (2) and (3) I have gender, quantitative ability, experiment experience, game theory background, and risk aversion as control variables. The dependent variable is the percentage of the FIGHT option that each participant chooses in the second stage of the experiment. By using treatment dummies as explanatory variables I find consistent results with what I get from rank-sum tests. It is confirmed that participants choose significantly more FIGHT option in the feedback_luck treatment compared to the control group participants.

Using a full set of control variables, I find that participants in the feedback_luck treatment choose the FIGHT option approximately 4.4 percentage more than participants in the control group. This indicates that contests in which results are determined by pure luck tend to yield an increase in the contest participants' willingness to fight. Hence these participants are more likely to get themselves involved in another conflict. This is important because even though my feedback_luck treatment is an extreme case, in real life there do exist competitions whose outcome lack transparency. In these kinds of competitions in which winning does not depend on contestants' performance, contestants' winning and losing have nothing to do with their own ability nor performance and the results are easily manipulated by authorities or organizers. My experiment shows that with previous experience in these contests, people can get more aggressive and are more likely to pick up another competition with others.

The result above is robust to the inclusion of gender, quantitative ability, experience on experiment and game theory as well as risk aversion as control variables. I find that gender, quantitative ability, and game theory experience are not significantly correlated with participants' percentage of choosing the FIGHT option. Though experiment experience contributes positively to the percentage of FIGHT option, with a magnitude of 7.9 points in percentage, which is even larger than the feedback_luck treatment effect. I believe this is due to the fact that participants with experiment experience are more familiar with experiment settings and hence more likely to explore hidden stages in an experiment. In my experiment setting, choosing the FIGHT option means a larger probability to experience the contest game again. My last finding is that risk aversion is significantly negatively correlated with participants' FIGHT option, this is an expected finding as the more risk averse a person is, the less likely he or she is to take risks to fight again.

Apart from the willingness to fight, another post-conflict behavior aspect that I are interested in is people's aggressiveness. I use participants' fighting effort to represent aggressiveness, the higher the effort, the more aggressive participants are.

Result 3: Winning does not make contestants become more aggressive. Instead, the opposite happens. That is, aggressive people tend to win with higher percentage than less aggressive people.

Result 3.1: Winning does not make people more aggressive.

First, I test the hypotheses about whether winning makes people more aggressive. As is the case in both real life and my experiment, winning in previous competitions is not a one-shot game but a series of winning results. Hence I divide participants into two groups by their accumulative winning results in the first stage. Participants whose aggregate winning times above the median value are grouped as "HighWinners", the rest are grouped as "LowWinners". If my hypothesis holds, I should expect HighWinners exert higher fighting effort in stage 2 than LowWinners in treatments with winning information while there is no such difference in treatment without winning information. However, my tests show mixed results. In the feedback treatment in which participants choose their own effort, HighWinners do choose higher fighting effort in stage 2 than LowWinners do (p=0.0451; rank-sum test). In the feedback_luck treatment in which computers choose effort in stage 1, there is no significant difference in effort in stage 2 between HighWinners and LowWinners (p=0.4965; rank-sum test). While I could argue that participants are indifferent to winning and losing in the feedback_luck treatment because how participants win matters, my hypothesis is rejected by my finding in the control treatment in which no winning information is shown to participants. I found that Highwinners (unknown to participants themselves) in the control treatment still invest more in fighting effort in stage 2 compared to LowWinners (p=0.0096; rank-sum test). Surprisingly, even without knowing whether they win or not, HighWinners in the control treatment also exert more effort than Lowwinners in stage 2.

