COSTLY CONTESTS AND THE WILL TO WIN

Thesis submitted for the degree of

"Doctor of Philosophy"

By

Einav Hart

Submitted to the Senate of the Hebrew University of Jerusalem

May/2015

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This work was carried out under the supervision of:

Yaakov Kareev and Judith Avrahami

Abstract

Competitions are ubiquitous in plant, animal and human societies – for food, living space, mates; in schools, in the workplace, in sports, in research and development enterprises, in political races as well as in state conflicts and wars. Many resources are spent on such competitions – time, effort or money – investments which are often non-refundable. One contestant wins the prize for the invested amount, while all others lose their investments without receiving compensation. High investments may benefit society in general, for example in innovative endeavors; yet, high investments can also be largely wasteful or even detrimental for society when the competition is exacerbated and no new wealth is created. Hence, understanding what factors determine the total investment by contestants is of much interest.

Three studies examined behavior in costly competitions using an experimental game paradigm, "Invest Game", involving repeated investment decisions. I varied the competitive setting, in order to explore whether –and how– various economic and psychological aspects affect investment behavior. I examined several aspects of investment behavior: Overall investments in the different competition settings; the corresponding earnings from the competition; earnings were compared between the different competitions, and compared to the initial resources; the dynamics of investment over time, which could show escalation or moderation of the competition; and round-to-round changes in investment, in regard to the outcome (win or loss) in the previous round.

In Chapter I, I examine how behavior is affected by asymmetry (inequality) among the contestants. Competitions are frequently asymmetric, due to contestants' differing resources or prize valuations. Two experiments explored investment behavior in asymmetric contests: Contestants were unequal in either their strength – via their initial amount of resources – or in their motivation – via the size of their potential prize. Subjects repeatedly competed in both symmetric and asymmetric contests, enabling within-subject comparisons. Does asymmetry discourage the weaker contestants from investing? Do stronger contestants take this into account, and also invest less? Or does the desire to win abolish these differences? I show that compared to symmetric contests, asymmetry in strength led to lower investments and especially by weaker contestants; in contrast, asymmetry in motivation did not change investments.

Chapter II explores how noisy determination of the winner affects investments in symmetric and asymmetric contests in which contestants differ in strength. The competition winner was

determined via different winner-resolution rules: a probabilistic rule, a rule including error terms, and a deterministic rule for comparison. When people of unequal strength decide how much effort to invest in competition, does noise in the evaluation of investments affect decisions? Investments were higher in the error competitions than those in both the probabilistic and the deterministic competitions. Inequality reduced investments by both contestants, but the effect was moderated in the probabilistic competition. The findings suggest that noise, often inherently present, may in some cases be advantageous. Specifically, it may diminish the effect of the inequality between the contestants.

In Chapter III, I examine investment behavior in competitions in which the winner's prize is not fixed, but depends on the contestants' investments. That is, contestants may benefit from their opponents' investments, or be hurt by them. Do contestants care only about winning the prize, or about beating their opponent by the widest possible margin? Do they care about the overall "pie" – the overall revenue, namely aggregate benefit for all contestants? I observe higher investments when the loser's investment increased the winner's prize, and lower investments when the loser's investment decreased the prize. I also observe higher investments when the winner's investment increases the prize. Notably, in certain situations this tendency may lead to a larger waste of resources: Subjects earned less in some settings in which the prize depended on investments than in competitions with a fixed prize.

In all competitions, I analyzed the changes between consecutive investments, examining whether investments differ following a previous win compared to a previous loss. Indeed, across all settings and conditions, these round-to-round dynamics reflect reactions to the previous outcome (win or loss): Investments decreased following a win, and increased following a loss. This pattern held across rounds, implying it is not a result of learning or adjusting towards an optimal investment, but rather that contestants react to winning versus losing.

In sum, the findings further our understanding of competitive situations in general, and of the influence of specific contextual features or facets in particular. The setting affects several aspects of behavior, namely, investment and participation rates, the degree of overinvestment and the corresponding earnings in the competition. At the same time, other aspects stay constant across competitions, namely, contestants' drive toward winning and its consequences.

Included Papers

The three main chapters in this dissertation, Chapters I-III, are based on papers published in or submitted to refereed academic journals:

I. Hart, E., Avrahami, J., Kareev, Y., & Todd, P. (2015). Investing Even in Uneven Contests: Effects of Asymmetry on Investment in Contests. *Journal of Behavioral Decision Making.* Article first published online: 6 MAR 2015. DOI: 10.1002/bdm.1861

II. Hart, E., Avrahami, J., & Kareev, Y. (*under review*). The Strong, the Weak, and Lady Luck: Competitive Behavior moderated by Inequality and Noise in the Winner Resolution Rule.

III. Hart, E., Avrahami, J., & Kareev, Y. (*under review*). Enlarging the Market Yet Decreasing the Profit: Competitive Behavior When Investment Affects the Prize.

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Introduction

Many aspects of life involve competitions: Animals and plants compete for food, water, mates, and living space. Among humans, competitions can be found in sports, in financial markets, in the educational system, in the workplace, between politicians or lobbyists, between companies attempting to secure a contract or a patent, between rivals vying for a mate, and so on (see, e.g., Vaughn & Diserens, 1938).

Two features that characterize many contests are that (1) contestants aim to attain a goal or win a prize, and (2) participation demands investments that are costly for the contestants, regardless of the contest outcome. In such contests, to win the prize contestants invest resources such as effort or money, which are non-refundable and will not be returned, independent of win or loss. The money spent on campaigning for presidency and athletes' training efforts are examples of such investments. A similar structure can be applied to buying lottery tickets or waiting in line in hope of receiving a ticket for a sold-out show, to animals engaging in a courting ritual (e.g., birds' lek – Payne, 1984; male deers – Clutton-Brock & Albon, 1979), or to countries preparing for war. Whereas the above structure is usually an implicit auction or model of the contest, it may also be explicit, in that a contest organizer (e.g., a company manager or a sporting event organizer) can decide to judge contestants on their actual, recent effort rather than on commitments and promises of performance (Che & Gale, 1996).[1]

Competitions impact the way contestants behave, which can result in different levels of overall utility for society. On the one hand, contests can create or increase benefits for society, and lead to higher efficiency in both production and allocation (Smith, 1776; Vickers, 1995). On the other hand, competitions can, and often do, lead to significant losses of money, resources or energy; they are often expensive for contestants and society. Competitive motivations may decrease the size of the prize (or pie), and may harm both one's opponent and oneself (e.g., Garcia, Tor, & Gonzalez, 2006; Ku, Malhotra, & Murnighan, 2005). This is discussed in more detail in the next section.

Thus, to enhance the efficiency of competitive interactions, it is important to identify the factors that can yield beneficial levels of investment, and more generally, to understand what factors determine the overall investment by contestants. Many aspects have been explored and surveyed in the theoretical literature, as the following sections will show. For many competition

[1] In economic literature, these competitions are called all-pay auctions or contests (Tullock, 1967; 1980). Commonly studied instances include lobbying for licenses and rights, rent-seeking, R&D races and architectural contests, as well as political races (Dasgupta, 1986; Hillman & Samet, 1987; Krueger, 1974; Tullock, 1967).

settings, there are known game theoretic solutions. Specifically, there are known equilibrium strategies, from which one can derive mean investments and mean gains in the competition. I present the game theoretic solution for the conditions which coincide with my experimental conditions in Appendix I. I also compare the predicted mean investments and earnings to those observed in the relevant experimental conditions.

There have also been experimental studies which examined the effects of various aspects on the contestants' investments (for a survey, see Dechenaux, Kovenock, & Sheremeta, 2012). The studies in this work extend the literature in examining the separate and combined influence of various psychological and economic variables on competitive investment behavior. I further extend previous studies in examining the investment dynamics over time, in addition to the average investment across different competitive settings – and the willingness to compete rather than sit out the competition. Specifically, I examine whether contestants react to their preceding outcome in the competition – winning or losing – when deciding on their subsequent investment.

In all studies, I used the "Invest game" – an experimental competition game designed by Judith Avrahami, Yaakov Kareev and myself, in which subjects repeatedly make investment decisions under different competition settings. The repeated decisions paradigm enabled exploring both investments over time in general, and the round-to-round investment dynamics. The game allowed changing various parameters of the competition setting while retaining the basic structure, so as to allow for more direct comparisons of behavior.

The rest of the work is laid out as follows: The next two sections describe the literature regarding costly competitions and the phenomenon of overinvestment, and explanations for the latter. I survey studies pertaining to competitive motivation, specifically reactions to winning and losing, and the potential influence of regret on investment behavior. The last part of the introduction describes the "Invest Game" in detail. Chapter I explores the effect of asymmetry between the contestants, in either their strength – via their initial amount of resources – or their motivation – via the size of their potential prize. Chapter II explores how noisy determination of the winner – via a probabilistic decision rule, or including random errors in judging investments – affects investments in both symmetric and asymmetric competitions. Chapter III examines investments in competitions in which contestants may benefit from their opponents' actions, or be hurt by them. The three main chapters include the relevant experiments and their background, and discuss their results. The concluding chapter summarizes and discusses the implications of this work.

1 Contests and Costs

Two musicians meet at a pub. One excitedly exclaims:

"Would you believe it? I finally managed to get an album out!"

"Wow, good for you! Have you sold anything?"

"Of course... My house, my car..."

(Common joke)

1.1 Two sides of the overinvestment coin

In 1503, Leonardo da Vinci and Michelangelo Buonarroti were commissioned to decorate two opposite walls in the same space, with the winner getting another, more prestigious, commission. The two famous painters were publicly known rivals. It was clear that putting them opposite one another would lead to intense competition, both personal and artistic. Competition was in fact the goal: Both painters were notorious for leaving paintings unfinished; the competition was thus intended to bring about the completion not just of one painting, but of two – and better ones at that.

In 2008, TransCanada Company proposed a pipeline project called "Keystone XL" which would transport daily hundreds of thousands of oil barrels through the USA. The Environmental Protection Agency declared that the project has dangerous environmental repercussions. Since then, there has been expansive and expensive lobbying efforts from both sides of this conflict – although, admittedly, more so from the oil and gas companies. Whereas investments in these lobbying activities are meant to change whether the pipeline is built, the resources invested in lobbying will not change the contribution of the pipeline – whether positive or negative – for the welfare of society.

There is a long and ongoing debate whether competitions, specifically those which require investing non-refundable resources, are beneficial or detrimental. The two competitive situations above exemplify the two positions regarding the usefulness and desirability of competitions. Some competitions are good for the contestants, and good for society. For example, in contests aimed towards innovations, such as research and development and patent races, or towards achievements, such as sporting events or design competitions, high investments could be construed as socially desirable (Runkel, 2006; Szymanski, 2003). Moreover, Hayek (1948) argues that competition enables customers to more readily select the best provider, service or solution – and that suppressing competition (e.g., allowing a monopoly) may hold many evils, and lead to high costs for society. Competitions can also be used in order to maximize participation and enjoyment, or as motivating mechanism for the contestants. For example, competition has been found to enhance the performance of groups – and to reduce the amount of free-riding in social dilemmas (in both a lab and a real-effort field experiment – Bornstein, Erev, & Rosen, 1990; Erev, Bornstein, & Galili, 1993). Vorderer, Hartmann, and Klimmt (2003) demonstrated that competition or elements thereof are a major component in the enjoyment and success of computer games. Yet, they also found that the risk of losing, prevalent in competitive tasks, led to negative emotions and a decrease in enjoyment. This supports the many voices opposed to competitions.

Competitions may, in some situations, lead to waste and other adverse effects; often contestants exert, on aggregate, too much effort or resources (O'Keeffe, Viscusi, & Zeckhauser, 1984). This result is of concern in politics and lobbying: When the sum of investments is large yet little or nothing is produced, resources are wasted. In rent-seeking activities, which comprise attempts to obtain a given resource without creating new wealth (e.g., increasing one's share of a fixed amount – be it monetary prize, tax or subsidy – or retaining monopoly privileges in a specific, known market), high investments are particularly undesirable (Tullock, 1980). In natural settings, competition may cause a decrease in population size (Schoener, 1983).

The approaches above have one thing in common – competitions increase the investment of effort or resources. In contests with non-refundable investments, this is very acute: Experimental and empirical investigations have established that the sum of investments often exceeds the prize amount, a phenomenon termed "overinvestment" or "overdissipation". Overinvestment has been observed in many studies of costly competitions with various contest features – such as how much one can spend on the contest, the potential prize, one's experience, or the number of opponents (Baye, Kovenock, & de Vries, 1999; Davis & Reilly, 1998; Gneezy & Smorodinsky, 2006; Lugovskyy, Puzzello, & Tucker, 2010; Potters, de Vries, & van Winden, 1998; Sheremeta, 2010; for a review, see Dechenaux et al., 2012).

As mentioned above, the desirability of high investments, and specifically overinvestment of resources, is debatable; it depends on the type of competition and the goals of its organizers. Either way, overinvestment is considered irrational, as more resources are spent than are attained by the contestants; there is no economic, game-theoretic solution which assumes contestant rationality that leads to this result (Anderson, Goeree, & Holt, 1998). Notably, overinvestment can be explained by various accounts, as can be seen in the next section.

1.2 Attempts to explain overinvestment

Several explanations have been proposed for the difference between the theoretic prediction and the empirical findings of substantial overinvestment. I shall delineate a few of these – including a statistical explanation (Baye et al., 1999), one of bounded rationality (Anderson et al., 1998), and the notion of non-monetary utilities (Sheremeta, 2010).

Baye et al. (1999) suggest that overinvestment can be explained within the original theoretical framework of Tullock (1967). Even when contestants are completely rational, their use of mixed strategies in equilibrium will probabilistically result in the spent amount exceeding the prize value. In the symmetric equilibrium, overinvestment is expected with probability of approximately one-half (the probability is slightly decreasing with the number of contestants). Importantly, Baye et al. (1999) define four types or incidences of overinvestment: Expected individual- and aggregate-overinvestment, and probabilistic individual- and aggregate-overinvestment. They claim that the last type of overinvestment is that which is observed, namely that overinvestment occurs with a positive probability (but not in expectancy). However, looking at experimental data, it is difficult to accept this conjecture, as overinvestment is much too prevalent (Davis & Reilly, 1998; Gneezy & Smorodinsky, 2006; Sheremeta, 2010).

Other scholars claim that the assumption of contestant rationality must be relaxed in order to account for overinvestment. For example, Anderson et al. (1998) posit a bounded rationality model in which investment behavior contains errors. Behavior follows a logit probabilistic decision rule, containing an error (or irrationality) parameter: The higher the expected payoff from a specific investment level, the more likely it is to be chosen, but even the best choice of investment is not selected with certainty. A logit equilibrium demonstrates the observed overinvestment when choice probabilities are proportional to an exponential function of the expected payoffs. In this equilibrium, a contestant's strategy depends on their value for the prize – unlike the Nash equilibrium in which investments depend only on the other contestant's value. Anderson et al. state that this model accurately describes the noisy behavior in experiments, and fits the data well (as can be seen by its accordance with findings by Davis & Reilly, 1998). However, not all of the model predictions are corroborated by data (Gneezy & Smorodinsky, 2006). Gneezy and Smorodinsky claim that the theory in Anderson et al. (1998) can explain behavior only in the early rounds of their game.

Gneezy and Smorodinsky (2006) instead suggest a two-stage decision model: In the first stage, each contestant decides whether to participate or not (invest zero); in the second stage, conditional on participation, each contestant sets their investment. Their data demonstrated that it is mostly the number of contestants who sit out that increased with the number of potential contestants – whereas the value of the non-zero investments was comparable between various group sizes. The distinction between participation and the performance conditional on entry can be seen also in a study by Cason, Masters and Sheremeta (2010): More subjects chose to participate in contests of effort against weaker opponents than against stronger opponents; more chose to participate in contests with prizes proportional to effort rather than in contests in which the winner takes it all (as in the competitions in this work). Nevertheless, the actual effort, conditional on participation, was not influenced by the latter factors.

Many researchers argue that non-monetary utilities and motivations play an important role in investment decisions (Amaldoss & Rapoport, 2009; Goeree, Holt, & Palfrey, 2002; Herrmann & Orzen, 2008; Parco, Rapoport, & Amaldoss, 2005; Schmitt, Shupp, Swope, & Cadigan, 2004; Sheremeta, 2010). However, such motivations have rarely been examined directly. An exception is Sheremeta (2010), who suggests that behavior is derived from a utility function which includes utility from winning. Sheremeta demonstrated that approximately 40% of the subjects invested positive amounts even when the prize was worth zero. The "non-monetary variable" was a significant predictor of subjects' behavior in prize-awarding contests. This finding also ties with the model posited by Gneezy and Smorodinsky (2006), in that there is one element which regards the prize and investment values, and another element which relates to competing or winning per se.

2 Winning or Losing

Winning isn't the most important thing, it’s the only thing. -- Vince Lombardi

People (and other organisms) obviously enter into contests and invest costly resources in large part due to the attraction of winning, yet the other, unattractive, side of the coin is no less consequential: the impacts of losing. Whereas winning may lead to positive emotions and an increase in perceived competence (Reeve & Deci, 1996), losing can lead to negative emotions, such as shame, anger and frustration (Kohn, 1992; Standage, Duda, & Pensgaard, 2005). Some researchers argue that winning, specifically besting others, is the strongest competitive motivation, overshadowing the desire to do well (Bazerman, Loewenstein, & White, 1992; Kohn, 1992; Malhotra, 2010; Messick & McClintock, 1968; Sheremeta, 2010). This could be because characteristics of the competitive situation cause arousal, which focuses the contestant on beating the opponent even at a high personal cost (Mead, 1937; Whittlemore, 1924; 1925).

Deciding how much to invest in costly competitions entails a tradeoff between a desire to win and a desire to not spend (too) many resources for an uncertain prize. Correspondingly, behavior in competitions can be framed as a choice between sitting out the competition (and not losing nor gaining any amount), or paying an amount – one's investment – for a chance to win the prize (Fehr & Schmid, 2014; Klose & Schweinzer, 2012). As it turns out, the tradeoff between winning and saving one's resources seems to be often settled in favor of the attempt to win. This can be seen in the ubiquitous finding of overinvestment, and more directly in several experimental studies which observed a large impact of winning (Cooper & Fang, 2008; Lacomba, Lagos, Reuben, & Van Winden, 2014).

In a survey of the experimental contest literature, Sheremeta (2013) proposes that investment behavior can be at least partly accounted for by preferences towards winning and losing. He further suggests that the emotions that come with winning or losing can help explain heterogeneous investment behavior. However, he focuses on more general emotions or moods, such as hate or guilt, rather than on affective reactions which are specific to the game-play and to the outcomes experienced by the contestants.