Since I have HighWinners investing more effort in stage 2 in both control and feedback treatments, it cannot be due to the sole effect of winning information. In Table 4.8, I use OLS regression while controlling for participants' effort in stage 1, I find no significant effect of HighWinners on subsequent choice option, effort choosing

Table 4.8: OLS Regressions Controlling for Effort Polynomial

	(1) FIGHT Choice	(2) SecondStageEffort	(3) SecondStageWin
HighWinner	-0.0532	-0.193	0.00865
	(0.0382)	(1.467)	(0.0324)
Feedback_luck	0.0289	7.158^{***}	0.0436
	(0.0513)	(2.278)	(0.0403)
Male	0.0200	2.241^{*}	0.0164
	(0.0234)	(1.309)	(0.0220)
Risk averseness	-0.00285	-0.111	0.000411
	(0.00410)	(0.283)	(0.00423)
Quant	-0.00453	-0.514^{*}	0.00122
	(0.00423)	(0.270)	(0.00457)
Experiment experience	0.0376	1.161	-0.00887
	(0.0290)	(1.387)	(0.0271)
Game theory experience	0.0618^{***}	0.900	0.0200
	(0.0235)	(1.326)	(0.0237)
Constant	0.755	22.08	0.613
	(0.677)	(29.06)	(0.462)
Observations	180	178	178
Adjusted R^2	0.031	0.270	-0.025

Note. Robust standard errors are in parentheses.

*, **, and *** denote significance at the 10%, 5%, and 1% level, respectively.

nor second stage winning.

Result 3.2: Aggressive people win more in stage 1 and keep being aggressive in stage 2.

To examine the effect of aggressiveness, I divide participants into two groups by their effort in stage 1. Since I are interested in the chosen effort of participants, I only consider control and feedback treatments in which participants choose their own effort level in stage 1. Participants whose average effort is above the median are labeled aggressive while those with a lower-than-median effort are called Non-aggressive people. I are interested in the difference between these two groups on winning and effort in stage 2. I found that aggressive people win more in stage 1 than non-aggressive people ($p<0.001$; rank-sum test). This result comes as no surprise as according to my model, the higher the effort, the larger the winning probabilities. However, on top of that, aggressive subjects invest more in effort in stage 2 ($p<0.001$; rank-sum test) and therefore continue to win more in stage 2 ($p=0.0613$; rank-sum test). I test further using OLS regressions and the results in Table 4.9 confirm my finding. This result is interesting as I confirm that aggressive people continue being aggressive despite previous experiences of conflict.

Result 4: Winning previous contests has no significant effect on contestants' incentive to choose the FIGHT option.

Next, I explore the effect of winning on people's willingness to fight. The problem with winning and FIGHT option is that I believe winning is endogenous. The reason is random shocks that affect participants' FIGHT option could also affect winning and losing in the first stage contests. Meanwhile in the first stage in my experiment setting, based on the contest success function I use, winning and losing is determined by participants' effort level as higher effort level leads to larger winning probability. Hence it is reasonable that I use participants' effort level in stage 1 as an instrumental variable.

Table 4.10 shows the instrumental variable regression results. To study the effect of winning on subsequent FIGHT choice, I use data from the two treatments with feedback: the feedback treatment and the feedback_luck treatment. The dependent variable is again participants' percentage of FIGHT option in stage 2. The first stage

Table 4.9: OLS Regressions (Control and Feedback Treatments)

	(1) FirstStageWin	(2) SecondStageEffort	(3) SecondStageWin
Feedback	-0.00605	-1.954	0.0218
	(0.0203)	(1.352)	(0.0254)
Aggressive	0.159^{***}	9.546^{***}	0.0545^{**}
	(0.0214)	(1.370)	(0.0261)
Male	-0.00662	0.943	-0.00818
	(0.0206)	(1.365)	(0.0263)
Risk averseness	-0.00777	-0.519	-0.0105^{*}
	(0.00477)	(0.334)	(0.00552)
Quant	0.00710	-0.307	0.00170
	(0.00547)	(0.310)	(0.00649)
Experiment experience	-0.0154	-0.692	-0.00393
	(0.0234)	(1.431)	(0.0326)
Game theory experience	-0.0184	1.825	-0.0152
	(0.0224)	(1.322)	(0.0268)
Constant	0.445^{***}	41.51^{***}	0.518^{***}
	(0.0542)	(2.746)	(0.0570)
Observations	176	174	174
Adjusted R^2	0.258	0.250	0.014

Note. Robust standard errors are in parentheses.