Thinking about competitions in which all investments are non-refundable, it is easy to see that loss may give rise to regret over having invested in the competition at all, rather than keeping one's resources to oneself – or, conversely, over not having invested enough to win the competition. But regret may also occur after winning the contest: Along with the positive emotions associated with winning, one may regret having invested too much, surpassing the opponent by a larger-than-necessary margin. Importantly, when contestants compete repeatedly, they have a chance to react to their previous outcomes and payoffs by adjusting their subsequent investments. In my studies, I examine whether contestants react differently to winning versus losing the competition when deciding on their investment in the next competition.

2.1 Reactions to regret

Never look back unless you are planning to go that way. -- Henry David Thoreau

Two forms of regret that appear relevant to winning and losing in contests are thus winner regret ("money left on the table") and loser regret ("missed opportunity to win"). Anticipation of the former would decrease investment in competition in subsequent encounters (lowering bids in a sequence of auctions), whereas anticipation of the latter would increase the investments in subsequent competition (Engelbrecht-Wiggans & Katok, 2007, 2008). Over-investing in contests (e.g., overbidding in auctions) may be explained by the differential saliency of these types of regret: In most experimental settings – though not necessarily in most real-life situations – only the loser's regret is salient, as only the highest investment (e.g., bid) is announced (Engelbrecht-Wiggans & Katok, 2007, 2008; Filiz-Ozbay & Ozbay, 2007; Hyndman, Ozbay, & Sujarittanonta, 2012). Such responses would be in line with the extensive research showing that regret-based accounts can explain behavior in a variety of individual and interactive situations (Avrahami, Güth, & Kareev, 2005; Avrahami & Kareev, 2011; Avrahami, Kareev, & Hart, 2015; Grosskopf, Erev, & Yechiam, 2006; Hart, Kareev, & Avrhami, 2015; Kareev, Avrahami, & Fiedler, 2014; Mellers, Schwartz, & Ritov, 1999; Zeelenberg & Beattie, 1997; Zeelenberg, Beattie, van der Pligt, & de Vries, 1996)

In this work, I examine whether the competitive setting affects the behavioral consequences of regret (or counterfactuals): Does the specific setting, such as the way the outcome came about or the magnitude of the (missed or won) prize affect what people would do following an outcome which causes loser's regret or winner's regret? Several factors have been shown to affect the experience and intensity of regret (e.g., Connolly & Zeelenberg, 2002) or the arousal of counterfactuals (e.g., Kahneman & Miller, 1986; Roese & Olson, 1995). Such factors include responsibility and justifiability (which could translate to whether one won or lost justly or not, described further in Chapter II); the distance between the actual outcome and the counterfactual one (which could be translated to an effect of the prize value); the perceptual closeness of the two states of the world (how many events needed to be different); social and personal norms or beliefs. Studies examining behavior in gambling tasks demonstrated that following a near-miss, people tend to continue playing, which is similar to behavior following a win (e.g., Reid, 1986). Could this mean that people would react to some losses as they react to winning? Little research to date has focused on the dynamics of behavior in different cases or situations – on the actions following different types or degrees of regret.

In line with research showing effects of outcome on the immediately following decision (e.g., Avrahami & Kareev, 2011; Hart et al., 2015), I propose that investments are affected by reactions to the most recent outcome; I address the following questions: Will winning drive contestants to decrease their subsequent investments (perhaps due to their regret over investing too much)? Or will they increase their investment to remain winners? Will losing lead contestants to increase their investment and try to win the next time, or to decrease their investment so as to not waste further resources? And finally, does the structure of the competition affect such tendencies?

3 General Method: The "Invest Game"

The "Invest Game" is a repeated two-player contest with complete information, designed to explore investment behavior in different competitions. In each of the rounds of the game, subjects receive a certain resource endowment in points, and decide how many of them to invest in the current contest in order to win the prize. Investments are non-refundable, regardless of win or loss. Uninvested points and prizes accumulate and are exchanged for money after the experiment, but cannot be used in subsequent rounds. Importantly, on any round subjects can choose to not invest any points in the contest – thus effectively opting out or sitting out the contest.

Pairs are randomly (re-)matched in each round (in a "stranger design"). Subjects do not know the identity of the subject they are paired with. In each round, subjects are shown their opponent's endowment and potential prize (as well as their own). After each round, subjects are told whether they invested more or less than their opponent, whether they received a prize, and their earnings for the round. That is, all of the information in the game, other than the exact value of the opponent's investment, is common knowledge.[2]

[2] I chose to give subjects information only regarding the ordinal relation between the investments and not about the exact amount of the opposing investment, since I believe that this makes the setting more general, and closer to real life competitions. Further, pilot experiments showed no difference between conditions in which subjects were told the exact investment and conditions in which they were told only whether they invested more or less than their opponent.

This setting, while of course simplified, models many real life contests, such as financial markets, product development and sports competitions. It provides an experimental framework allowing a unified and combinatorial exploration of the influence of various factors on investment behavior.

In the competitions described in Chapters I and III, the competition winner in each pair was the contestant who invested more than their opponent (in case of a tie, the prize was split). This deterministic rule defines the all-pay contest, and is a special case of the contest success function (CSF) delineated by Tullock (1967). I use this rule as an approximation of the notion that in many contests, the best contestant or product is guaranteed to win. In Chapter II, noise was introduced to the rule determining the winner, through a probabilistic lottery rule, or by adding or subtracting random error components from contestants' investments.

Chapters I and II compare symmetric and asymmetric competitions. Contestants can be either one of two types, pertaining to their resource endowment or their prize value. Each contestant competes both against their own type (in "symmetric contests") and against contestants of the opposing type ("asymmetric contests"). In my setting, each subject plays both symmetric and asymmetric contests, in counterbalanced order: Half of the rounds are symmetric contests, and the other half are asymmetric contests.

In Chapter III, I introduce various contingencies between contestants' investments and the prizes they receive. Contestants may benefit from their opponents' actions, or may be hurt by them: Each contestant's investment may add or subtract from the winner's prize.

Chapter I

Investing Even in Uneven Contests: Effects of Asymmetry on Investment in Contests

This chapter involves asymmetry between the contestants, in either their strength – via their initial amount of resources – or their motivation – via the size of their potential prize. I show that asymmetry in strength leads to lower investments overall, and especially by weaker contestants; in contrast, asymmetry in contestants' motivation does not change their investments.

Jack and Jill are out camping, and a bear suddenly comes out and growls.
Jill immediately starts putting on her running shoes.
Jack says, "What are you doing? You can't outrun a bear!"
"I don't have to outrun the bear – I just have to outrun you!"

One key aspect of the contest structure is the contestants' relative strengths or positions. Indeed, most real-life contests are asymmetric, in at least two possible ways: contestants not having equal resources to invest toward winning the competition, or not holding the same valuation for winning the contest. For example, a small company trying to win a contract probably has fewer funds to invest in first producing its prototype for getting the contract than a big, established company, but it may have much more at stake from winning or losing the contract than the larger company.

Do these asymmetries affect the contestants' behavior? In particular, how much would each contestant invest in asymmetric competitions? Will weaker contestants choose to give up and not compete under some conditions? And how does asymmetry affect the contestants' investments in subsequent competitions after they win or lose a contest?

The focus of this chapter is the behavior of contestants in asymmetric contests compared to symmetric ones. As aforenoted, in the contests I study, all contestants forfeit their investments and only the contestant who made the greatest investment wins the prize. I explore how asymmetry between the contestants influences their aggregate investments, as well as the contestants' reactions to winning or losing, in terms of their subsequent investments when competing repeatedly. I examine the effects of asymmetries arising from two different sources: In Experiment 1A, contestants are asymmetric in their resource endowments; in Experiment 1B, contestants differ in the value of their prize.

The next two sections describe the literature regarding the effect of asymmetry on the overall intensity of competition and the contestants' reactions to winning or losing; then I turn to the experiments in the following sections.

11 Background

11.1 Asymmetric competitions

Theories and meta-analyses in ecology point out that asymmetric contests constitute the majority of cases in animal and plant competitions (Connell, 1983; Lawton & Hassell, 1981; Schoener, 1983). In such cases asymmetry, often arising from the contestants' relative sizes (Schoener, 1983), is predicted to lead to differential behavior: There is a trade-off between the probability and value of receiving the prize on the one hand, and the costs associated with competing on the other hand – and it may be settled differently by each contestant according to their relative competitive position (Enquist, 1985; Maynard Smith & Parker, 1976). For instance, in animal conflicts, the larger animals often dominate the smaller ones and can resort to more aggressive behaviors at a lower cost (Persson, 1985; Young, 2003). Similar characteristics are observed in competitions between plants for soil or light (Schwinning & Weiner, 1998). The following research questions immediately come to mind:

Q1.1: How is overall investment affected by asymmetry? Namely, is there evidence for a discouraging effect of asymmetry on investments?

Q1.2: Does asymmetry increase the tendency to sit out the competition?

When the relevant difference between the contestants (in either strength or motivation) is large enough, the weaker contestant, or the one with lower motivation, may be discouraged from competing altogether. The stronger (or more motivated) contestant, anticipating that behavior of their opponent, could then also invest less in the competition. This pattern – termed the "discouragement effect" – has been observed both in non-human animals (e.g., when smaller red deer males give up after assessing competitors as larger before engaging in potentially aggressive competitions – Clutton-Brock & Albon, 1979) and in several empirical and experimental studies in humans (for a review, see Dechenaux et al., 2012). For example, Brown (2011) examined golfers' behavior in the PGA Tour, and found that when a "superstar" (specifically, Tiger Woods) was competing, all other players' scores were lower than their own scores when there was no superstar player in the contest.

Economic analyses also predict that sufficient asymmetry – in either resources or prize valuations – decreases the mean investment by all individuals in a competition (Baik, 1994; Baye, Kovenock, & de Vries, 1993, 1996; Hillman & Riley, 1989; Nitzan, 1994; Rapoport &

Amaldoss, 2000; Runkel, 2006; Szymanski, 2003). Further, if the asymmetry between the contestants is large enough, the weak contestant will refrain from playing altogether (Baik, 1994; Nitzan, 1994; Szymanski, 2003).

Discouragement can be observed not only on an aggregate level, in contestants' summed investments, but – perhaps more acutely – in each contestant's tendency to opt out of the contest. In many natural settings, when contestants of differing strengths encounter each other, they (and especially the weaker ones) may choose not to compete (for an analysis of this behavior in animals, see Eshel & Cavalli-Sforza, 1982). To study this possibility, my setup allowed measuring the tendency to sit out the contest (instead of competing), and to assess the relation between the contest characteristics and the prevalence of sitting out. I also tested whether such opting out, if found, differs reliably between individuals.

Previous research has addressed some of the effects of asymmetry in resources and prize valuations on investments, but in separate studies and settings (for a review, see Dechenaux et al., 2012). The most relevant studies are those of Amaldoss and Jain (2002), Davis and Reilly (1998) and Fehr and Schmid (2014) – which examined the effect of asymmetry in valuations on investments in contests with two, five or three contestants (respectively) – and that of Rapoport and Amaldoss (2000), which examined asymmetry in resources. However, these studies were mostly concerned with comparing behavior in asymmetric contests to theoretic predictions (often finding deviations from the Nash equilibria and payoffs), rather than comparing symmetric and asymmetric contests. More importantly, I am not aware of any attempts to study in the same setting investments under different sources of asymmetry, namely in resources and in prize valuations. This study is thus more comprehensive than the aforementioned ones: Using the same setting and parameter space enables comparisons of the various effects and interactions.

The third research question I examine regards contestants’ earnings in the competition:

Q1.3: How does asymmetry affect contestants' earnings in the competition?

11.2 Investment dynamics

Another important aspect of investment behavior is the dynamics over time. As aforementioned, I explore not only overall investment but also whether people change their investments in a succession of competitive interactions. I examine two facets of the investment dynamics: Changes in overall investment over time, and contestants' reactivity to their previous outcome – reflected in changes in investment from round to round. Specifically, in the following two experiments, I address the following questions:

Q1.4: Does the intensity of competition change over time?

Q1.5: Do contestants react to the realized outcome – winning versus losing – in deciding on their next investment? That is, do investments differ following a win compared to following a loss in the previous round?

As discussed in more detail in Section 2, previous research has shown effects of outcomes on subsequent decisions involving strategic interactions (e.g., Avrahami & Kareev, 2011; Camerer & Ho, 1999; Erev & Roth, 1998; Roth & Erev, 1995). However, this was not examined in such a complex setting, in which contestants can choose among a wide array of strategies. I assume that in contests, decisions about how much to invest are affected most strongly by the reaction to the most recent contest outcome. I am thus interested in whether these dynamics reflect reactions to winning or losing the previous contest. Notably, inequality in contestants' strength or motivation may be apparent in their reactions to winning or losing the contest: For example, winning may be more crucial to the survival of weaker contestants than to that of stronger contestants.

Q1.6: Does the reaction to winning or losing, if it exists, depend on the contestant's relative strength or motivation?

12 Experiments 1A and 1B Overview

The following two experiments directly explored the influence of asymmetry: Each subject competed in multiple rounds of both symmetric and asymmetric contests, in two blocks. Asymmetry arose from either of two different sources: In Experiment 1A, the asymmetry between the contestants arose from the resources at their disposal; in Experiment 1B, the source of the asymmetry was the values of the contestants' prizes.

Subjects were assigned to different types defined in terms of their resources or how big of a prize they would win. A subject's type remained constant across the rounds, but they would meet opponents of various types. I believe this to be an important feature of contests in real life: One often retains one's own type throughout various contests in time (e.g., one's resources or how much one values winning). However, one's opponents vary across contests – in some situations one is faced with stronger opponents, and in others with weaker opponents.

13 Experiment 1A: Asymmetric Endowments

13.1 Method

I used the Invest game described above with the two types defined by resources of either 96 points per round ("R-96") or 72 points per round ("R-72"). These types varied as a between-subject factor, with half of the subjects in each session assigned to be R-96 and half to R-72. Symmetry was a within-subject factor, with each subject playing against both types (in one symmetric and one asymmetric block of 8 rounds each, in counterbalanced order). In each round, the pairings were determined randomly from the relevant group of subjects (i.e., stranger design).

There were two prize-versions of the contest: V-96, in which the prize was worth 96 points for both types, and V-72, in which the prize was worth 72 points for both types. At the end of the game, subjects received their summed earnings, according to a specified exchange rate. The exchange rates were set such that, on average, subjects earned about twice the student hourly wage for their time spent.

13.1.1 Subjects

Subjects were Hebrew University students, who participated for monetary pay. The experiment was run in eight sessions, each including 12 subjects. Students were randomly assigned to sessions. In V-96, 48 students participated, out of which there were 24 females (50.0%); 41 of the subjects (85.4%) were undergraduates. In V-72, 48 students participated: 32 females (66.7%); 44 undergraduates (91.7%).

In V-96, subjects earned an average of 1.75 NIS per round (New Israeli Shekel, one NIS worth approximately $0.27); in V-72, earnings averaged 1.17 NIS per round. No measures other than subjects' investment decisions were collected.

13.1.2 Procedure

The experiment was conducted at the Ratio-Lab at the Hebrew University, on PCs connected to the experiment webpage. The twelve subjects in each session were separated from one another by physical partitions between the PC stations, and were instructed not to communicate with each other. They read the experiment instructions at their own pace from the screen, and were asked to raise their hand if they had questions at any point in the experiment. See Appendix II for instructions.

The game as described above was explained to the subjects, so that the game and payoff structure, number of rounds (16) and the exchange rate from experimental points to NIS were all common knowledge. The computer randomly generated the contest pairings for each round. Subjects had no way of knowing the identity of their opponent at any stage of the game. After all subjects had submitted their investment for the round, they were shown the round outcome. After all subjects indicated they were ready to continue, another round began. At the end of the experiment, subjects saw their total payoff (in NIS). They were thanked and asked to enter the adjacent room, one by one, to receive their payment.

13.2 Results

13.2.1 Overall investments (Q1.1, Q1.2)

I examined the effects of asymmetry and prize version on investments on average, and on the rate of sitting out the contest. To this end, I conducted a linear regression on investments, with subjects' type, their opponent's type, and symmetry (representing the interaction between own type and that of the opponent), as well as prize version and round, as predictors; variance was clustered by subject.[3]

Figure 1.1 presents the average investments in the different conditions. As shown in the figure, investments were lower in asymmetric contests compared to symmetric contests ($t(96)=3.57$, $p=.001$). Subjects who had higher resource endowments invested more on average ($t(96)=2.99$, $p=.004$). Moreover, all subjects invested less when faced with a higher-endowed opponent ($t(96)=-2.46$, $p=.016$). There were no differences in the above patterns over rounds ($t(96)=-0.16$, $p=.875$). There was also no difference between prize versions (neither main effect nor interactions were significant; all p's>.22).[4]

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[3] This method of clustering the model variance by subject corrects for each subject's repeated observations across time; see e.g., Petersen (2009) and Williams (2000). These analyses were conducted using STATA's variance cluster option in linear and logistic regression (StataCorp. 2009).

[4] One should note that whereas the observed and predicted means often do not significantly differ from one another, the distribution of investments was mostly bimodal – centering on the more extreme points in the possible range of investments – rather than uniform over the range. To check whether this bimodality influenced the results, I recoded the investments as a binary variable of "high" or "low" compared to the middle of the possible range of each subject and submitted this variable to a logistic regression similar to that reported. This regression showed similar results to the linear regression.

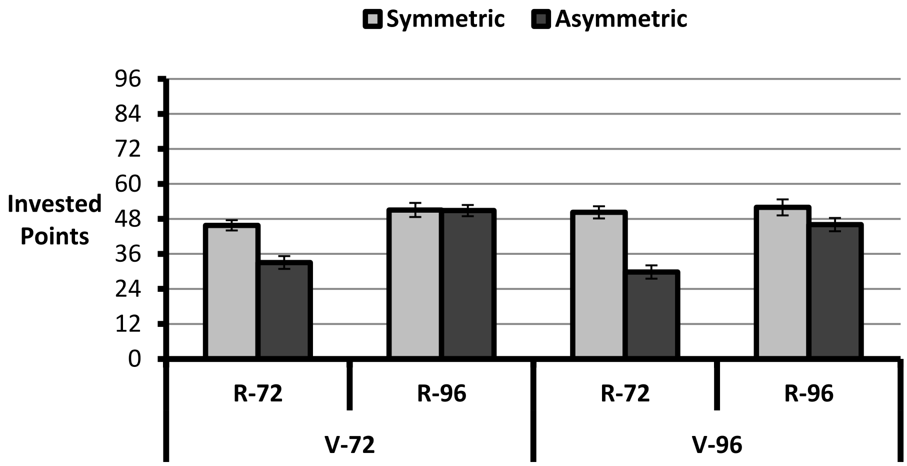


Figure 1.1. Experiment 1A: Average investments in the two prize value versions, V-96 and V-72, for each type of subject (low or high resource endowment, R-72 or R-96), in symmetric and asymmetric contests. Error bars represent standard error of the mean.