*, **, and *** denote significance at the 10%, 5%, and 1% level, respectively.

Table 4.10: IV Regressions (Dependent Variable: Percentage of FIGHT option in second stage)

	(1) FIGHT Choice	(2) FIGHT Choice	(3) FIGHT Choice
Winning percentage	-0.208	-0.252	-0.247
	(0.395)	(0.365)	(0.369)
Male		0.0207	0.0181
		(0.0262)	(0.0269)
Quant		-0.00406	-0.00446
		(0.00437)	(0.00435)
Experiment experience		0.0433	0.0448
		(0.0314)	(0.0309)
Game theory experience		0.0577^{***}	0.0567^{***}
		(0.0209)	(0.0211)
Risk averseness			-0.00397
			(0.00363)
Constant	1.021^{***}	1.010^{***}	1.035^{***}
	(0.196)	(0.151)	(0.146)
Observations	180	180	180
Adjusted R^2	.	0.003	0.002

Note. Robust standard errors are in parentheses.

The sample consists of participants in real effort and pure luck treatments.

*, **, and *** denote significance at the 10%, 5%, and 1% level, respectively.

dependent variable is the winning percentage in stage 1 with effort as the explanatory variable. The result shows that winning previous contests has no significant effect on participants' subsequent choices of FIGHT option. The result remains the same with the inclusion of control variables. Mixed results on the effect of winning have been found in previous literature. Some confirm a positive winning effect on subsequent behavior while some found a negative result (e.g. Buser 2016 reports that on the contrary, losers choose more challenging tasks compared to winners).

I further explore my results in winning by categorizing participants from treatments with feedback into two groups. Based on their winning percentage in the first stage, I define participants who have won half or more than half of the time as *HighWinners*, likewise, participants who have won less than half of the time in stage 1 are labeled *LowWinners*.

Table 4.11 shows the regression results using treatment and HighWin-LowWin dummies while controlling for effort. The dependent variable is the participants' percentage of FIGHT option. Participants in the control group are the baseline group here. The first thing to notice is that the regression results confirm my earlier finding of positive feedback_luck treatment effect on contestants' incentive to choose FIGHT option. Secondly, I show that I get consistent results from *HighWinners* and *LowWinners*. Conditional on full set of control variables, I found that neither *HighWinners* nor *LowWinners* in the feedback treatment choose FIGHT option differently from participants in control group (p=0.3483; Wald test). On the contrary, both *HighWinners* and *LowWinners* in the feedback_luck treatment choose significantly more FIGHT option compared to their peers in the control group. *HighWinners* in the feedback_luck treatment choose approximately 9.0 percent more FIGHT option while *LowWinners* choose about 6.3 percent more than participants in control group. Wald test of difference in FIGHT option between *HighWinners* and *LowWinners* in the feedback_luck treatment show no significant difference (p=0.3125).

4.5 Conclusions

Multi-contests conflicts, in which players compete in a series of contests, are ubiquitous. I experimentally test the effect of previous contests on players' subsequent

Table 4.11: OLS Regressions (Dependent Variable: Percentage of FIGHT option in second stage)