I further conducted regression analyses similar to that above but with only the relevant comparison sub-groups – for example, only with the R-72 subjects, comparing symmetric and asymmetric contests. When analyzing only the R-72 subjects, I found an effect of asymmetry ($t(48)=-4.39$, $p<.001$). In contrast, R-96 subjects invested similarly in symmetric and asymmetric contests ($t(48)=0.76$, $p=.452$). Interestingly, whereas the two types invested differently in asymmetric contests ($t(96)=3.89$, $p<.001$), the investments in symmetric contests did not depend on the resources at the subjects' disposal ($t(96)=0.79$, $p=.433$). That is, when competing with others of their own type, subjects who had 72-point or 96-point resource endowments invested, on average, similar amounts.[5]

Notably, the same patterns emerged when analyzing the investment *relative* to subjects' resource endowment (rather than the absolute investment): Asymmetry decreased investments ($t(96)=-3.92$, $p<.001$), as did competing against a High opponent ($t(96)=-2.97$, $p=.004$). Not surprisingly, there was no effect of subjects' own resources on their relative investments ($t(96)=-0.76$, $p=.451$). There were again no overall effects or interactions regarding the prize version (all p's>.21), and no difference over time ($t(96)=-0.06$, $p=.954$).

[5] In light of these results, one may expect that the aforementioned general regression demonstrate an interaction between subjects' types and symmetry. However, for statistical reasons this interaction variable could not be included in the regression.

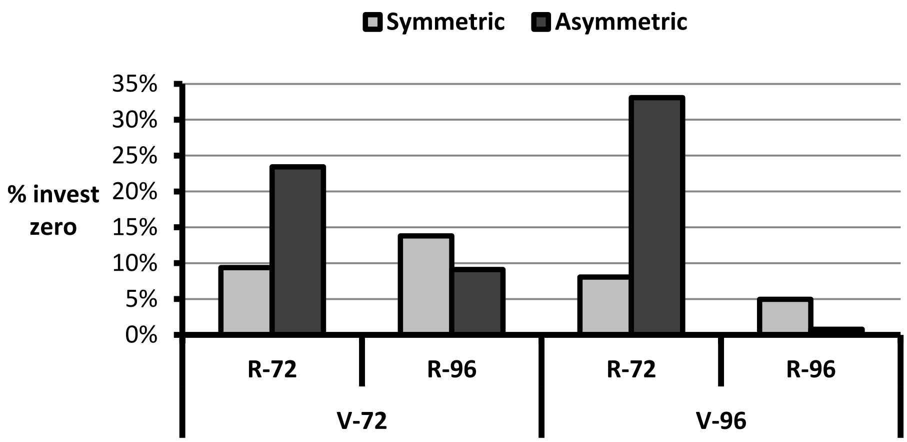


Figure 1.2. Experiment 1A: Percent of investments equal to zero in the two prize value versions, V-96 and V-72, for each type of subject (low or high resource endowment, R-72 or R-96), in symmetric and asymmetric contests.

As aforementioned, another aspect of investment behavior in which one may see the effect of asymmetry is the subjects' tendency to sit out the competition. In my setting, they cannot opt out of the contest per se, but can invest zero in a round and in essence sit out that competition. I thus examined the tendency to invest zero as another manifestation of the discouragement effect.

On average, across all contests and subject-types, 13.22% (203 of 1536) of investments were zero. Figure 1.2 presents the rate of sitting out in the different contests. To examine whether this rate differs for the different contests, I submitted the indicator variable to a regression (with variance clustered by subject), with the two subjects' types, symmetry, prize version and the interactions as predictors. There was again no difference between the two prize versions ($t(96)=0.56$, $p=.575$), and no significant interactions with the version (all p's>.06). In both versions, R-72 subjects tended to sit out more than R-96 subjects ($t(96)=3.21$, $p=.002$). Both types of subjects tended to sit out more against R-96 subjects ($t(96)=3.75$, $p<.001$) – that is, when faced with a highly endowed, strong, opponent, all subjects tended to sit out more, regardless of their own resources or the symmetry of the game. Importantly, in asymmetric contests, all subjects tended to sit out more often ($t(96)=2.58$, $p=.012$).

Sitting out did not differ across time ($t(96)=1.48$, $p=.139$). Further, it was not confined to only a small number of people: Nearly half of the subjects (41 of 96) invested zero in at least one round. In V-96, 13 of the 24 R-72 subjects invested zero at least once, along with 6 of the 24 R-96 subjects; in V-72, 13 of the 24 R-72 subjects invested zero, and 9 of the 24 R-96 subjects.

The rate of sitting out accounted for much, but not all, of the variance in investments across the different contests: Including the sitting out variable in analyzing the investments revealed a large effect of it ($t(96)=-22.65$, $p<.001$); the effect of symmetry remained the same ($t(96)=2.69$, $p=.008$), but the effects of own resources and the opponent disappeared (both p's>.20).

13.2.2 Earnings and worthwhileness (Q1.3)

The average investment per contestant across all contests was 44.85 points, that is, a sum of 89.70 points invested per contest (out of an average of 168 points available for investment across the two contestants). Surprisingly, there was no difference in investments between contests in which the prize was 96 points, and those in which the prize was 72 points ($M_{V\text{-}96}=44.51$, $M_{V\text{-}72}=45.19$, $t(94)=-0.19$, $p=.842$). This lack of difference hints at a lesser importance of the prize in determining investments, as will be discussed below, and results in a difference in earnings between the two prize versions. I examined whether subjects invested more than the average prize, that is, the amount they could expect to win (48 points in V-96 or 36 points in V-72) in the different conditions. Whereas in V-96 investments did not significantly differ from 48 points ($t(95)=-1.41$, $p=.162$), investments in V-72 significantly exceeded the average prize of 36 points ($t(96)=4.18$, $p<.001$). Thus, in V-72, in each round, subjects on average lost from competing: They would have earned more had they sat out the competition, keeping their initial resources.

I calculated subjects' average earnings for each round: Earnings consisted of the subject's resource endowment minus their investment in that round, plus the amount of the prize if they won. Figure 1.3 presents the average earnings in the different conditions.

I submitted the earnings variable to a linear regression with the predictors being the subjects' type, their opponent's type, symmetry, prize version and its interactions with the previous variables, and game round; the variance was clustered by subject. Not surprisingly, High subjects earned more than Low subjects ($t(96)=17.71$, $p<.001$); both types of subjects earned less when facing High subjects than when facing Low subjects ($t(96)=-4.69$, $p<.001$). Notably, subjects earned less in symmetric contests compared to asymmetric contests ($t(96)=-4.73$, $p<.001$), although this is mainly true for High subjects. Naturally, both because the prize was lower and because investments were higher, earnings were lower in V-72 than in V-96 ($t(96)=-7.42$, $p<.001$); yet, the lower prize value affected mostly the High subjects' earnings, reflected in the interaction between prize value and resource ($t(96)=-2.63$, $p=.010$). Earnings did not change over time ($t(96)=0.22$, $p=.827$).

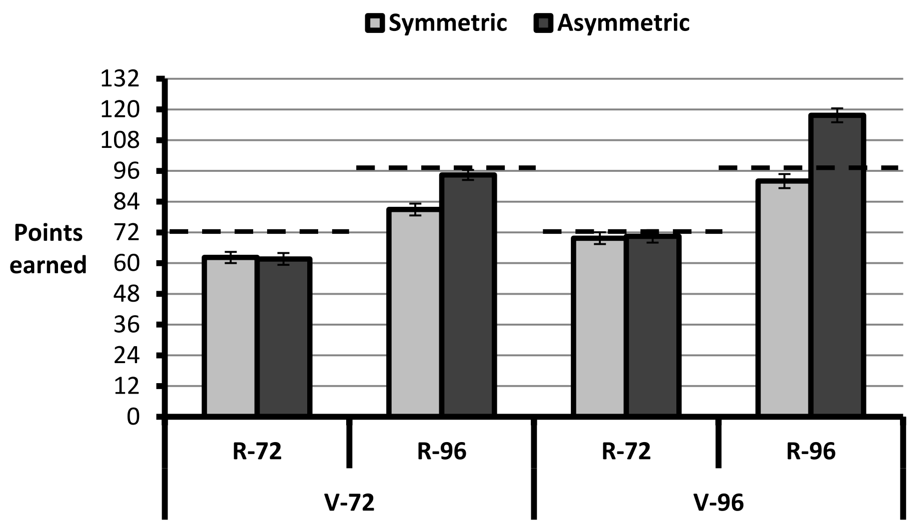


Figure 1.3. Experiment 1A: Average earnings in the two prize value versions, V-96 and V-72, for each type of subject (low or high resource endowment, R-72 or R-96), in symmetric and asymmetric contests. Error bars represent standard error of the mean. Dashed lines mark the initial resource endowments, which is what subjects would have earned had they sat out the competition.

13.2.3 Investment dynamics

13.2.3.1 *Investments over time (Q1.4)*

As noted in the previous analyses, I did not observe an effect of the experiment round on investments ($t(96)=-0.16$, $p=.875$), nor on the rate of sitting out the competition ($t(96)=1.48$, $p=.139$). That is, there was no escalation nor moderation of the competition over time.

13.2.3.2 *Effects of outcome (Q1.5, Q1.6)*

I set out not only to examine the average investments in the different contests, but also to find out whether there were changes in investments over time – and whether such changes were systematic. Specifically, I examined the influence of the outcome in the previous round – winning or losing the contest – on the investment in the consecutive round.

I analyzed the changes in investment from one round to the next (via a simple difference variable) using a linear regression model with the variance clustered by subject as above, with the outcome, subjects' resources, the opponents' resources, symmetry, prize version, round, and their interactions as predictors. I also included the previous investment as a predictor, so as to control for the possible influence of regression to the mean if it exists, and to observe the influence of the other variables beyond it, if these exist. The analysis did not include ties, since it is not clear whether subjects treat these outcomes as wins or losses, and this may differ between subjects.

The previous investment had a large negative impact ($t(96)=-9.25$, $p<.001$), which indeed could reflect regression to the mean. Importantly, the outcome (winning vs. losing, as a binary variable) had a negative influence as well ($t(96)=-4.39$, $p<.001$) which held above and beyond a subject's investment (see Figure 1.4). Following a loss, subjects tended to increase their subsequent investment (the average increase was 10.02 points), whereas they tended to decrease their subsequent investment following a win (an average decrease of 8.06 points).[6] There was also a significant interaction between the previous investment and outcome ($t(96)=3.40$, $p=.001$): Specifically, the more a subject invested, the less they were subsequently affected by the outcome. It should be noted though that this finding may be distorted by the small number of observations of high investments that resulted in a loss.

Regarding the manipulated variables in the contest, namely the subjects' and opponents' resources, symmetry, prize version and round, the regression revealed that subjects with high resource endowments (R-96) reacted more strongly to the outcome of the previous round than did R-72 subjects, with low resource endowments, as reflected in a significant interaction between subject type and outcome ($t(96)=-4.21$, $p<.001$). The effect remained significant, though its magnitude diminished somewhat, when analyzing the scaled change between subsequent investments – relative to the contestant's resource endowment. This suggests that the aforementioned interaction could not be fully accounted for by the differences in scale. There was no significant effect or interaction with the prize versions (all p's >.39).

Importantly, all of the above patterns were stable across experiment rounds; neither main effect nor interactions with the round reached significance (all p's>.36). Another regression, same as above but on the absolute difference in investments between rounds, also revealed no influence of round ($t(96)=-0.98$, $p=.329$). This demonstrates that the reactions to the outcomes did not diminish with time.

[6] Readers may notice that the average increase is larger than the average decrease and wonder how it is that investments do not therefore increase over time. However, excluding the first two rounds, the difference in the magnitude of changes is very small.

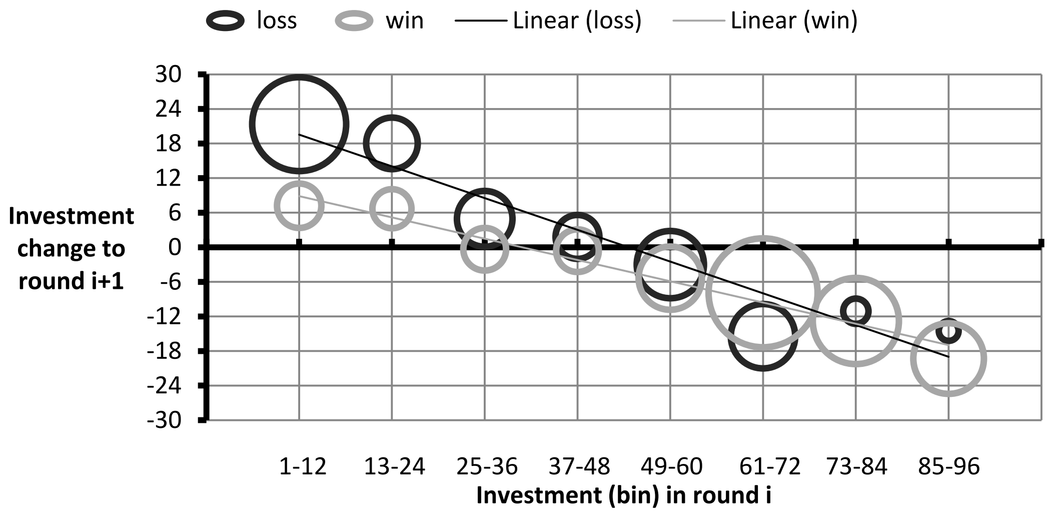


Figure 1.4. Experiment 1A: Changes in investments from round-to-round, following win and loss, averaged over prize value version, subject type (low or high resource endowment), and symmetry. Circle sizes indicate the relative number of observations.

13.3 Discussion A

Asymmetry – the inequality in the resources at subjects' disposal for competing – significantly affected investments and earnings in the contest. I observed a pattern similar to the discouragement effect reported in the literature: The average investments were lower in asymmetric contests, along with a higher proportion of subjects choosing to sit out those contests. However, the inequality mostly affected the weaker, lower-endowed subjects, who invested much less, and sat out more, when faced with a stronger opponent. When competing against an equally-endowed opponent, subjects did not seem to care much about the size of their resource endowment – subjects with equally low or high resources evinced very similar investment patterns.

Subjects' earnings also differed across the different competitions: In both prize versions, subjects earned less in symmetric contests than in asymmetric ones; asymmetry increased mostly the stronger types' earnings. On average, earnings were significantly lower when the prize value was lower, a direct result not only of the prize itself but of investments not differing between the two prize versions. Specifically, in V-72 subjects would have earned more had they sat out the competition and kept their initial resource endowments.

With regard to the investment dynamics, I observed a significant influence of the previous outcome on the subsequent investment: On average, investments decreased after winning, and increased following a loss – probably indicative of regretting having invested too much, or too little, respectively. This effect, which was evident beyond mere regression to the mean, held across contests and subject types, and remained throughout the experiment rounds. Hence, it does not seem to be a result of learning or an attempt to calibrate to a certain level of investment. That is, while there is reactivity, which is at the base of directional learning and reinforcement models, I do not see the accumulation of response propensities that characterizes these models: If experience and propensities had been accumulating, reactivity would have diminished over time.

As aforementioned, the investments – in symmetric as well as in asymmetric contests – did not vary with the size of the prize, evidenced by the similarity of investments between the two versions, V-96 and V-72. A possible explanation (suggested by Sheremeta, 2010) is that subjects play in order to win, rather than for the actual, absolute value of the prize. To further examine the effect of the contest prize, Experiment 1B introduced asymmetry in the subjects' prizes, while keeping their resource endowments equal to each other. I could thus explore whether the prizes, which had no effect when they differed between contests (in Experiment 1A), would influence investment decisions when they differ between the contestants within contest rounds. More importantly, this enabled exploring whether the impact of asymmetry holds across its different sources, namely resources and prize amounts.

14 Experiment 1B: Asymmetric Prizes

14.1 Method

As in Experiment 1A, there were two types of subjects, this time regarding the subjects' prizes: "V-72" (subjects who would win a prize of 72 points) and "V-96" (those with a prize of 96 points). The subjects' types were, as before, a between-subjects factor: In each session of twelve subjects, half of the subjects were assigned to be V-96, and half were V-72. Symmetry was a within-subject factor (in two counterbalanced-order blocks). The matching was again randomized for each round (stranger design).

There were two versions of the game, this time relating to both types' resource endowments: R-96, in which both types had 96 points to invest in each round; and R-72, in which the resource endowments were 72 points for both types.

14.1.1 Subjects

Subjects were 96 Hebrew University students, participating for monetary pay. As in Experiment 1A, 12 subjects participated in each of 8 sessions. Students were randomly assigned to sessions. In R-96, 48 students participated, out of which there were 33 females (68.7%); 45 of the subjects (93.7%) were undergraduates. In R-72, 48 students participated: 32 females (66.7%); 46 undergraduates (95.8%). None of the subjects in Experiment 1B had participated in Experiment 1A.

In R-96, subjects earned an average of 2.12 NIS per round; in R-72, they earned an average of 1.04 NIS per round. No measures other than subjects' investment decisions were collected.

14.1.2 Procedure

The experimental procedure was identical to that of Experiment 1A; the game was again played for 16 rounds. As aforenoted, instructions (translated from Hebrew) are in Appendix II.

14.2 Results

14.2.1 Overall investments (Q1.1, Q1.2)

I examined the impact of asymmetry and resource version on both the average investments and the rate of sitting out, paralleling the analyses in Experiment 1A.

I conducted a linear regression of investment amount, by subjects' types, symmetry, resource version and its interactions with the latter, and the game round; variance was clustered by subject. There was a significant main effect of the subject's own type: The V-96 subjects, who stood to win more, invested more than did the V-72 subjects ($t(96)=2.34$, $p=.021$). However, there was no main effect of the opponent's type ($t(96)=-1.40$, $p=.164$). The effect of symmetry was also not significant ($t(96)=1.00$, $p=.318$), in contrast with Experiment 1A. These patterns can be seen in Figure 1.5. There was a significant difference between the two resource versions, R-72 and R-96, with investments lower in R-72 ($t(96)=-2.04$, $p=.044$); yet, the version did not interact with any of the other variables (all *p*'s >.38).[7] Investments somewhat decreased over time ($t(96)=-1.84$, $p=.069$).

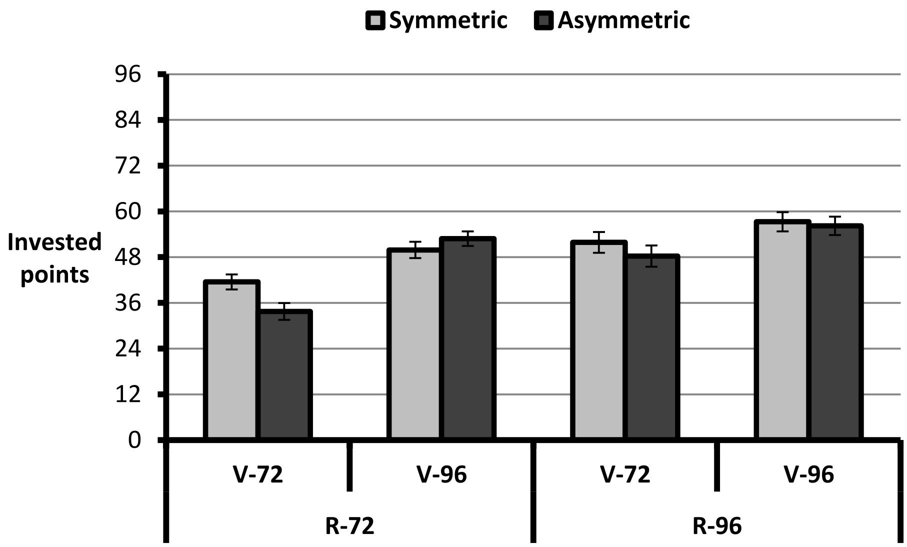


Figure 1.5. Experiment 1B: Average investments in the two resource versions, R-96 and R-72, for each type of subject (low or high prize value, V-72 or V-96), in symmetric and asymmetric contests. Error bars represent standard error of the mean.

Overall, 14.19% (218 of 1536) of investments were equal to zero, a rate close to the 13.22% found in Experiment 1A. Sitting out rates in the different contests are presented in Figure 1.6. A regression on the indicator variable revealed no significant effect of one's own prize ($t(96)=-1.52$, $p=.131$), nor of symmetry ($t(96)=-0.69$, $p=.492$). However, subjects chose to sit out more when facing a V-96 opponent, who stood to win more ($t(96)=2.99$, $p=.004$). This effect was stronger in R-72 compared to R-96 ($t(96)=2.30$, $p=.024$). One should note that the effect of one's opponent on the rate of sitting out was mostly due to the V-72 subjects sitting out more when facing V-96 ($t(96)=-2.25$, $p=.024$); V-96 subjects sat out at a similar rate against the two types of subjects ($t(96)=1.53$, $p=.126$). On average, the rate of sitting out increased over time ($t(96)=3.49$, $p=.001$).

Sitting out was distributed among almost half of subjects (47 of 96): In R-96, 14 of the 24 V-72 subjects and 9 of the 24 V-96 subjects chose to invest zero in at least one round; in R-72, 13 of the 24 V-72 subjects, and 11 of the 24 V-96 subjects did so.

[7] As in Experiment 1A, the distribution of investments was mostly bimodal, centering on the more extreme points in the possible range of investments. To check if this bimodality influenced the results, I recoded the investments as a binary variable of "high" or "low" in regard to the middle of the possible investment range of each subject. I analyzed this variable via a logistic regression similar to that reported above – observing similar results.

As in Experiment 1A, I ran a regression analysis on investments which included sitting out as a predictor. Sitting out had a large effect (t(96)=-20.97, p<.001). In this regression, the influence of one's own prize did not reach significance (t(96)=1.83, p=.071); however, an interaction of own prize and resource version (pertaining to both subjects' resources, either at 72 or 96 points) indicated that one's own prize still influenced investments – but mostly in R-72 (t(96)=2.16, p=.033).

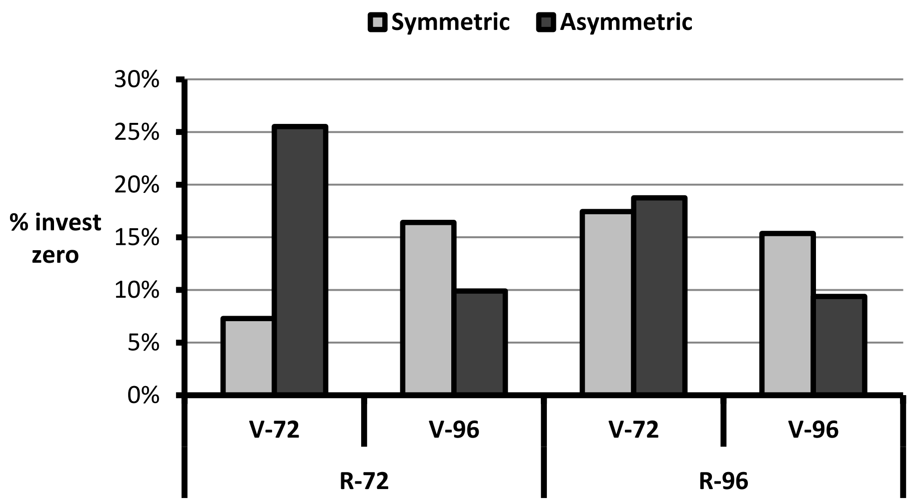


Figure 1.6. Experiment 1B: Percent of investments equal to zero in the two resource versions, R-96 and R-72, for each type of subject (low or high prize value, V-72 or V-96), in symmetric and asymmetric contests.

14.2.2 Earnings and worthwhileness (Q1.3)

Across all contests, the average investment was 48.95 points (that is, 96.90 points for a competition pair): The average investment was 53.41 in R-96, in which subjects' resource endowments were 96 points, and 44.49 in R-72, in which they had 72 points. The former is significantly higher than the latter (t(94)=1.97, p=.051). I examined whether subjects invested more than the amount they could expect to win – that is, their average prize, worth either 48 points or 36 points. To this end, I examine each type of subjects separately, in each of the resource versions. Low-V subjects' investments were close to their average prize of 36 points in R-72 (t(47)=0.50, p=.618), but they overinvested relative to their average prize in R-96 (t(47)=3.35, p=.002). A similar pattern is seen in High-V subjects' investments: Investments were close to the High-V subjects' average prize of 48 points in R-72 (t(47)=1.14, p=.262); in R-96 there was significant overinvestment (t(47)=2.38, p=.021). That means that in R-96, both types of subjects on average gained less than they would have had they kept their initial resource endowments and sat out the competition.

Earnings per round, as in Experiment 1A, were calculated as the subject's resource endowment minus their investment in that round, plus the amount of the prize if they won. Figure 1.7 presents the average earnings in the different conditions.

I analyzed earnings via a linear regression with the predictors being the subjects' type, their opponent's type, symmetry, resource version and its interactions with the previous variables, and game round; the variance was clustered by subject. Subjects for whom the prize value was higher, High subjects, earned more than Low subjects ($t(96)=4.79$, $p<.001$); both types of subjects earned less when facing a High opponent than when facing a Low opponent ($t(96)=-3.06$, $p=.003$). There was a marginal effect of symmetry, in that subjects earned somewhat less in symmetric contests compared to asymmetric contests ($t(96)=-1.83$, $p=.070$). Not surprisingly, earnings were higher in R-96 compared to R-72 – when the resource endowment of all subjects was larger ($t(96)=6.01$, $p<.001$). There was also a significant interaction between resource version and the opponent's prize ($t(96)=-2.06$, $p=.042$): The opponent's prize value had a larger impact on earnings in R-72 compared to R-96. In general, earnings increased over rounds ($t(96)=2.35$, $p=.021$), in line with the aforementioned decrease in investments over time.

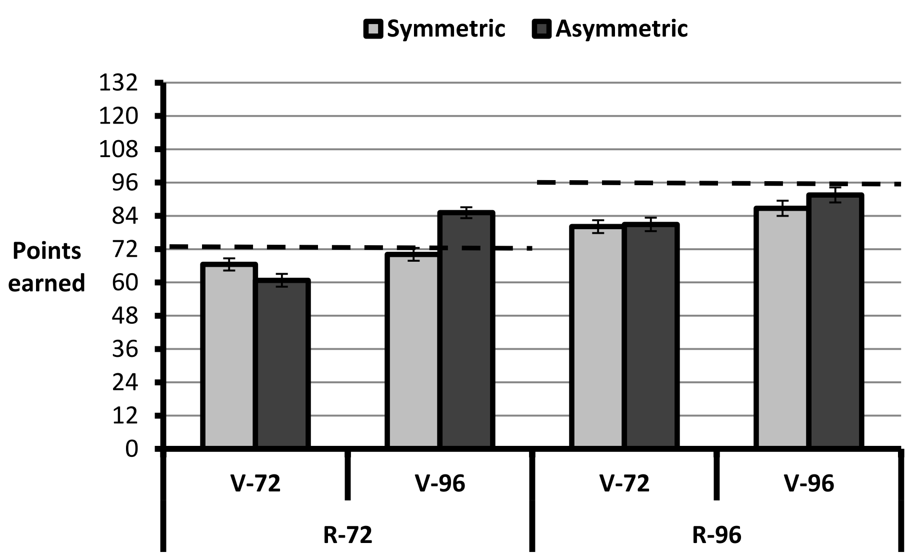


Figure 1.7. Experiment 1B: Average earnings in the two resource versions, R-96 and R-72, for each type of subject (low or high prize value, V-72 or V-96), in symmetric and asymmetric contests. Error bars represent standard error of the mean. Dashed lines mark the initial resource endowments, which is what subjects would have earned had they sat out the competition.

14.2.3 Investment dynamics

14.2.3.1 *Investments over time (Q1.4)*

I observed only a marginally significant effect of the experiment round on investments, in that investments slightly decreased over time (t(96)=-1.84, p=.069). Furthermore, the rate of sitting out the competition increased over time (t(96)=3.49, p=.001). That is, the competition did not escalate over time, but was slightly moderated.

14.2.3.2 *Effects of outcome (Q1.5, Q1.6)*

I again explored the changes in investments between consecutive rounds, in regard to the previous investment and outcome (win or loss),[8] via a regression which included also subjects' type, their opponent's type, symmetry, version and round as predictors.

Similar to Experiment 1A, I observed a large negative impact of the previous investment (t(96)=-8.09, p<.001). Importantly, as shown in Figure 1.8, winning vs. losing (a binary variable) had a substantial negative influence (t(96)=-6.26, p<.001) beyond the effect of the previous investment: subjects tended to increase their subsequent investment following a loss (by an average of 9.87 points), and decrease it following a win (by an average of 5.91 points).[9] There was also a significant interaction between the previous investment and the outcome (t(96)=4.97, p<.001): The larger the previous investment, the smaller the reactivity to the outcome (though, again, this result may be slightly misleading due to low numbers of observations for mid-level investments).

When subjects played against V-96 opponents, who stood to win a large prize, they tended to make larger changes in their investments (t(96)=2.39, p=.019). However, this effect diminished with time (t(96)=-2.09, p=.039). One should note that the investment dynamics were not generally influenced by round and no interactions with round, other than that with the opponent type, reached significance (all p's>.37). A regression similar to the above was conducted on the absolute difference in investments, and also revealed no influence of round (t(96)=1.26, p=.210).

[8] As before, the analysis did not include ties, since it is not clear whether subjects treat these situations as wins or losses. There was not a large number of ties in the data.
[9] As in Experiment 1A, here too the average increase and decrease seem to suggest an increase in investments over time – but this is not the case – in fact the opposite, as aforenoted; similar to Experiment 1A, after the first few rounds the increases and decreases from round to round almost balance each other out, to a slight decrease.

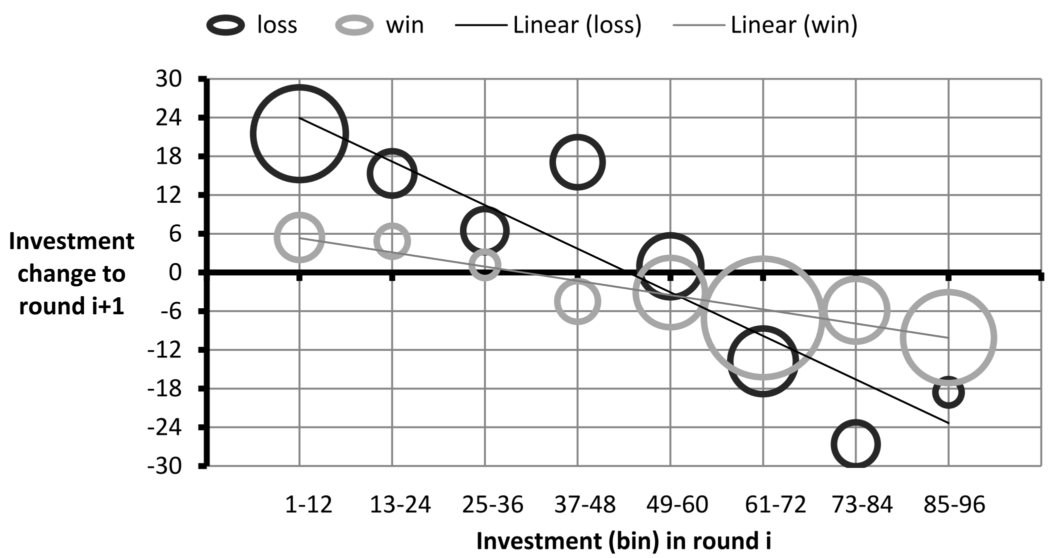


Figure 1.8. Experiment 1B: Changes in investments from round-to-round, following win and loss, averaged over resource version, subject type (low or high prize value), and symmetry. Circle sizes indicate the relative number of observations.

14.3 Discussion B

I found that subjects' investments were affected by the size of their potential prize: When they stood to win a larger prize, they invested more. Yet, this influence of the prize amount was not in relation to the size of the opponent's prize, nor to whether the two prizes were equal or not. There was no discouragement effect on mean investments as a consequence of asymmetry in contestants' prizes. However, I did observe some discouragement as a result of others' prizes in the subjects' decisions to sit out the contest: When subjects faced an opponent who stood to win a large prize, they tended to sit out more often. Not only did one's prize, but also one's resource endowment, played a role in the investment decision: When subjects had more resources and could invest more (in R-96 versus R-72), they did so.

Regarding subjects' earnings, like for their investments, asymmetry in prize value did not have much of an effect. Yet, the amount of resources at both subjects' disposal did significantly affect earnings: When subjects had more resources, they invested more and thus earned less in the competition – and in fact would have been better off sitting out the competition.

In the round-to-round dynamics, I again observed a large impact of the previous outcome (win or loss); however, there was no influence of the magnitude of this outcome (prize) – neither one's own, nor the opponents' – suggesting that there is some utility in the mere fact of winning or losing, rather than in the absolute or relative revenue.

15 Discussion

The two experiments directly contrasted behavior in symmetric and asymmetric contests, mimicking common competitions, often involving contestants competing against either similar or non-similar counterparts (Schoener, 1983; Szymanski, 2003). Each subject took part in both symmetric and asymmetric contests, while their own type (regarding resource endowment in Experiment 1A, and prize value in Experiment 1B) was kept constant.

In the two experiments, the different sources of asymmetry had different effects on behavior: Inequality in contestant strength (resources, in Experiment 1A) mattered more than inequality in motivation (prize value, in Experiment 1B): In the case of unequal resources subjects invested less in asymmetric contests than in symmetric contests, whereas asymmetry in prize value had no such effect. That is, *only* when resources differed, did subjects evince the discouragement effect described in previous literature (Dakin & Arrowood, 1981; Dechenaux et al., 2012; Festinger, 1954; Kilduff, Elfenbein, & Staw, 2010).

Another, perhaps more extreme, manifestation of the discouragement effect is subjects' propensity to sit out the contest. In the experiments I indeed found that sitting out was related to relative strength and motivation: When facing an opponent with greater resources or a greater prize, subjects were more inclined to sit out the contest. Whereas the average investment was affected only by the contestants' relative strength, the tendency to sit out was influenced by both strength and motivation.

A possible explanation for the lesser effect of prize difference than resource difference on investments is that when the prizes differ for the two contestants (but their resources do not), it is not entirely clear who has an advantage; while the contestant who has a larger potential prize has more of an incentive – and indeed, more of a tendency – to compete and invest more, this does not necessarily put that contestant in an advantageous position. In this case, contestants may have no clear idea about how to decide on their investments and hence may invest similarly to the symmetric-prize situation. On the other hand, in contests in which the resources differ, the weaker contestants may be more likely to realize that they are in a disadvantageous position and so may be inclined to invest less. Another possibility is that only when contestants differ in strength (and not motivation) can one contestant ensure victory by investing more than the opponent could. Thus, the inequality in strength may actually be more apparent and influential.

It is interesting to note that inequality affected mostly the weaker contestants or those with lower motivation; the stronger or more motivated contestants did not much adjust their behavior to suit their opponent's characteristics.

As can be derived from the overall investment patterns, subjects' earnings from the competition also varied across the different settings. Not surprisingly, earnings depended both on subjects' resources and the available prize. In Experiment 1A, asymmetry in resources led to higher earnings overall, but mostly for the stronger contestants. Naturally, across both symmetric and asymmetric contests, earnings were lower when the prize value was lower. This effect stemmed not only from the size of the prize itself but also because subjects didn't decrease their investments in line of the prize. As aforementioned, subjects overinvested when the prize value was low – which means that in essence, subjects lost from competing compared to sitting out and keeping their entire initial resource endowment. Overinvestment and low earnings (that is, losses) were also observed in Experiment 1B when subjects had high resource endowments: When subjects had a lot at their disposal, they committed many resources to the competition, and in fact diminished their resources by competing.

Whereas on average the investments varied across the different competitions, the investment dynamics – changes between consecutive rounds – were consistent and stable across the competitions and over time. As conjectured, the round-to-round changes in investments were strongly influenced by the outcome (win or loss) in the previous round: Subjects tended to invest a smaller amount following a win, and invest a larger amount following a loss. These reactions tie in with findings regarding the influence of regret on investments (Engelbrecht-Wiggans & Katok, 2007): It may be that subjects regretted winning by what they thought might be too large of a margin, and regretted not having invested enough when they lost. Importantly, the investment changes between rounds were above and beyond the statistical regression to the mean. The fact that they were similar throughout the contest rounds indicates that they were indeed reactions to outcomes rather than calibration or learning of the optimal or preferred investment.

Taken together, the impact of winning versus losing and the small influence of the prize amount to be won suggest that contestants compete in order to win rather than for the actual, absolute value of the prize (Bazerman et al., 1992; Kohn, 1992; Malhotra, 2010; Messick &

McClintock, 1968; Sheremeta, 2010). If a contestant is driven by the desire to win and the likelihood of winning, the resources of both contestants – influencing that likelihood – can be expected to play a role (as indeed observed in Experiment 1A), whereas the possible prizes are of lesser importance (as observed in Experiment 1B).

Importantly, I show that introducing – or eliminating – asymmetry among contestants may significantly change the contest outcome and the contestants' earnings. On first glance, symmetric contests seem to be better for the contestants themselves: Contestants will not feel disadvantaged or that their chances of winning are slim, and will choose to compete. This conclusion echoes the ideas of Adam Smith, proposing that competition organizers should attempt to help weak contestants (firms) and hinder the strong contestants' dominance (Bain, 1956). As noted in the introduction, this is desirable when higher investment is beneficial to society – such as in research and innovation endeavors. However, in other situations, symmetry (or perception of it) may be detrimental. Symmetric competitions may rouse the contestants, and lead to a waste of resources, and to higher or longer escalation of the struggle between them – and correspondingly to a larger expenditure (and possibly waste) of resources. In this respect, pointing out asymmetries, which may discourage contestants from investing large amounts or competing at all, may actually be beneficial.