	(1) FIGHT Choice	(2) FIGHT Choice	(3) FIGHT Choice
Feedback_HighWin	-0.000532	0.00199	-0.000912
	(0.0313)	(0.0296)	(0.0294)
Feedback_LowWin	0.0385	0.0408	0.0374
	(0.0359)	(0.0371)	(0.0368)
Feedback_luck_HighWin	0.104***	0.0938***	0.0896***
	(0.0304)	(0.0296)	(0.0289)
Feedback_luck_LowWin	0.0725*	0.0709**	0.0633*
	(0.0372)	(0.0357)	(0.0348)
(mean) Effort	0.00428***	0.00407***	0.00392**
	(0.00158)	(0.00155)	(0.00152)
Male		0.00697	0.00259
		(0.0206)	(0.0205)
(mean) Quant		-0.000733	-0.00111
		(0.00396)	(0.00391)
(mean) exp_experience		0.0730**	0.0729**
		(0.0294)	(0.0293)
(mean) theory_experience		0.00545	0.00474
		(0.0211)	(0.0211)
(mean) Risk			-0.00774**
			(0.00355)
Constant	0.731***	0.685***	0.746***
	(0.0659)	(0.0634)	(0.0640)
Observations	268	268	268
Adjusted R^2	0.059	0.082	0.090

Note. Robust standard errors are in parentheses.

*, **, and *** denote significance at the 10%, 5%, and 1% level, respectively.

performance. Specifically, I are interested in the effects of 1)how players win and 2)winning information on players' aggressiveness and willingness to fight. I designed a novel game called Contest in Prisoners' Dilemma (CPD) to measure these two factors. In CPD game, players can choose whether to fight or not. If both players choose to fight, they will compete in a standard Tullock contest game; If both players choose not to fight, they will divide the prize peacefully. Hence I use players' Fight option percentages to measure players' willingness to fight. Meanwhile, the expenditures players invest should they both choose to fight can be used to measure players' aggressiveness.

I employ three treatments to examine different manners of winning and winning information. The three treatments only differ in the first stage. I found that players invest much more effort in stage 2 than in stage 1. Since in stage 1 it is compulsory to participate in the contest while in stage 2 players can choose whether to fight or not. It shows that people fight more aggressively when they willingly choose to compete. The second result I get on aggressiveness is that winning does not make people more aggressive. On the contrary, aggressive people win more. The result shows that in the feedback treatment in which players are given immediate feedback on the result of the contest, HighWinners do invest higher effort in stage 2 compared to LowWinners. At first glance, this result serves as proof that winning leads to more aggressiveness. However, I also found similar results in the control treatment in which the winning information is not revealed to players. Without winning and losing information, HighWinners in the control treatment still spend more than LowWinners in stage 2. This suggests that something other than winning information is responsible. To test this, I further divide the players into two groups based on their effort in the first stage. Again, players whose effort is above median value are labeled as Aggressive while players whose effort is below median value are Non-aggressive. I compare the two types of players' efforts in stage 2 and found that Aggressive type players spend more than Non-Aggressive type players. As a result, Aggressive type players win more in the second stage than Non-aggressive type. Hence it is not winning makes people more aggressive, on the contrary, it is aggressive people win more.

As for the effect on people's willingness to fight, I found that winning previous contests has no significant effect on players' choice of Fight options in stage 2. However, I do find significantly more Fight options are chosen in the feedback_luck treatment. In the feedback_luck treatment, players are deprived of the opportunity to choose their own efforts in the contest while they still suffer or gain from the results of contests. It can be read like a real-life situation in which working output is not related to workers' own input. My result shows that this kind of unfair environment may have a negative effect on people's cooperation. Players from this environment are more willing to choose Fight options instead of cooperation. Hence my result highlights the importance of maintaining a fair reward system in that it helps to yield cooperation among fellow workers.

My findings on winning information also have important implications on how to design feedback mechanisms to motivate workers and employees in organizations and other workplaces. Several studies have shown that feedback have potential effect on employee's productivity (Pritchard et al. 1988; Aoyagi 2010; Kim and Hamner 1976). For example, Luttmer (2005) found that workers increase their productivity if they are provided with feedback information on their relative performance to other colleagues, this is especially true for workers who are concerned about their relative position among their fellows. My study shows that this kind of feedback-provision policy may be less effective than we have hoped. what is more, my evidence indicates that more productive workers will continue to be productive regardless of the feedback provided. Meanwhile less productive workers will not perform better with feedback. Hence, it is worthwhile to explore other ways to increase workers' productivity.