Chapter II

The Strong, the Weak, and Lady Luck: Competitive Behavior moderated by Inequality and Noise in the Winner Resolution Rule

This chapter explores how noisy determination of the winner affects investments in symmetric and asymmetric competitions. The findings suggest that noise, often inherently present, may in some cases increase investments, and in other cases diminish the effect of the inequality between the contestants.

All competitions are inherently uncertain: One does not know how much one's opponents will invest in the competition, and so how much to invest oneself in order to win while not overspending resources. Further, contestants' invested efforts may themselves be inherently noisy and not certain: Contestants' performance itself may fluctuate, a contestant may have an off day, the weather may not be in a contestant's favor, and so forth. Another aspect of the competitive situation which increases uncertainty is the way the contestants' investments are evaluated, and correspondingly, how the competition winner is determined. Although in some competitions investing more than one's opponent assures one of winning the competition, in most real-life competitions the evaluation process itself is noisy. For example, a competition judge's attention may temporarily wander, and product features may be overlooked or misjudged.

When contestants are not necessarily equal to one another, the latter kind of uncertainty (or noise) is especially interesting. Noise in the evaluation may misrepresent the true difference between the contestants – and correspondingly, the impact of initial inequality if and when it exists. Yet, to date, the combined effect of noisy evaluation and asymmetry among the contestants on competitive investments has not been explored.

This chapter examines the joint influence of inequality in strength and noisy winner-resolution. As for the latter, I compare a deterministic contest in which the contestant who invests the most wins, to two competitions which involve noisy resolution: One in which random error is added to the investments (henceforth: error contests; Lazear & Rosen, 1981; O’Keeffe et al., 1984), and another in which a contestant's chance of winning is that contestant's relative part of the overall investment by the two contestants (henceforth: probabilistic or lottery contest; Tullock, 1980).[10] Within each contest-resolution structure, contestants are either equal or unequal in their resources (strength).

As in the previous chapter, in addition to studying the overall investment by the contestants and their willingness to compete rather than sit out the competition, I explore the effects of inequality and noisy resolution on the round-to-round investment dynamics. I examine whether contestants react to their preceding outcome in the competition – winning or losing – when deciding on their subsequent investment. In Chapter I, I demonstrated that contestants behave differently following a win than following a loss – decreasing their investment following the

[10] These two structures are closely related theoretically (Baye & Hoppe, 2003; Chowdhury & Sheremeta, 2011; Fu & Lu, 2007; Hirshleifer & Riley, 1992; Jia, 2007). However, there are several differences in the relevant assumptions between contests with varying sensitivity and those with noisy performance (Amegashie, 2006; Che & Gale, 2000).

former, but increasing it after the latter. However, in that study I employed only the deterministic resolution rule; here, in contrast, I examine whether noisy evaluation affects how contestants react to winning or losing the competition: Does winning (losing) due to random noise or probabilistic resolution rule have the same effect as winning (losing) due to the true ranking of investments?

The following section describes the literature relevant to unequal (asymmetric) competitions and competitions which include noise in the resolution function. I then describe the possible effect of noisy resolution on contestants' perception of their outcomes in the competition. Next, I describe the experimental methodology and results. I conclude with a discussion of the findings and their implications.

21 Background

21.1 Contests, resolutions, and asymmetry

Many studies examined how much people invest in various competitive situations, including competitions similar to those I study. As already indicated, the most common finding is of over-investment, meaning that the sum of investments exceeds the prize amount. This has typically been observed in studies of symmetric competitions in which the winner is always the contestant who invested the most (for a review, see Dechenaux et al., 2012). Notably, the invested amounts differ between various contests – both in theory and in experimental findings. Two important factors are the symmetry or asymmetry of the contestants (discussed in greater detail in Chapter I), and the degree of noise in the evaluation of investments – and correspondingly, in the determination of the contest winner.

As for the effect of asymmetry, previous studies, including that described in Chapter I, have shown that asymmetry among the contestants usually leads to discouragement: People tend to invest less in asymmetric contests compared with symmetric ones (e.g., Szymanski, 2003; Dechenaux et al., 2012; see Chapter I). This is presumably due to the weaker contestant being discouraged from competing, while the stronger contestant, anticipating such discouragement, also invests less. The discouragement effect is also predicted by theoretic analyses (Baik, 1994, 2004; Baye et al., 1993, 1996; Dubey & Sahi, 2012; Fonseca, 2009; Hillman & Riley, 1989; Nitzan, 1994; Nti, 1999; Szymanski, 2003). This leads to the first research question:

Q2.1: Does asymmetry between contestants have a discouraging effect on investments?

Much of the theoretical, empirical, and experimental work on noise has focused on the measures that people should – or do – take to handle its effects. Actions such as the spreading and hedging of investments, or the use of mixed strategies in strategic interactions are but some of the obvious reactions. Lesser known, though of great importance, are the motivational effects of noise or uncertainty. Studies of labor markets, for example, revealed that uncertainty in income increased labor supplies or efforts (e.g., Block & Heineke, 1973); experimental studies showed that the greater uncertainty arising from minimal scrutiny increased the effort exerted by contestants competing for a prize (Kareev & Avrahami, 2007).

In regard to the influence of different resolution rules on competitive investment, there have been studies of symmetric competitions with noisy resolution – in which the winner is not necessarily the contestant who invested the most. As noted above, I examine two types of noisy resolution rules: One in which noise arises from probabilistic resolution (e.g., Tullock, 1980), and one in which random error components are added or subtracted from contestants' investments (e.g., Lazear & Rosen, 1981). In probabilistic lottery contests, overinvestment has been observed to be less pronounced (but not completely eliminated) compared to the deterministic contest (Potters et al., 1998; Schmitt et al., 2004; Sheremeta, 2010, 2011; Sheremeta, Masters, & Cason, 2012). In error contests the results are more mixed, with several experiments observing no overinvestment at all, but greater variance than predicted (Bull, Schotter, & Weigelt, 1987; Harbring & Irlenbusch, 2003; van Dijk, Sonnemans, & van Winden, 2001).

In general, increasing the uncertainty of winning, through a lottery rule, means decreasing the impact of each point invested on the odds of winning compared to a deterministic contest. Investing is less profitable (or more costly) when the investments do not translate as directly to the chance of winning. Therefore, investments may be lower in probabilistic competitions, and overinvestment less pronounced (Amegashie, 2006; Che & Gale, 2000; Chowdhury & Sheremeta, 2011; Szymanski, 2003; Wang, 2010). However, when noise enters the evaluation process through error terms, contestants may wish to counter its effect by increasing investments (Kareev & Avrahami, 2007). The two types of noisy resolution may thus have opposite effects:

Q2.2: Does noise in the contest resolution affect the overall investment – regardless of the contestants' relative strengths?

The main question I explore here concerns the effect of asymmetry in the face of noisy resolution. The discouraging effect of asymmetry on investments has been observed also in lottery and error contests (for lottery contests, see: Anderson & Stafford, 2003; Davis & Reilly, 1998; Fonseca, 2009; for error contests, see: Bull et al., 1987; Chen, Ham, & Lim, 2011; Harbring & Lünser, 2008; Schotter & Weigelt, 1992; van Dijk et al., 2001; Weigelt, Dukerich, & Schotter, 1989; for a review see Dechenaux et al., 2012). Nevertheless, the effect of asymmetry may be less pronounced in noisy competitions: When the contest resolution is less discriminating the asymmetry among the contestants is blurred. Hence, noise may negate or diminish the discouragement effect of asymmetry (Bos, 2011; Cowen & Glazer, 1996; Dubey & Haimanko, 2003; Dubey & Wu, 2001; Wang, 2010).[11] The rationale is that if there is one strong contestant who is more likely to win, decreasing the contest accuracy gives the weaker contestant a (larger) chance to win. Thus, the weak contestant will invest more, and as a result, so will the strong contestant.

To the best of my knowledge, there has been no study to date jointly examining the effects of inequality and noisy resolution. Testing the effects of these factors in the same setting allows examining the pervasiveness of the discouraging effect of asymmetry on investments across different contests or contexts; further, it allows examining whether noisy resolution moderates the latter effect.

Q2.3: Does noise in the contest resolution moderate the discouragement effect? Does noise decrease the difference between symmetric and asymmetric contests?

As surveyed in Chapter I, in many natural settings contestants may choose not to compete. Investing zero can express risk aversion but can also be taken as an extreme manifestation of the discouraging effect of asymmetry. For example, when contestants meet opponents of differing strengths, they (and especially the weaker contestants) may walk away from the competition, and instead look for opponents more similar in capacity (for an analysis of this behavior in animals, see Eshel & Cavalli-Sforza, 1982). In Chapter I, I indeed observed such an effect of inequality in strength: Contestants tended to sit out the competition more often when it was asymmetric, and most often when they were at a disadvantaged position.

It is possible, of course, that when the competition is very noisy (or noisy enough), all contestants may view investment in it as fruitless, and choose to opt out. The experimental

[11] It should be noted that if the strong contestant is significantly stronger than the others, increasing the uncertainty should not change the investments.

setting enabled measuring the tendency to sit out the contest, and to assess the relation between the contest characteristics and the prevalence of sitting out.

21.2 Investment dynamics

Two aspects of the dynamics of investment over time are examined in the following experiment. The first involves potential changes of the average investment over time.

Q2.4: Does competition escalate over time? Or do contestants invest less (and hence, gain more) the longer they compete? Does investment in the competition remain similar over time?

The second aspect of investments over time involves (immediate) reactivity to outcomes: Do contestants react differently to winning versus losing the competition, and if so, is it related to the type of contest?

In the previous chapter, I demonstrated that changes in investments from round to round were influenced by the most recent outcome (win or loss): Subjects tended to invest less following a win, and invest more following a loss. These reactions tie in with findings regarding the motivating influence of winning (Bazerman et al., 1992; Kohn, 1992; Malhotra, 2010; Messick & McClintock, 1968), and are also in line with the role of regret observed in previous studies of investment decisions (Engelbrecht-Wiggans & Katok, 2007).

Noise in the contest resolution is interesting in this respect, as it enables disentangling people's reactivity to the competition outcome in deciding on their subsequent investment. Assuming people react to winning versus losing the competition, do they take into account how this outcome came about, namely, whether it was due to the true ranking of investments, or due to luck that acted in their favor or to their detriment? In other words, in contests with noisy resolution it is not clear whether losing would cause loser's regret and lead to an increase in the subsequent investment – or whether an unjust loss would cause regret for the wasted investment and lead to lower investments.

To summarize, the literature surveyed above – including the findings of Chapter I – raises the following questions:

Q2.5: Do contestants react to the realized outcome – winning versus losing? That is, do investments differ following a win compared to following a loss in the previous round?

Q2.6: Do contestants react to having invested more, or less, than their opponent – regardless of the realized outcome (win or loss)?[12]

Q2.7: Do contestants react differently to outcomes (win or loss) which are in line with the initial ranking of investments, compared to outcomes that result from the noisy resolution?

22 Experiment 2: Noisy Resolution

22.1 Method

Subjects competed in 32 rounds of the "Invest game" described in Section 3. I contrasted three contest resolution rules, manipulated between-subjects: The deterministic contest, the lottery contest, and the error contest. In the ***deterministic condition (SURE)***, in each round, the subject who invested more than the opponent, won the prize; in case of a tie, each subject received half of the prize. In the ***probabilistic lottery condition (PROB)***, each subject's probability of winning was their own investment relative to the sum of investments by the pair. In the two ***error conditions (ERR)***, ***ERR8*** and ***ERR16***, an error component (with a mean of zero and a known distribution, as in Lazear & Rosen, 1981) was added or subtracted independently from each subject's investment. In ***ERR8***, errors were sampled from a discrete uniform distribution between [-8;8]; in ***ERR16***, errors were sampled from a discrete uniform distribution between [-16;16]. The resulting "bid values", of the investment and the error, determined the winner in a deterministic fashion similar to the SURE condition.

As in Experiment 1A, subjects in each session were either one of two types, defined by resource endowments of either 96 points per round ("High") or 72 points per round ("Low"). The prize for both types of subjects was 96 points. Half of the subjects in each session were assigned to be High and half to be Low. Symmetry was a within-subject factor, with each subject playing against both types (in two symmetric and two asymmetric blocks of 8 rounds each). In each round, the pairings were determined randomly from the relevant group of subjects (i.e., stranger design).

Before each round, subjects were told their opponent's resource endowment (type). They

[12] This question applies only to the probabilistic lottery contest, in which the contest outcome (win or loss) and the initial ranking of investments (i.e., whether one invested more or less than one's opponent) are sometimes at odds: One may invest more than one's opponent and lose, and vice versa. Thus, the lottery contest enables examination of the two possible influences on contestants' subsequent decisions.

were also notified when a change from the symmetric to the asymmetric block (or vice versa) occurred. After each round, subjects were told their determining investment (which included the error term in the ERR conditions), whether their determining investment had been larger or smaller than their opponent's, whether they received a prize, and their earnings for the round. It should be noted that in the ERR conditions, subjects could derive the value of their error term by comparing their determining investment to the amount they invested.

22.1.1 Subjects

Subjects were 168 Hebrew University students, participating in exchange for monetary pay, in 16 sessions of 8-12 subjects. Subjects were randomly assigned to conditions. 44 subjects participated in the SURE condition, 48 in the PROB condition, and 40 and 36 in the ERR conditions (ERR8 and ERR16, respectively). 84 (50%) were female; 147 (87.5%) undergraduates. None of the subjects in this experiment had participated in Experiments 1A or 1B.

Subjects earned an average of 1.16 NIS per round (1 New Israeli Shekel was worth approximately $0.27). No measures other than subjects' investment decisions were collected.

22.1.2 Procedure

The procedure was identical to Experiments 1A and 1B. See Appendix III for a translation of the Hebrew instructions.

22.2 Results

22.2.1 Overall investments (Q2.1-Q2.3)

I first wanted to see whether investments were affected by symmetry, resource endowments and by the type of resolution rule. To this end, investments were analyzed via a linear regression model, with experiment round, subjects' type (resources), their opponent's type, and symmetry (represented by the interaction between one's own type and that of the opponent), as well as contest conditions and their interactions with the subjects' types and symmetry, as predictors (variance was clustered by subject to control for the repeated observations). The contest conditions were defined as indicator variables as follows: PROB compared to the other three conditions, ERR as an indicator variable grouping together the two ERR conditions, and an indicator variable for the ERR16 condition, testing for differences between the two ERR conditions.

Answering Q2.1, and replicating previous results (including Experiment 1A), I observed that asymmetry reduced investments compared to symmetric contests ($t(168)=2.53$, $p=.012$). There was a main effect of one's type: High subjects invested more than Low subjects ($t(168)=3.03$, $p=.003$). There was also a main effect of the opponent's endowment – subjects invested less against High compared to Low subjects, across all contests ($t(168)=-3.60$, $p<.001$). The average investments for symmetric and asymmetric contests for High and Low subjects, across contest conditions, are presented in Figure 2.1.

In regard to Q2.2, I observed that investments in the two ERR conditions were higher than in the other two (SURE and PROB) conditions ($t(168)=3.43$, $p=.001$). The larger error did not further impact the average investment ($t(168)=-0.61$, $p=.540$). The average investment in the PROB condition did not significantly differ from the other three conditions ($t(168)=-0.95$, $p=.341$). Figure 2.2 shows the average investments in the different contest conditions, averaged over the subject types and asymmetry.

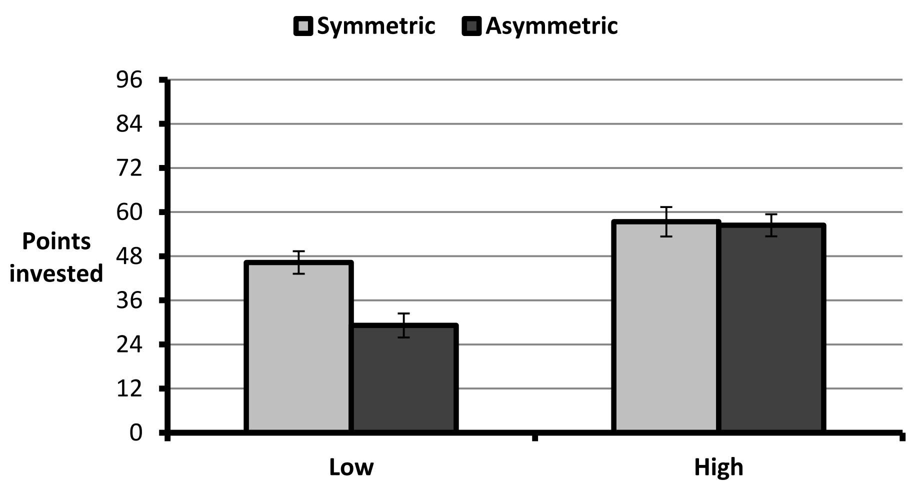


Figure 2.1. Average investments for each type of subject (low or high endowment, Low or High) in symmetric and asymmetric contests, averaged over the contest resolution conditions. Error bars represent standard error of the mean.

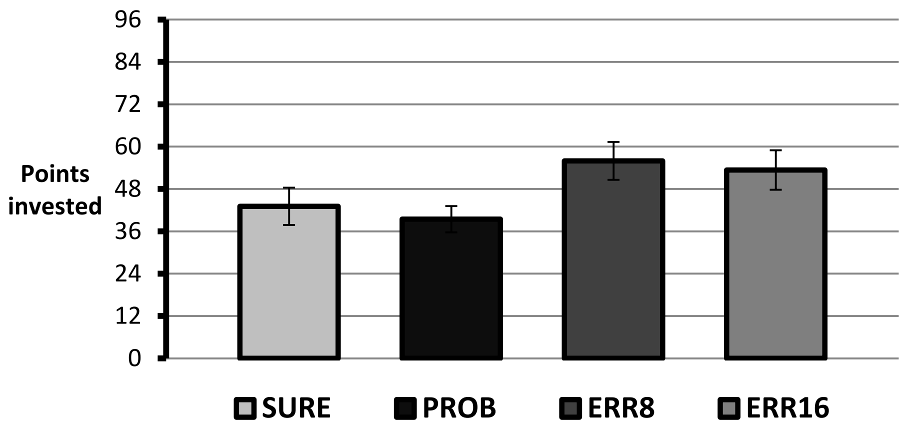


Figure 2.2. Investments in the four contest resolution conditions, averaged over subject types (low or high endowment) and symmetry. Error bars represent standard error of the mean.

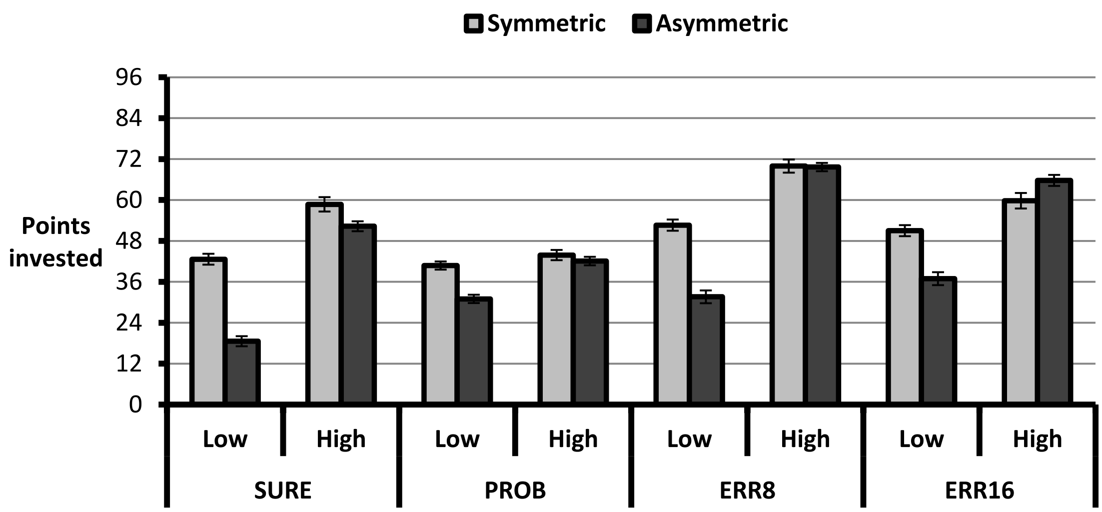


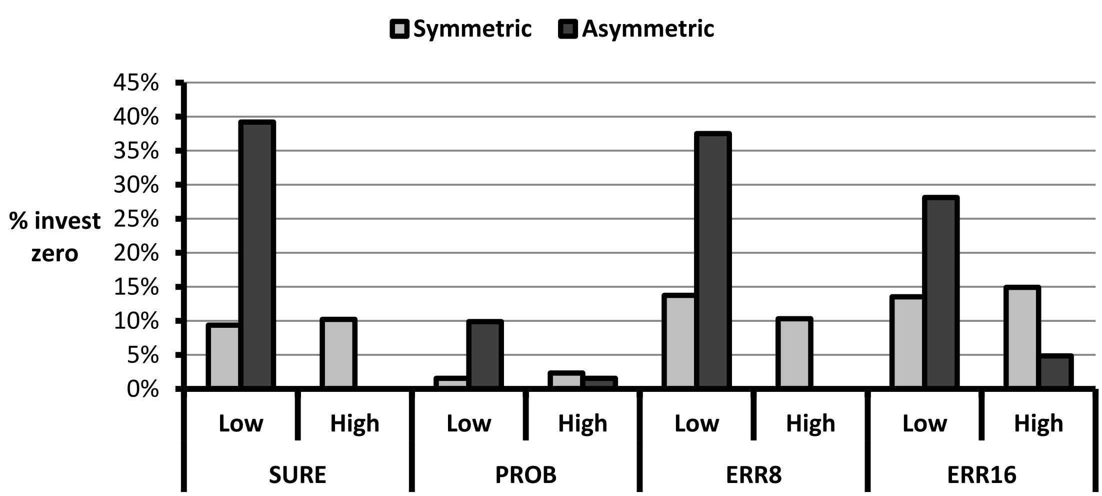
Figure 2.3. Average investments in the four contest conditions, for each type of subject (low or high endowment, Low or High), in symmetric and asymmetric contests. Error bars represent standard error of the mean.

Most interestingly, and related to Q2.3, the significant effects of asymmetry and of one's own endowment presented before were not the same in all conditions. Both the effect of symmetry and the effect of one's resources were smaller in the PROB condition compared to the other conditions ($t_{PROB*symm}(168)=-2.08$, $p=.039$; $t_{PROB*self}(168)=-2.34$, $p=.021$). That is, subjects were less affected by their relative strength in the lottery contest compared to the other conditions. Conversely, there were no interactions of either of the ERR conditions with the subjects' types nor with asymmetry (all p's >.19). It should also be noted that there was no effect of round (*t*(168)=-0.84, *p*=.404). That is, the average investment did not change over time. The average investments for symmetric and asymmetric contests for each resolution rule are presented in Figure 2.3.[13]

I remind the reader that though subjects cannot opt out of the contest per se, they can do so by choosing to invest zero. On average, across all contest conditions and subject types, 11.90% (640 of 5376) of investments were zero. It should be noted that sitting out was not confined to a few subjects: About half of the subjects (89 of 168) invested zero in at least one round.

Figure 2.4 presents the rates of sitting out in the different conditions. As is evident in the figure, a regression on the indicator variable of sitting out revealed that the highest rate of sitting out was found when Low types faced High types, and the lowest rate of sitting out when High types faced Low types (*t*(168)=4.21, *p*<.001). The rates of sitting out in symmetric contests were quite similar for Low and High types. A striking shrinking of these differences was found in the PROB condition, in which there was less of a difference in sitting out between the Low and High types ($t_{PROB*self}$(168)=2.54, *p*=.012), and the influence of the opponent was also smaller ($t_{PROB*opp}$(168)=-3.18, *p*=.002). Moreover, in general, subjects tended to sit out more in the PROB condition compared to the other three conditions (*t*(168)=-3.59, *p*<.001).

I observed no effect of the ERR conditions on the tendency to sit out, and there were no significant interactions with the types or with asymmetry (all *p's*>.31). Across all conditions, the rate of sitting out increased over time (*t*(168)=3.40, *p*=.001).



[13] As for Experiment 1A, an analysis on the investment relative to subjects' initial resources, revealed the same influences as above, except that here there was no influence of subjects' own resources, as is to be expected.

Figure 2.4. Rate of sitting out (investing zero points) in the four contest conditions, for each type of subject (Low or High), in symmetric and asymmetric contests.

22.2.2 Earnings and worthwhileness

I examined whether subjects invested more than the average prize, that is, the amount they could expect to win (48 points) in the different contest conditions. Since investments in the PROB and SURE conditions were similar, and the investments in the ERR conditions were similar, I compared the average investment in each pair of conditions to 48 points. In the ERR conditions subjects significantly *over*invested relative to 48 points (M=54.74; $t(39)$=2.70, p=.009), whereas in the PROB and SURE conditions subjects significantly *under*invested (M=41.17; $t(39)$=-3.23, p=.002).

I next calculated subjects' earnings in the competition. For each round, earnings consisted of the subject's resource endowment minus their investment in that round, plus the amount of the prize if they won. Figure 2.5 presents the average earnings in the different conditions. One can see that compared to the initial resource endowments (which is what subjects could have earned had they sat out the competition), in the PROB and SURE conditions subjects gained from competing, whereas subjects actually diminished their overall resources in the ERR conditions.

I submitted the earnings variable to a linear regression with the predictors being the subjects' type, their opponent's type, symmetry, contest condition, and experiment round, with the variance clustered by subject. Not surprisingly, High subjects earned more than Low subjects ($t(168)$=10.67, p<.001); all subjects earned less when facing High subjects than when facing Low subjects ($t(168)$=-4.44, p<.001). On average, subjects earned less in symmetric contests than in asymmetric contests ($t(168)$=--2.45, p=.015), although this is mainly true for the High types. As noted above, earnings were lower in the two ERR conditions compared to the PROB and SURE conditions ($t(168)$=-6.65, p<.001), and there was no added effect of the ERR16 condition ($t(168)$=1.20, p=.230). Earnings in the PROB condition did not on average differ from the other conditions ($t(168)$=1.55, p=.124); however, in this condition the opponent's type and asymmetry had a smaller impact on earnings ($t_{PROB*symm}(168)$=2.56, p=.011; $t_{PROB*opp}(168)$=4.53, p<.001) – a result which is in line with their smaller impact on investments in this condition. In addition, earnings did not change over rounds ($t(168)$=0.84, p=.403).

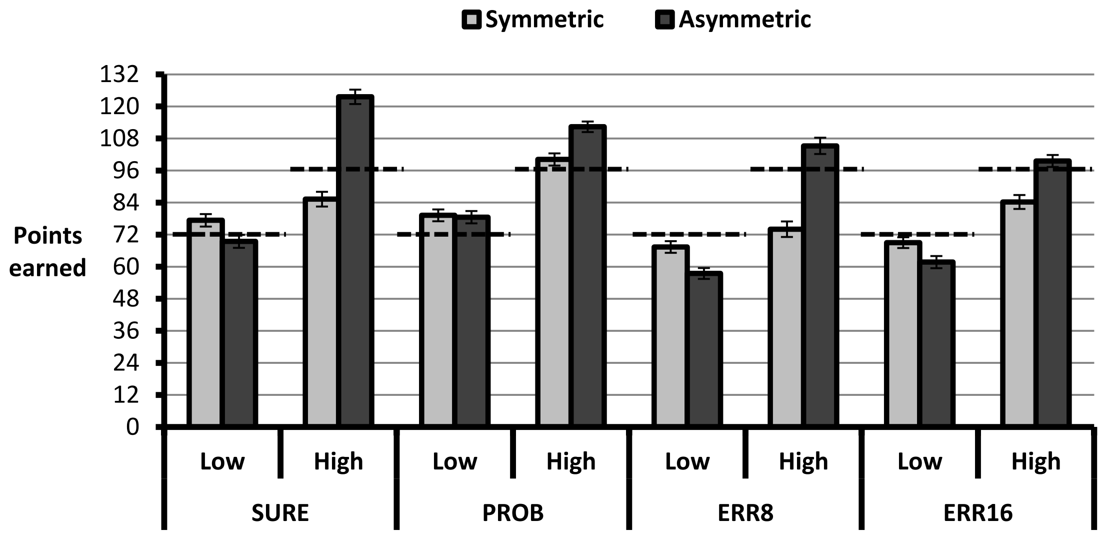


Figure 2.5. Average earnings in the four contest conditions, for each type of subject (low or high endowment, Low or High), in symmetric and asymmetric contests. Error bars represent standard error of the mean. Dashed lines mark the initial resource endowments, which is what subjects would have earned had they sat out the competition.

22.2.3 Investment dynamics

22.2.3.1 *Investments over time (Q2.4)*

I did not observe an effect of the experiment round on investments in the aforementioned analysis ($t(168)=-0.84$, $p=.404$). Yet, there was an increase in the rate of sitting out the competition over time ($t(168)=3.40$, $p=.001$). Thus, there is no escalation of the competition over time, but a small moderation (although average investments did not change, as noted above).

22.2.3.2 *Effects of outcome (Q2.5-Q2.7)*

I explored the effects of an outcome (win versus loss, as a binary variable)[14] on changes between consecutive investments, and whether the outcome had a different influence in the different contest conditions. A linear regression model was used to analyze the differences between consecutive investments, with round, winning (vs. losing), the previous investment, PROB and ERR (as indicator variables), and the interactions as independent variables (variance was again clustered by subject). The outcome of the previous round had a large impact on the

[14] As in Chapter 1, the round-to-round analysis did not include ties, as it is not clear whether subjects treat these situations as wins or losses.

subsequent investment ($t(168)=-7.22$, $p<.001$): After winning, investments decreased, by an average of 5.69 points; after losing, investments increased, by 6.79 points on average. There was also a large negative effect of the previous investment, which can be thought of as reflecting regression to the mean ($t(168)=-11.11$, $p<.001$). The outcome also interacted with the previous investment ($t(168)=-7.42$, $p<.001$): The larger the previous investment, the smaller the reactivity to the outcome (although one should note that this result may be slightly misleading due to low numbers of observations for mid-level investments). The changes in investment between consecutive rounds by investment and outcome are presented in Figure 2.6.

Overall, the average of the differences decreased over time ($t(168)=-3.15$, $p=.002$). The PROB condition differed somewhat from the other conditions with respect to the effect of outcome: Winning versus losing had a somewhat larger impact in PROB ($t(168)=-1.88$, $p=.037$). There were also two significant 3-way interactions: Between the PROB condition, previous investment and outcome ($t(168)=3.19$, $p=.002$), and between the ERR condition, previous investment and outcome ($t(168)=2.25$, $p=.026$). For low initial investments, the difference in subsequent investments following win versus loss was larger in the ERR condition than in the other conditions; for high initial investments, the difference in subsequent investment following win versus loss was larger in the PROB condition than in the other conditions.

I next wanted to test specifically whether the correspondence between the outcome and the initial ranking of investments affected the changes between consecutive investments. I thus analyzed the investment dynamics separately for each condition. In the ERR condition, I defined a "luck" variable, as the sign of the error added (or subtracted) from the subject's investment.[15] In the PROB condition, I defined a "justness" variable, signifying whether the outcome matched the ranking of the two subjects' investments (i.e., an indicator for contests in which the subject who invested the most of the pair, won).

If, for example, a negative error term discourages subjects from competing, then one would see a main effect of the luck variable (representing the error sign) on the changes from round to round. If the error affects subjects' reactions to winning or losing, one would expect to see an effect of the interaction between the outcome (win or loss) and the luck variable. Similarly, if the way the outcome came about plays a role in determining the following investment, one would see an effect of the interaction between the outcome and its "justness".

[15] I remind the reader that subjects could derive the value of their error term by comparing the determining investment to the amount they actually invested.

In both regressions I observed significant effects of the previous investment and of the outcome (win or loss), as above. In the ERR condition, there was no significant effect of luck ($t(76)=1.27$, $p=.207$), but there was a marginally significant interaction of luck and outcome ($t(76)=-1.68$, $p=.057$). Good versus bad luck had an impact on the subsequent investment only if one lost: Having good luck and losing led subjects to a larger increase in the subsequent investment compared to losing with bad luck. In the PROB condition, there was no influence of justness ($t(48)=0.41$, $p=.687$), nor did this variable interact with the outcome ($t(48)=-1.70$, $p=.096$).

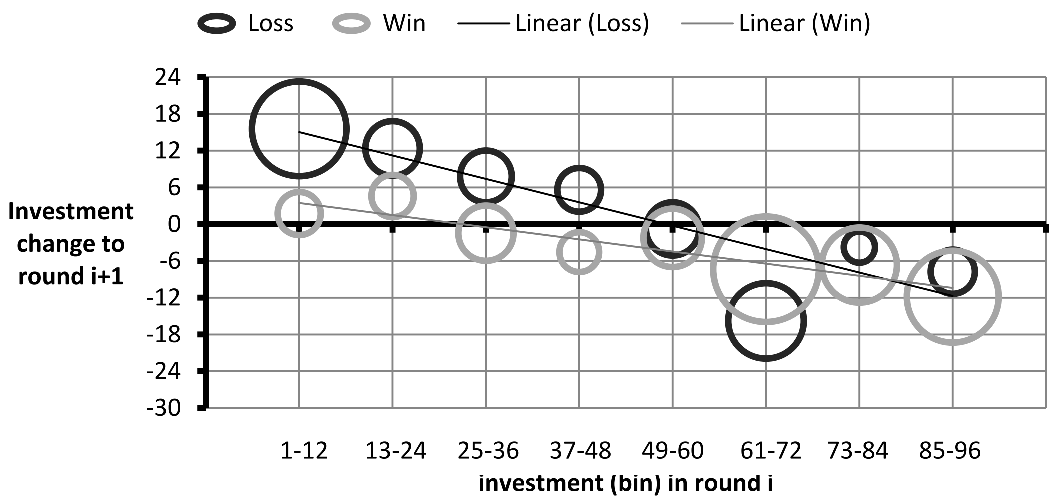


Figure 2.6. Changes in investments between consecutive rounds, following win and loss, averaged over contest condition, subject type (Low or High), and symmetry. Circle sizes indicate the relative number of observations.

23 Discussion

This study sheds light on investment behavior in competitions in which the contestants are not equal in their strength, and the evaluation of their investments may be noisy or include errors. Extending previous studies, I directly compared the investment behavior in the different competitions.

One important element of competitive behavior remained across situations: The dynamics of investment. Contestants in all situations took their previous outcome into account when making their subsequent decision. That is, loss (or win) had the same influence on the contestant's subsequent investment, irrespective of their strength or their chances of losing (or winning). This corroborates previous findings (Engelbrecht-Wiggans & Katok, 2007; see also Chapter I). I observed that these reactions are indeed reactions to the outcome, and arise irrespective of whether the outcome was in line with the initial ranking of the investments. What is more, reactions held throughout the rounds of the experiment; that is, the dynamics did not reflect moving towards a preferred strategy, but rather that subjects changed their investments in light of winning or losing.

In contrast, the situational factors of inequality and noisy evaluation did play a large role in determining the intensity of competition. I set out to explore whether and how noise influences investments, and observed that when noise was introduced through error terms it increased investments in the competition – in both symmetric and asymmetric competitions; yet, when noise was introduced via a probabilistic lottery rule, it did not affect the average investments relative to the deterministic competition. Naturally, a similar pattern emerges in subjects' earnings from the competition: On average subjects earned less in competitions in which error terms were added or subtracted from investments than in the deterministic competition or the probabilistic lottery competition. Not only did they earn less, but they actually diminished their funds: In the error competitions, subjects' winnings did not compensate for the invested amounts, meaning that subjects would have earned more had they sat out the competition.

Across all conditions, and replicating previous findings (Dechenaux et al., 2012; see also Chapter I), I observed that asymmetry moderated the intensity of competition and decreased investments. Refining earlier findings, I observed that the discouraging effect of asymmetry on investments was less pronounced in lottery contests than in the deterministic contest. That is, in the lottery condition there was less of a difference among subjects facing opponents of equal or unequal strengths, in average investments, in the tendency to sit out the contest and in subjects' earnings from the competition. In contrast, when the noisy resolution was introduced through error terms, the effect of asymmetry was similar to that observed in the deterministic contest.

In sum, the results suggest that the competition structure affects the way people behave in light of their relative strengths. Consequently, it also affects how much contestants earn in competing. The findings thus have important implications for the design of real life competitions. For example, competition organizers – such as policy makers, universities, organizers of sports events – may wish to use different resolution rules, depending on the organizers' goals and the nature or degree of diversity among the contestants.

Chapter III

Enlarging the Market Yet Decreasing the Profit: Competitive Behavior When Investment Affects the Prize

This chapter examines investments in competitions in which contestants may benefit from their opponents' actions, or be hurt by them. Investments were higher when the opponent's investment increased the winner's prize, and lower when the opponent’s investment decreased the prize. Notably, this tendency may lead to a larger waste of resources in certain situations.