4.6 Appendix

4.6.1 A Sample of Experimental Instruction: Control Treatment

General Information

You are now taking part in an interactive study on decision making. **Please pay attention to the information provided here and make your decisions carefully**. If at any time you have questions to ask, please raise your hand and we will attend to you in private.

Please note that unauthorized communication is prohibited. Failure to adhere to this rule would force us to stop the experiment and you may be held liable for the cost incurred in this experiment. You have the right to withdraw from the experiment at any point, and if you decide to do so your payments earned during this study will be forfeited.

By participating in this study, you will be able to earn a considerable amount of money. The amount depends on the decisions you and others make.

At the end of this session, this money will be paid to you privately and in cash. It would be contained in an envelope which is indicated with your unique user ID. You will need to sign a receipt form to acknowledge that you have been given the correct payment amount.

General Instructions

Each of you will be given a unique user ID at the beginning of the experiment. Your **anonymity will be preserved** for the study. You will **never be aware of** the personal identities of other players during or after the study. Similarly, other players will also never be aware of your personal identities **during or after** the study. You will only be identified by your user ID in our data collection. All information collected will **strictly be kept confidential** for the sole purpose of this study.

At the beginning of the experiment, we will randomly divide you into **two** groups: **Group 1** and **Group 2**. Each group consists of half of the players in the lab.

Group composition will **remain the same** throughout the experiment. We will randomly assign you into pairs within your group. In each pair, there are **two players** (including you). Your pair composition will **change in every period**. Players in each pair will interact with the other player for several periods of decision-making. Your earnings will depend on the decisions you and the other player make.

Your earnings in the experiment are denominated by "**Experimental Currency Unit(s)**" or "**ECU(s)**". At the end of the experiment, they will be converted into Singapore Dollars at the rate of

1 ECU = 0.04 SGD

The real-dollar equivalent of your final earnings will be added to your **show-up fee** and paid to you in cash at the end of the experiment.

You will participate in **four** stages, the specific instructions for each stage are explained below.

Specific Instructions

Stage 1

In this stage, you will form a pair and play a contest game for several periods against the other player. Your pair composition will **change in every period**.

There are two results of the contest game: **win** and **lose**.

In each period, if you win the contest game, you will receive a prize. The prize is denoted by **V**, which is equal to **150 ECUs**.

V = 150 ECUs

If you lose the contest game, you will not receive the prize.

At the beginning of each period, you and the other player will both be given an endowment. The endowment is denoted by **E**, which is equal to **50 ECUs**.

E = 50 ECUs

In the contest game, you will compete by choosing your effort level. The effort level is denoted by **X**, which is represented by the amount of ECU you would like to spend out of your endowment to win the contest game. **Note that the amount you allocate as your effort level should be round numbers (integers)**.

You will have to pay this amount, regardless of the result of the contest. Whatever remains in your endowment will be given to you as a part of your profit at the end of the period.

The more ECU you allocate into the contest game relative to the other player, the higher your chance to win the contest. **Note that higher chance does not mean you will win for sure, likewise lower chance does not mean you will lose for sure**.

Specifically, your chance of winning the contest game is denoted by **P**, and it is expressed as:

$$P = \frac{X_i}{X_i + X_j}$$

where X_i is your effort level and X_j is the other player's effort level.

After you and the other player in the group have made your allocations for one period, you will be informed of your allocation of effort level as well as the other player's allocation of effort level. You will also be informed of your chance of winning as well as the other player's chance of winning based on your effort levels. **The computer will choose the winner of this period based on these chances**.

Your profit from each period is based on the result of the contest game.

If you **win** the contest game, you profit is expressed as:

$$Profit = V + E - X$$

.

If you **lose** the contest game, your profit is expressed as:

$$Profit = E - X$$

.

This is the end of the decision making process for one period. After this, a new period begins.

Note that you will only be told who wins the contest game and your profit in each period of this stage at the **conclusion** of the experiment.

Do refer to the above steps as a guide. You will have to do the same exercise for several periods. At the end of the experiment, **two of the periods** in this stage will be randomly selected as binding periods to determine your actual payment.

Stage 2

In this stage, you will form a pair and play a choice game for several periods against the other player. Your pair composition will **change in every period**.

At the beginning of each period, you and the other player will both be given an endowment. The endowment is denoted by **E**, which is equal to **50 ECUs**.

E = 50 ECUs

In the choice game, you will make a choice to get a prize. The prize is denoted by **V**, which is equal to **150 ECUs**.

V = 150 ECUs

You and the other player will be asked to choose an option from two available options: **Option A** and **Option B**. So your profit in every period depends on your and the other player's options.

Specifically, you and the other player's profits are calculated as follows:

1) If both of you and the other player choose **Option A**:

Each of you will get your endowment E (E=50 ECUs) plus half of the prize V (V=150 ECUs), which is equal to **125 ECUs**.

2) If you choose **Option A** and the other player chooses **Option B**:

You will get your endowment E, which is equal to **50 ECUs**.

The other player will get the prize V (V=150 ECUs) plus his or her endowment E (E=50 ECUs), which is equal to **200 ECUs**.

3) If you choose **Option B** and the other player chooses **Option A**:

You will get the prize V (V=150 ECUs) plus his or her endowment E (E=50 ECUs), which is equal to **200 ECUs**.

The other player will get his or her endowment E, which is equal to **50 ECUs**.

4) If both of you choose **Option B**:

You and the other player will be asked to use your endowments E (E=50 ECUs) to play the **contest game** described in **Stage 1**. You and the other player will be asked to allocate effort level out of your endowments to compete. Winner of the contest game will get the prize V, which is equal to 150 ECUs. Your profits will be shown to you at the end of the contest game.

For your reference, the following table illustrates you and the other player's profit configurations conditional on you and the other player's options.

You/The other player	Option A	Option B
Option A	125 ECUs,125 ECUs	50 ECUs,200 ECUs
Option B	200 ECUs,50 ECUs	You and the other player will play a contest game to determine who gets the prize.

This is the end of the decision making process for one period. After this, a new period begins.

Do refer to the above steps as a guide. You will have to do the same exercise for several periods. At the end of the experiment, **two of the periods** in this stage will be randomly selected as binding periods to determine your actual payment.

Stage 3

In this part of the experiment you will be asked to make a series of choices. How much you receive will depend partly on chance and partly on the choices you make. The decision problems are not designed to test you. What we want to know is what choices you would make in them. The only right answer is what you really would choose.

For each line in the table on the computer screen, please state whether you prefer **Option L** or **Option R**. Notice that there are a total of ten lines in the table but **just one line** will be randomly selected for payment. You do not know which line will be paid when you make your choices. Hence you should pay attention to the choice you make in every line. After you have completed all your choices, the computer will randomly generate a number, which determines which line is going to be paid.

Your earnings for the selected line depend on which option you chose: If you chose **Option L** in that line, you will receive **20 ECUs**. If you chose **Option R** in that line, you will receive either **60 ECUs or 0**. To determine your earnings in the case you chose Option R, there will be a second random draw. The computer will randomly determine if your payoff is 60 ECUs or 0, with the **chances stated in Option R**.

Stage 4

In this part of the experiment you will be asked to answer a series of quantitative questions. For each question you answer correctly, you will be given **5 ECUs**. You will not be punished if your answer is wrong. And if you have no idea about the answer, you can leave it blank. You have **6 minutes** to answer these questions. The reward will be added to your total earning.

This is the end of the specific instructions for each stage.