If you can't win, make the guy ahead of you break the record. Or his leg. – Anonymous

In some competitions, the prize value is independent of the contestants' investments. For instance, the payment that comes along with winning a contract may remain the same regardless of the winner's expenditures; monopoly rights in a known market often retain their value regardless of lobbying expenses. However, in many situations the prize does not remain fixed: Lobbyists may compete not only to win but to determine the transfer amount; athletes' absolute performance (and not only their having won or lost) is taken into account for sponsorships (Baye, Kovenock, & de Vries, 2005, 2012; Bullock & Rutstrom, 2001; Chowdhury & Sheremeta, 2011). In the case of research and development races, investing more in the competition could lead to the design of a better product and then increase sales (Kaplan, Luski, Sela, & Wettstein, 2002). In this study, I ask whether the relation between the amounts invested and the size of the prize affects total investment in the competition.

I address the following questions: What do dependencies between investments and prize (henceforth termed the impacts of the contestants' investments) entail for the actual amounts invested in the contest? And what do they entail for the intensity of the competition, as evidenced in the contestants' earnings? Will specific competitions lead to overinvestment, in that investments will largely exceed the prize amount – or will specific dependencies between investments and the prize lower investments such that the prize (and correspondingly, the contestants' earnings) will be larger than the sum of investments?

Examining behavior in different competition settings also enables examining which features play a role in determining investments. When competing, do people care only about winning the prize, or about beating their opponent by the widest possible margin? Do people care about the overall "pie" – the overall revenue, namely aggregate benefit for all contestants? For example, will one invest more in a competition in which one's investment increases the opponent's prize when one loses the competition – suggesting that aggregate revenue considerations play a role in deciding how much to invest? Or will one be deterred from investing in such a competition, in order to not help one's opponent and not increase their possible advantage? The effect of the relation between investment and prize on overall investment may differ according to which considerations come into play, as described in the following section.

This study examines the effect of different impacts of investments by the eventual winner and loser on the prize, using the same "Invest Game" of the previous chapters. Yet, unlike the competitions described in the previous chapters, here the prize is not a-priori determined; it includes elements depending on the winning contestant's investment, on the losing contestant’s investment, or both.

In the next sections I survey previous studies regarding winning (and losing) as competitive motivation, and the literature regarding social preferences, suggesting that people take into account others' outcomes and payoffs as well as their own. I then turn to the specific literature about competitions in which the contestants' investment impact the prize, and describe how such impacts may affect investment behavior. After that, I present the experimental setting and results, concluding with a discussion of their implications.

31 Background

31.1 Competitive motivation

Deciding how much to invest in costly competitions entails a tradeoff between a desire to win and a desire to not spend (too) many resources for a prize that one is not certain to attain. Correspondingly, behavior in competitions can be framed as a choice between sitting out the competition (neither losing nor gaining any amount), or paying an amount – one's investment – for a chance to win the prize (Fehr & Schmid, 2014; Klose & Schweinzer, 2012).

As discussed in Section 2, some researchers argue that winning – and specifically besting others – is the strongest competitive motivation, overshadowing the value of the prize or the desire to perform well (Bazerman et al., 1992; Kohn, 1992; Malhotra, 2010; Messick & McClintock, 1968; Sheremeta, 2010). Indeed, the tradeoff between winning and saving one's resources seems to be often settled in favor of the attempt to win. As aforenoted, many studies of costly competitions observed overinvestment of resources relative to the prize and relative to the theoretic benchmarks (Baye et al., 1999; Davis & Reilly, 1998; Gneezy & Smorodinsky, 2006; Lugovskyy et al., 2010; Potters et al., 1998; Sheremeta, 2010; for a review, see Dechenaux et al., 2012). In the two previous chapters, I demonstrated also that winning or losing the current competition plays a large role in determining the subsequent investment. Further, this effect holds regardless of the size of the prize to be won.

But what if one cares not only about one's own payoff, as standard economic theory suggests (e.g., Luce & Raiffa, 1957; Von Neumann & Morgenstern, 1947), but about the payoff received by one's opponent?

31.2 Preferences over others' outcomes

A vast literature demonstrates that people have preferences over the payoffs received by others – and especially regarding others' payoffs in light of their own payoff (e.g., Camerer, 2003; Charness & Rabin, 2002; Fehr & Fischbacher, 2002; Fehr & Schmidt, 2006). These preferences shape people's decisions in addition to the general wish to earn as much as possible. For example, people may choose to maximize the favorable difference between their payoffs and those of others, or may choose to help others achieve high payoffs (e.g., Messick & Thorngate, 1967). Theories and models have posited three main motivations regarding others' payoffs (e.g., McClintock, Messick, Kuhlman, & Campos, 1973; Messick & McClintock, 1968; Messick & Sentis, 1985): (1) no social motivation, namely individualistic or selfish, considering only one's own payoffs; (2) competitive, aiming to be at an advantage and above others as much as possible (mostly wishing to not fall behind); (3) cooperative or prosocial, aiming to increase the overall payoff for everyone.

The different preferences may entail different investment decisions in competitive situations. If one is competitive, the attraction of winning, of besting another person and increasing the (positive) difference in payoffs, should be greater than if one is merely individualistic. Conversely, if one is prosocial, the important factor would be the size of the overall "pie" – which, in costly competitions with a fixed prize, is largest when investments are low or at zero.[16] That is, when the prize is fixed, prosocial preferences entail lower investments than selfish preferences, with competitive preferences entailing the highest investments, and likely, smallest overall gains. These patterns may be more extreme when investments also change the size of the prize.

[16] The pie may be maximal when both contestants invest zero, or when one of them invests the minimum amount and the other invests zero – depending on the allocation rule when both contestants sit out the competition.

31.3 Investment-dependent prizes and outcome preferences

The competition prize, awarded to the winner, could or could not depend on the winner's investment: The prize could be positively related to the winner's investment (e.g., when investment in a product increases the market for it), or be independent of it.[17] The prize could also depend on the loser's investment, either negatively – the loser's investment decreasing the winner's prize (e.g., Alexeev & Leitzel, 1996) – or positively, with the loser's investment increasing the winner's prize (e.g., Baye et al., 2005; D'Aspremont and Jacquemin, 1988). An interesting example involves the different contingencies between investments and prizes in various legal systems: In the American system, each litigant (contestant) pays their own cost as in the basic competition model described in the previous chapters; conversely, in the British and Quayle systems, the losing litigant compensates the winning litigant for a part or all of the winner's legal costs, thus in essence increasing the winner's earnings and decreasing their own (Baye et al., 2005). See Baye et al. (2012) and Chowdhury and Sheremeta (2011) for theoretical models of such situations.

Three previous experimental studies compared investments in games mimicking the American and British systems above, in which the loser refunds none, some, or all, of the winner's expenditures (Cohen & Shavit, 2012; Coughlan & Plott, 1997; Dechenaux & Mancini, 2008). They demonstrated that investments are higher in competitions in which the loser refunds the winner's costs – in part or in full. They observed that investments exceeded the gains in both types of systems, but this overinvestment was more pronounced in the British, refunding, system. However, it should be noted that these studies examine only one specific type of dependence – in which the winner's investment increases the loser's losses. Moreover, this increase does not depend on the loser's investment, and so does not directly apply to the situations I study.

Theoretic economic analyses have considered both positive and negative impacts of contestants' investments on the prize (Baye et al., 2012; Chowdhury & Sheremeta, 2011; Chung, 1996). Competitions with positive impacts (refunds of some sort) are predicted to yield higher investments than contests with a fixed, independent, prize (Chung, 1996; Matros & Armanios, 2009).

[17] The case in which the winner's investment decreases the prize is not very interesting in my setting: One decreases one's expected earnings the more one invests in all situations, since investments are non-refundable.

If one cares only about one's own expenses and payoffs, then the investment impacts on the prize should have a straightforward effect: When investments positively impact the prize (either the winner on their own prize, or the loser on the winner's prize), investments are in essence less costly and therefore should be higher. That is, one's investment is not entirely wasted – some of the investment is "returned" to the contestant through the prize. However, when this return on the investment is not very high, such a contest might lead to more waste (higher overinvestment) than the regular contest. Conversely, when there's a negative impact, investments are even more costly than in the regular contest – and therefore investments should be lower.

The investment predictions become more complex when taking into account the various preferences people may have over outcomes. This study thus examines how investments are affected by the impact of the winner and loser's investments on the prize:

Q3.1: Does a positive impact of the winner's investment on the prize increase investments?

If one is competitive – if one cares about increasing the (advantageous) difference between oneself and one's opponent – then for the same reasons described above, investments should increase. If one is prosocial – caring about the aggregate revenue, the size of the overall pie – investments should be slightly higher than in competitions with a fixed, independent prize (as predicted for the other types of preferences described above). This is because higher investments do not decrease the pie as much as in competitions without the positive impact. In sum, when the winner's investment increases the prize, irrespective of contestants' motivations, investments should increase.

Q3.2: How does a positive (negative) impact of the loser's investment on the winner's prize affect investments in the competition?

Consider first competitions in which the loser increases the winner's prize; in these, prosocial and competitive motivations lead to opposing predictions. If one is competitive, then the loser's impact increases the attraction of winning, but on the other hand, there is the disliked possibility of having increased the opponent's prize: If one wins, one wins a larger prize; however, if one loses, not only is the opponent's payoff higher than one's own, but it is increased due to one's own investment. Considering the negative value of losing by a large margin, I therefore assume that competitive types' investments would decrease in such competitions. Conversely, if one is prosocial, a positive loser's impact would increase investments: Either one wins a larger prize, or the opponent wins a larger prize – both involving a greater utility than the corresponding utilities in a contest with a fixed prize.

Predictions again diverge, but in the opposite direction, when the loser decreases the winner's prize. If one is competitive investments should increase, since even if one loses the competition, the opponent's prize (and thus, their advantage) decreases. In contrast, if one is prosocial, then one will refrain from investing a lot of resources in such competitions: By sitting out the competition, one does not decrease the opponent's payoff, or the overall pie.

To sum up, when the winners increase their own prize, investments should increase on average. However, the predictions are not clear cut when the loser's investment impacts the winner's prize: When the loser has a positive impact on the winner's prize, investments could increase (due to increasing the size of the pie), or could decrease (due to an increased difference between the payoffs of the winner and the loser). When the loser has a negative impact on the winner's prize, investments could decrease (because high investments would decrease the size of the pie) or increase (in order to decrease the winner's payoff and advantage if one loses).

In addition to examining contestants' investments in the competition, I examine their earnings in light of the value added or subtracted from the initial competition prize:

Q3.3: How do the winner’s and loser’s impacts affect contestants' earnings in the competition?

As in the previous chapters, here too I examine not only the overall investments and earnings, but whether and how these change over time. I address two aspects of investment dynamics, namely whether there is escalation (or moderation) of the competition over time, and the round-to-round dynamics. Specifically, I examine whether contestants react to winning versus losing the previous competition – and whether this effect holds regardless of the impacts of contestants' investments on the prize; that is, whether winning per se drives the dynamics, and whether the prize to be won plays a role.

Q3.4: Does the competition escalate over time – regardless of the winner and loser impacts?

Q3.5: Does the most recent outcome – winning or losing – affect contestants' subsequent investment?Does this effect depend on the winner and loser impacts?

32 Experiment 3: Investment-Dependent Prizes

32.1 Method

Subjects played 16 rounds of the "Invest game" previously described. In each round, subjects were endowed with 96 points and decided how many of them to invest in the current contest, against a randomly chosen opponent (a stranger design). For each competing pair the subject who invested more won the prize; in case of a tie, each subject received half of the prize. Again, investments were non-refundable, regardless of win or loss. Uninvested points and prizes accumulated and were exchanged for money after the experiment, but could not be used for investment in subsequent rounds.

The basic value of the prize was 96 points. I introduced various contingencies between subjects' investments and the prizes received – resulting in six experimental conditions. Conditional on winning, subjects may have had a positive impact on their payoff in that each point they invested added 0.25 points to their prize (***Winner(+)*** condition); in the ***Winner(0)*** condition, the prize was unaffected by winner's investment. These conditions were crossed factorially with three conditions pertaining to the impact of the loser on the winner's prize: Conditional on losing, one’s investment could increase the winner's prize by 0.25 points for each point invested (***Loser(+)***); decrease the winner's prize by 0.25 points for each point invested (***Loser(-)***); or have no impact on the winner's prize (***Loser(0)***).

After each round, subjects were shown their investment, whether they invested more or less than their opponent, the size of the prize they won (or zero if they lost), and their earnings for the round. That is, all of the information in the game, other than the exact value of the opponent's investment and the opponent’s prize if the opponent won, was common knowledge.[18]

32.1.1 Subjects

Subjects were 108 Ben Gurion University students, participating in exchange for monetary pay, in six sessions of 16-20 subjects. Subjects were randomly assigned to conditions. 63 of the subjects (58.3%) were female; 99 (91.7%) undergraduates. No measures other than subjects' investment decisions were collected.

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[18] The reader may note that in the Loser(-) and the Loser(+) conditions, the winner could, in principle, derive the loser's investment from the prize they themselves received.

Subjects earned an average of 1.3 NIS per round (1 NIS was worth approximately $0.27). None of the subjects had participated in Experiment 1A, 1B or 2.

32.1.2 Procedure

The experiment was conducted in a computer lab at Ben Gurion University, on PCs connected to the experiment webpage. Subjects sat at computer desks and were instructed not to communicate with each other. As in Experiments 1 and 2, subjects read the instructions at their own pace from the screen, and were asked to raise their hand if they had questions at any point of the experiment. See Appendix IV for a translation of the Hebrew instructions.

32.2 Results

I first describe the average investments in the different conditions (pertaining to the possible impacts of the winner and the loser on the winner's prize). Next, I describe the subjects' earnings in the different conditions: The correspondence between the investments and the amounts of the prizes won, entailing the degree of (in-)efficiency of the competition. I then turn to the dynamics of investment, describing the overall effect of time on investments and the changes in investment between consecutive rounds – examining subjects' reactions to winning and losing across the different conditions.

32.2.1 Overall investments (Q3.1, Q3.2)

As seen in Figure 3.1, average investments varied considerably across conditions. I conducted a linear regression, with the condition – winner's impact and loser's impact – their interaction, and experiment round as predictors; variance was clustered by subject to control for the multiple decisions made by each subject. As was to be expected, when the winner had a positive impact on the prize, investments were higher ($t(108)=2.73$, $p=.006$). While this may seem intuitive, it is important to remember that even when winning in Winner(+), one still loses three-quarters of a point for every point invested. Most interesting from a social perspective is that investments were higher when the loser's impact on the winner's prize was positive and vice versa ($t(108)=3.10$, $p=.002$). The interaction between Winner and Loser impacts was also significant, and seems to arise mostly from the low investment in the Winner(0)*Loser(-) condition ($t(108)=-2.03$, $p=.042$).

There was a significant effect of round, in that investments increased over rounds ($t(108)=7.28$, $p<.001$). However, after the first five rounds, investments reached a plateau; when analyzing rounds 6-16, there was no effect of round ($t(108)=1.20$, $p=.234$). All of the other abovementioned effects remained the same within the last 11 rounds.

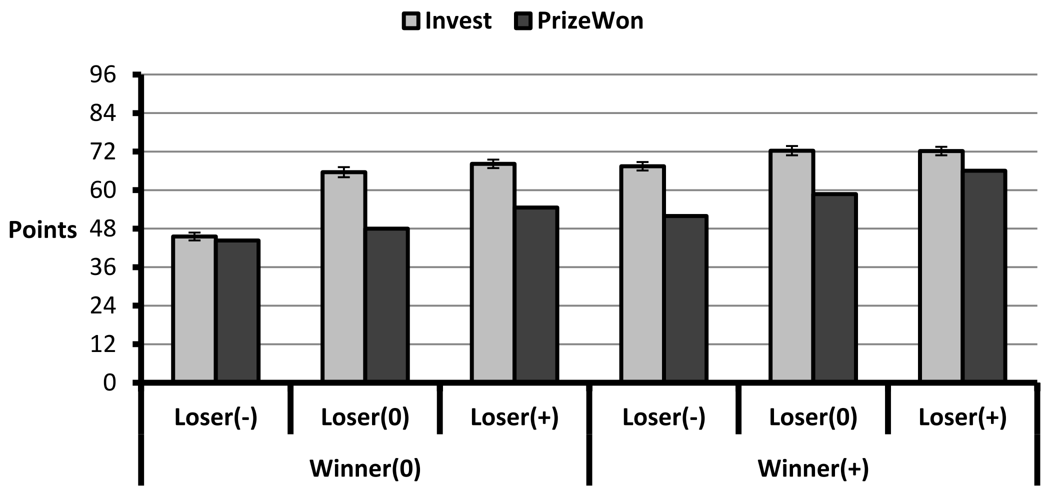

Figure 3.1. Average investments and average amounts received (i.e., half of the prize) for the six conditions pertaining to the winner and the loser's impacts on the winner's prize. Error bars represent standard error of the mean.

32.2.2 Earnings and worthwhileness (Q3.3)

Across all conditions, the average investment was 65.4 points, meaning that the average investment for a *pair* of subjects was 130.8 points – which is well over the prize won, at 108.4 points. That is, subjects exhibited significant overinvestment, in that they invested (together) more than the prize they gained, entailing a loss of efficiency. In other words, they would have earned more had they sat out the competition. I compared investments in each of the six conditions to their average prize: This loss of efficiency was observed in all conditions but was only negligible in the Winner(0)*Loser(-) condition, and marginal in the Winner(+)*Loser(+) condition ($t_{Winner(0),Loser(-)}(17)=-0.42$, $p=.681$; $t_{Winner(0),Loser(0)}(15)=-3.69$, $p=.002$; $t_{Winner(0),Loser(+)}(19)=-3.81$, $p=.001$; $t_{Winner(+),Loser(-)}(17)=-7.78$, $p<.001$; $t_{Winner(+),Loser(0)}(15)=-5.98$, $p<.001$; $t_{Winner(+),Loser(+)}(19)=-1.99$, $p=.061$). The average earnings in the six conditions (compared to the subjects' initial resource endowment) are presented in Figure 3.2.

The loss of efficiency variable was submitted to a linear regression, with the winner's impact and the loser's impacts, their interaction and round as predictors, and with the variance clustered by subject. There was a significant interaction between the Winner and Loser impacts (*t*(108)=-3.64, *p*<.001). As can be seen in Figure 3.2, this is mostly due to the smaller gap between resource endowments and earnings in both the Winner(+)*Loser(+) and the Winner(0)*Loser(-) conditions. That is, in these conditions subjects wasted fewer resources, and earned more, than in the other conditions. I return to this finding in the Discussion.

There was a significant effect of round, in that loss of efficiency increased (i.e., earnings decreased) over rounds (*t*(108)=7.21, *p*<.001). However, this effect was due to the first five rounds (as above); when analyzing rounds 6-16, there was no effect of round (*t*(108)=-0.77, *p*=.444), and all other effects remained the same.