For your reference, your total payoff in this experiment would be the sum of following five parts:

(1) Show-up fee: 2 dollars

(2) Total profits of **two randomly chosen** binding periods in Stage 1

(3) Total profits of **two randomly chosen** binding periods in Stage 2

(4) Payoff from Stage 3

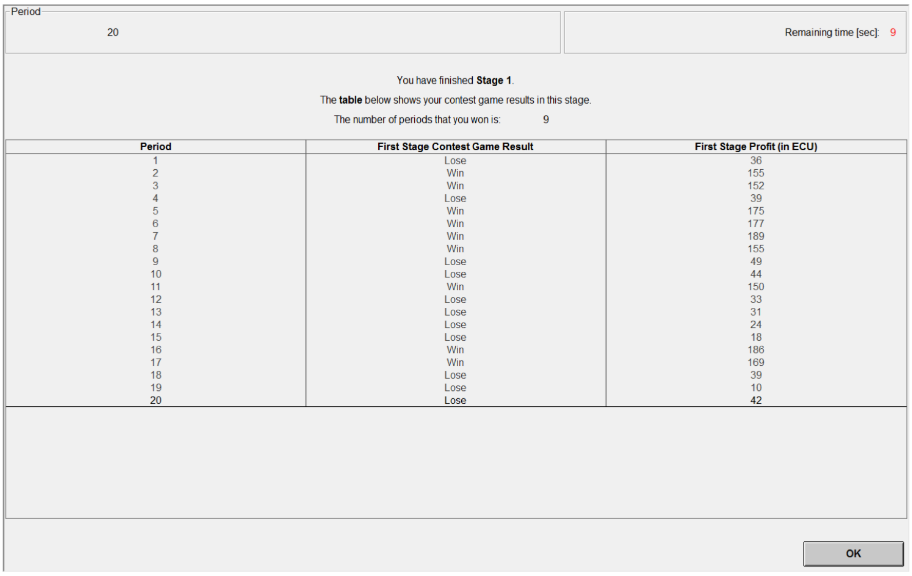
(5) Payoff from Stage 4

Thus, your total earning in this experiment equals to:

(1) + 0.04*(2) + (3) + (4) + (5),

where 0.04 is the exchange rate.

4.6.2 Screenshots of the Experiment



You have finished **Stage 1**.

The **table** below shows your contest game results in this stage.

The number of periods that you won is: 9

Period	First Stage Contest Game Result	First Stage Profit (in ECU)
1	Lose	36
2	Win	155
3	Win	152
4	Lose	39
5	Win	175
6	Win	177
7	Win	189
8	Win	155
9	Lose	49
10	Lose	44
11	Win	150
12	Lose	33
13	Lose	31
14	Lose	24
15	Lose	18
16	Win	186
17	Win	169
18	Lose	39
19	Lose	10
20	Lose	42

5 Chapter 5 Conclusion

5.1 Summary and contributions

In this thesis, I present three essays that use lab experiments to study players' strategic behavior in contest games. In all three experiments, I use the Tullock contest game. Experimental literature has discovered a mismatch between the theoretical predictions in contests and players' actual behaviors in contest games. Several explanations have been given regarding these discrepancies; examples are non-monetary utility from winning, spiteful preferences, or simply because subjects make mistakes (Sheremeta 2010; Cason, Sheremeta, and Zhang 2012; Eisenkopf and Teyssier 2013). I examine whether or not players behave according to theory predictions when faced with various incentives and measure the distance to which they deviate. I provide evidence that players' actual behaviors are in accordance with model predictions for the most parts; however, there are still some discrepancies observed.

In Chapter 2, I offer further support to the theoretical prediction regarding asymmetry in contests by differentiating players' costs of participating in a contest and allowing players to choose whether or not to hire an agent to fight for them. I find that, in line with theoretical predictions, players who suffer from higher costs in contests are more likely to hire a delegate.

While in Chapter 2, I use one-shot contest game to examine the effects of cost structure on contestants' delegation choices in contest game, I go one step further in Chapter 3 by employing different degrees of the "shadows of the future". I vary the continuation probabilities in this chapter to obtain settings from one-shot games to almost infinitely repeated games. I also test the theoretical predictions when there is asymmetry between competing players and in situations in which conflict is destructive. I found mixed results in my experiment. In accordance with model predictions, players fight less aggressively when conflict is destructive. However, in opposition to predictions regarding asymmetry that posit that players with greater abilities are more cooperative than less able players, the opposite is true in my experiment. Finally, I do not observe much difference in players' behaviors when varying the continuation probabilities.

Finally, in Chapter 4, I developed a novel game called Contest in Prisoners' Dilemma (CPD) to study post-conflict effects in a lab environment. Players choose whether or not to take part in a contest. The contest will only happen when both players have chosen to fight. To examine the influence of the availability of information regarding winning and the effect of the manner in which players win the contest, I take advantage of a two-stage game with three treatments in my experiment. Comparing the control treatment, in which no information regarding winning is given, and the feedback treatment, in which players are provided with the results of the contests, I am able to measure how the availability of information regarding winning influences players' behavior in subsequent contests. Identifying the differences between the feedback treatment, in which players choose how much effort to expend to win a contest, and the feedback_luck treatment, in which players have no control over the results of the contest, allows me to examine how different manners of winning a contest affect players behaviors in subsequent conflict situations. Contradicting extant field studies and literature on animals' behaviors, I find no effect of information regarding winning on players' willingness to fight again and their aggressiveness in subsequent conflicts. On the contrary, I argue that aggressive people win more.

5.2 Directions for future research

My thesis opens several new avenues for future research. In each chapter, some additional questions could be investigated.

In Chapter 2 I observe that players make more delegation choices when the cost of participating in the contest themselves is larger than the cost of delegates participating. The payment scheme I use in my experiment is fixed payment; the delegate only receives this fixed payment if he or she wins on behalf of the principal. Various factors could affect the principal's choice and the delegate's behavior. For example, what if the payment that the delegate receives is not fixed? It would be interesting to adopt a contingent payment scheme in which the payment to delegates consists of two parts: one fixed payment paid to delegates regardless of the results of the contest and a second part of the payment that is only paid if the delegate wins the contest.

In Chapter 3, I study the effect of different degrees of the "shadows of the future" on players' cooperative behaviors. To vary the lengths of different games, I employ four different values of continuation probabilities: 0, 0.3, 0.6, and 0.9. Among the four values, 0 stands for a one-shot game, while 0.9 represents a game that has a large probability of continuing after the current period. The advantage of this design is that I can directly compare games with different continuation probabilities. However, one problem with this design lies in the fact that, for small continuation probabilities, I have relatively few data points. For example, when the continuation probability equals 0, there is only one period within this super-game whereas, whereas, for a continuation probability of 0.9, the expected length of the super-game is 10 periods. To obtain a more balanced data set, one future extension would be to adopt a block random termination design (BRT) in which subjects play in blocks with a fixed number of rounds (see Fréchette and Yuksel 2017). Within a block, there is a different number of super-games depending on their individual length.

In Chapter 4, I examine the effect of winning history on players' subsequent behaviors in a finitely repeated setting. However, I do not observe the subjects' behavior immediately after winning or losing. Instead of looking at the aggregate history of winning and losing, it would be interesting to measure the direct effect of winning immediately after a conflictual situation. Since aggregate winning history consists of results from more than one contest, it may blur the results by providing mixed feedback information involving both winning and losing. A one-shot game, however, provides sharp comparisons between winning and losing a previous contest and may help to explain subjects' behavior in a repeated setting. Another interesting extension would be adding a new treatment based on "pure luck". In this new treatment, players choose how much effort to expend, but the result of the contest is still random, in that it does not follow the contest success function. In my current setting, players cannot choose how much effort to expend in the feedback_luck treatment. Although this provides an environment in which winning is determined by pure luck and allows for an examination of the ways in which the method of winning affects players' behavior, I cannot directly observe the players' efforts in this setting. Hence, it is difficult to measure players' effort and examine how they are influenced by an unfair game setting. After all, effort is an important factor in contest theory and it has the potential to provide more insights into players' reactions to incentives.

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