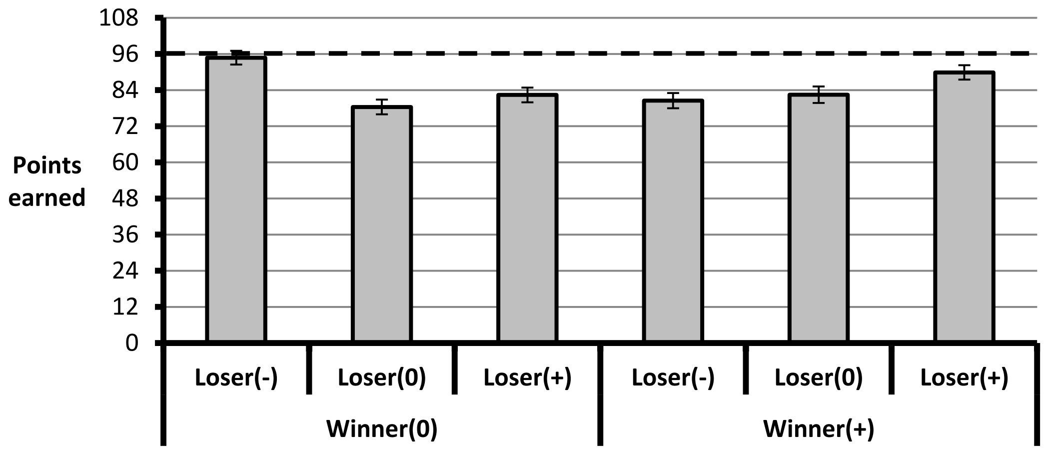

Figure 3.2. Average earnings for the six conditions pertaining to the winner and the loser's impacts on the prize. Error bars represent standard error of the mean. The dashed line marks the initial resource endowment of 96 points, which is what subjects would have earned had they sat out the competition.

32.2.3 Investment dynamics

32.2.3.1 *Investments over time (Q3.4)*

As mentioned above, I observed a slight increase of investments over rounds, but this increase was limited to the first five rounds. That is, after a short period, which could perhaps indicate practice in the game, investments remained similar and did not escalate over time.

32.2.3.2 *Effects of outcome (Q3.5)*

As in the previous experiments, I tested whether investments were influenced by the outcome – winning or losing – in the previous round, and whether there were different dynamics in the different conditions (winner's and loser's impacts). I calculated the difference in investments between consecutive rounds, and submitted this variable to a linear regression model (again with variance clustered by subject). The outcome (win or loss),[19] one's previous investment, the conditions – winner's and loser's impacts – their interaction, and experiment round were the predicting variables.

As can be seen in Figure 3.3, there was a significant impact of winning versus losing: After winning, the subsequent investment was smaller, by an average of 5.35 points; after losing, investments increased, by an average of 14.42 points ($t(108)=-3.46$, $p=.001$).[20] The previous investment had a significant effect, probably reflecting regression to the mean ($t(108)=-5.87$, $p<.001$). There was also a significant interaction between the outcome and previous investment ($t(108)=2.46$, $p=.016$).

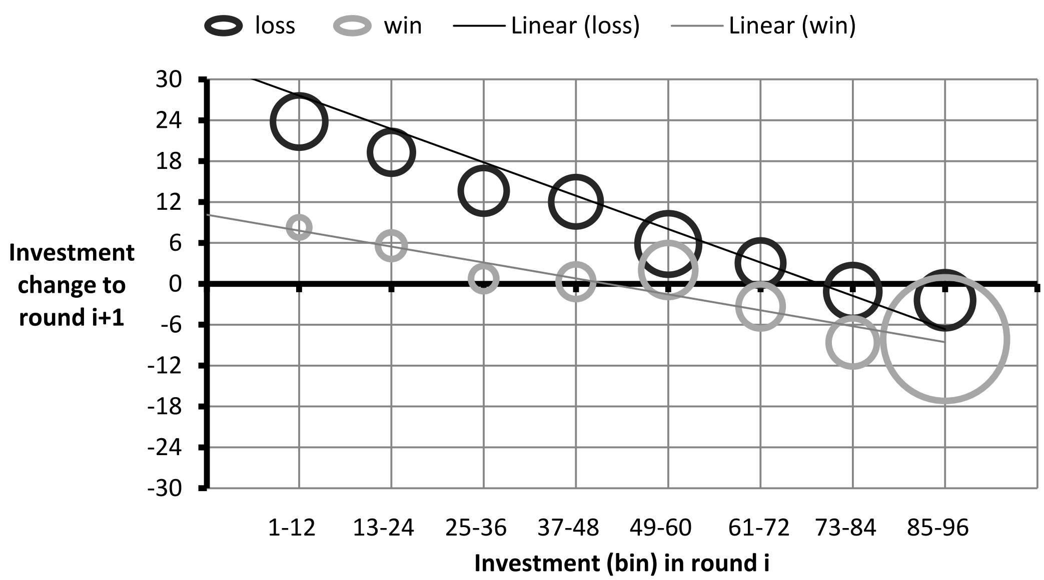

Figure 3.3. Changes in investments between consecutive rounds, following win and loss, averaged over the six conditions pertaining to the winner and the loser's impacts on the prize. Circle sizes indicate the relative number of observations.

In addition, the average of the difference between consecutive investments was larger in the Winner(+) condition than in the Winner(0) condition ($t(108)=2.39$, $p=.018$); the average

[19] As in the previous chapters, I did not include ties in the analysis.

[20] Readers may notice that the average increase is larger than the average decrease, seemingly contrary to the finding investments do not much increase over time. These two findings can be reconciled by looking at the situations in which there was a tie: Following ties, investments decreased by an average of 8.58 points. Taking all of these changes together, the average investments indeed shouldn't increase or decrease.

difference was larger the more positive the impact the loser had on the winner's prize ($t(108)=2.69$, $p=.008$). There was also a significant interaction between the loser's and the winner's impacts ($t(108)=-2.05$, $p=.043$). The effect of the loser's impact on the prize was moderated by the winner's impact on their own prize: When it was positive, the loser's impact had less of an effect. There were no significant interactions of the winner or loser's impact conditions with the outcome (win or loss; all p's $>.41$). The average of the differences only slightly increased over rounds ($t(108)=1.89$, $p=.062$).

33 Discussion

This study examined investment behavior in competitions in which the contestants' investments may affect their prize. As in many competitive situations in the world, and like previous studies (Cohen & Shavit, 2012; Coughlan & Plott, 1997; Dechenaux & Mancini, 2008; see also previous chapters), subjects in the experiment invested heavily, arguably too much, in the competition.

Importantly, investments differed according to how they might have impacted the competition prize. Investments were higher when the loser's investment increased the winner's prize, and lower when the loser's investment decreased the prize. I also observed higher investments when the winner's investment increased the prize. Investments were high even though in some cases they led to lower overall earnings compared to competitions in which the prize did not depend on investments. The pattern of investments in the different competitions may imply that the subjects considered the overall pie, in that they were more motivated when their investments increased the aggregate revenue, and did not seek to hurt their opponents.

Investments exceeded the prize amounts in all of the conditions. Yet, there was a smaller gap between the investments and the prize in two of the conditions: When the winner and the loser both had a positive impact on the prize (Winner(+)*Loser(+) condition), and when the loser's investment diminished the winner's prize (Winner(0)*Loser(-) condition). These two conditions had higher earnings and less waste than in the other conditions. Notably, the smaller losses of efficiency in the two conditions arose from different reasons. In the Winner(0)*Loser(-) condition, subjects invested much less than in the other conditions, and so the prize did not much decrease; thus the invested amounts were more similar to the prize. Conversely, in the Winner(+)*Loser(+) condition, subjects' investments were high but the prize itself increased by a quarter of the summed investments; that is, a significant part of the investments was "returned" via the increase of the prize, leading to a smaller loss of efficiency compared to other conditions.

As for investment dynamics, corroborating previous findings (Engelbrecht-Wiggans & Katok, 2007; also see previous chapters), subjects changed their investments between consecutive rounds in light of their previous outcome (win or loss): After winning, investments decreased; after losing, investments increased. This pattern was observed in all conditions, demonstrating that merely winning (or losing) plays a larger role in determining subsequent investments than does the amount of the prize. Moreover, these reactions remained throughout the rounds of the experiment, suggesting that subjects did not move toward a "correct" response over time through adjusting their investments in light of having invested too much or too little, but in fact responded to their outcome in the previous competition.

In sum, high investments in competition can be considered wasteful and undesirable when the contestants' investments do not change the social welfare or their own welfare – in cases of political lobbying or rent-seeking activities. They may also be undesirable when contestants' activities decrease the pie – for example by spending resources which could be used for other purposes, or by harming one another physically or financially (as in wrestling and lawsuits, respectively). Therefore, better understanding of investment behavior can help in designing the proper incentives via dependencies of the prize on investments so as to achieve the desired behavior. In order to discourage investments in these cases, one can plan the benefit structure so that contestants incur higher costs – via diminishing the prize – the higher (or longer) the competition. In contrast, when contestants' investments increase social welfare (such as additional knowledge, innovative products or beautiful paintings), high investments could be construed as desirable. In order to encourage investments in such cases, prizes could be set so that they increase with the contestants' aggregate effort.

General Discussion

Competitions are ubiquitous – constituting an important part of social and economic interactions, such as those between performers, lawyers, developers and companies. Many resources are spent on such competitions – time, effort or money – investments which are often non-refundable. While high investments may benefit society in general, for example in innovative endeavors, investments are often wasteful or even detrimental for society, when the competition is exacerbated and no new wealth is created. Why is competition so prevalent and investments in it so high – even though it often depletes our resources or those of others? What does it accomplish?

Three studies examined behavior in costly competitions, varying the competitive setting in order to explore whether – and how – various psychological and material aspects affect investment behavior. The studies in this work used an experimental game paradigm involving repeated investment decisions. In this "Invest Game", subjects competed against one another by investing resources in an attempt to secure the prize. As aforenoted, the investments were not refunded – they were not returned to the subjects regardless of winning or losing the competition. This game enabled the manipulation of variables pertaining to the competition structure, while allowing for direct comparisons between the different settings. The three main chapters describe the influence of three important (and often inherently present) features of competitions: (1) asymmetry (inequality) between the contestants; (2) noisy evaluation of investments – and correspondingly, noisy determination of the competition winner; (3) different contingencies (dependencies) between the contestants' investment and the prize.

In all experiments, I examined several aspects of investment behavior. I examined overall investments in the different competition settings, and whether they changed over time. I compared earnings in the different competitions, and further compared these to the contestants' initial resources. In addition, I examined the investment dynamics: How contestants reacted to their previous outcome; specifically, whether investments were different when they were preceded by a previous win as compared to a previous loss. The following sections summarize and discuss the findings regarding these aspects of investment behavior, across the three studies.

41 Overall Investments

As is the case in many real-world competitive situations, in all three studies subjects invested heavily in competing. Yet, there were large differences in investments depending on the specific competition setting or structure. In Experiment 1, I found that investments in asymmetric competitions were lower than those in symmetric competitions. This finding was observed within-subject, as subjects competed in both symmetric and asymmetric competitions. The lower investments in asymmetric competitions seem to replicate previous findings reflecting a "discouragement effect" (see Dechenaux et al., 2012). However, this effect was present only when the asymmetry involved the resources at the subjects' disposal, and not when it involved the prize value. I replicated the discouraging effect of resource asymmetry in Experiment 2, and extended the results of Experiment 1 in showing that noise in the evaluation of investments – and correspondingly, in the determination of the winner – diminished the discouragement effect. Moreover, when the noise arose from a random error term added or subtracted from subjects' investments, noisy evaluation increased overall investments, across both symmetric and asymmetric competitions.

Experiment 3 examined another aspect of the prize value, exploring prizes which partly depended on subjects' investments. Subjects invested more when their investments increased the winner's prize than in competitions in which investments did not affect the prize – that is, when there was a positive impact of the winner or of the loser's investments on the prize. In contrast, when the loser's investment decreased the winner's prize, investments were lower than in the fixed-prize competition. Hence, while the results of Experiments 1A and 1B imply that the prize value plays only a small role in determining investments, Experiment 3 demonstrates that this is not always the case: The prize value mattered when subjects could influence their prize via their own investments.

In sum, comparing investments in the different settings to investments in the simplest, symmetric and deterministic competition, one can see that all features examined – asymmetry, noisy resolution and investment-dependent prizes – affected investments. Specifically, asymmetry discouraged competitions, leading to lower investments on average, noisy resolution on average increased investments, and so did positive dependency of the prize on the contestants' investments.

As aforementioned, subjects in the experiments made repeated investment decisions in multiple rounds. The repeated observations enabled examining whether investments increased or decreased over time – reflecting escalation or moderation of the competition. Overall, I did not observe any such meaningful patterns or directionality over time in any of the experiments. In Experiment 1B I observed that over time, subjects tended to sit out slightly more; in Experiment

2, I observed that investments slightly decreased over time. Conversely, in Experiment 3 I observed a slight increase in investments. However, these patterns were mostly limited to the early rounds of the respective experiments, and thus probably reflect a short period of learning the environment and settling on behavior rather than an intentional tendency of escalation or moderation of the competition.

42 Earnings and Efficiency

Earnings differed significantly between the different contests, as can be surmised from the variation in investment rates. Subjects earned less in symmetric, compared with asymmetric contests – in both Experiment 1A and Experiment 2. That is, when competing against equal others, subjects invested more and ended up wasting more of their initial resource endowments. This tendency was even more pronounced when the evaluation of investments included noise: In competitions with random noise added or subtracted from investments, subjects earned less than in competitions with accurate evaluation of investments and competitions with a probabilistic resolution rule – across both symmetric and asymmetric contests. In Experiment 3, earnings were higher in some conditions in which the prize depended on the contestants' investments compared to the fixed-prize competition. Specifically, subjects earned more in competitions in which the losing contestant's investment decreased the winner's prize, and in competitions in which both contestants' investments increased the winner's prize.

Nevertheless, while earnings varied between competitions, in none of the studies did subjects gain from competing – in fact the opposite was true: In all competitions and across all conditions, subjects staked and risked often quite high amounts compared to the resources at their disposal and those available to be won. In line with previous findings (Baye et al., 1999; Davis & Reilly, 1998; Gneezy & Smorodinsky, 2006; Lugovskyy et al., 2010; Potters et al., 1998; Sheremeta, 2010; for a review see Dechenaux et al., 2012), I observed that contestants earned less than their initial resource endowments. That is, contestants actually diminished their funds by investing in the competition.

Why take the risk and invest in the first place, with the expected gains being zero in most cases, and the actual, observed gains typically being negative? Why not sit out and keep one’s endowment without risking it (or even losing some of it)? One possible explanation has to do with the nature of the game employed (and the many competitions it represents): If one is known to sit out with certainty, one's opponent can invest very little and win the prize, which would render the opponent much richer than oneself. According to this explanation, it is not only one's gains, but one's standing relative to that of others which matters. Only by entering the competition, and risking part of one’s endowment, can one better retain one's relative position.

Another, related, explanation relies on the inherently motivating (or demotivating) value of winning (losing), offsetting the small risks and losses incurred. As suggested by previous studies and various theories (Bazerman et al., 1992; Kohn, 1992; Malhotra, 2010; Messick & McClintock, 1968; Sheremeta, 2010; see Section 2), winning may in itself be motivating and cause positive affect or utility – regardless of the absolute value of the prize. I believe that the findings regarding round-to-round reactivity support this idea, as described below.

43 Effects of Previous Outcome

I examined the round-to-round changes in investments to see whether subjects were affected by the outcome of the previous round. Specifically, I tested whether winning (versus losing) a competition affected subjects' investment in the subsequent competition. In all experiments and across all conditions, I indeed found that the previous outcome had a large influence on the subsequent investment: After winning a previous competition subjects invested less, whereas after just losing a competition, subjects invested more than they did in the last competition. This tendency was very strong, and observed above and beyond the amount previously invested and the value of the prize; it was evinced regardless of the competition settings – irrespective of the contestants' strength, prize value, and the resolution rule. Further, the reactions to wins hardly changed over time. The observed dynamics cannot be construed as directional or reinforcement learning, since there was no evidence for an accumulation of response propensities (which characterizes such models): Reactivity did not diminish over time. Therefore, supported by previous research and theories (Avrahami & Kareev, 2011; Engelbrecht-Wiggans & Katok, 2007, 2008; Hart et al., 2015; Sheremeta, 2010; see Section 2), the findings imply that the dynamics do not reflect learning or consecutive adjustments until reaching an "optimal" investment, but reactivity to – or the utility of – winning versus losing.

44 Implications

The findings presented in this work have important implications for the design of real life competitions and the participation in them. For one, the results of the three studies – separately and taken together – suggest ways to increase (or at least not decrease) one's resources. In different settings, one should invest more or less, or in some cases refrain from competing at all. Take for example the case of online design competitions, say, for a new company logo.[21] When considering participation in such a competition – that is, working on and submitting a logo, or even several versions thereof – one should assess one's own strengths and resources, and those of one's potential opponents: Does one have the necessary skills for the competition? Does one stand a chance against one's colleagues-turned-contenders? If one is at a significant enough disadvantage, one should probably save one's effort for another time; if one faces mostly-equal opponents, one should invest quite a lot in one's proposed logo. Nevertheless, one should consider the possible prize value and whether high investments will pay off: Does the committee take into account the value of the logo when determining the awarded amount? Will a winning logo award its designer a fixed amount, or will a better logo result in a higher amount? The latter incentive would (or should) probably lead one to invest more effort in the design.

The correspondence between investments and the awarded prize is interesting not only from the contestants' point of view, but from the vantage point of competition organizers (such as policy makers, department heads, or even parents): What incentives should be given to contestants in order to bring about higher investments – most likely resulting in better proposals, prototypes or products? Further, competition organizers should consider how they evaluate the contestants' investments, and in turn, how this affects the contestants' respective chances of winning (or perception thereof). For example, a lottery-based mechanism might make inequality less prominent and so less discouraging for weaker contestants. Of course, an organizer could also aim for relative homogeneity, or relative heterogeneity of the contestants, in order to heighten or diminish the intensity of competition.

While asymmetry or noise are present in many competitions and are often considered undesirable and even harmful, my findings imply that in some cases they may be advantageous –

[21] This is in fact quite a common occurrence. See, for example, https://www.designcontest.com, a design competition website with over 150,000 designers, or http://99designs.com, boasting 950,000 members and a design uploaded every 1.5 seconds. http://www.topcoder.com/ is a similar webpage with over 780,000 members, in which competitions involve programming as well as design.

depending on the goals of the competition organizers, and the potential benefits for society. One might not want to add noise to already noisy situations (such as evaluative tests or interviews), or make the contestants more different than they initially are. For example, when we want to judge contestants by their ability and choose the most capable contestant, we would indeed want to minimize noise as much as possible. However, the presence of these features is not necessarily that bad. In some situations, contestants' initial positions, strength or resources are irrelevant to the aspect we wish to judge: Money spent on advertising is unrelated to a product's efficiency or desirability; a more wealthy political candidate, who can spend more on campaigning and public recognition, is not necessarily better suited for the job. In these cases, we might want to winner to be determined via a probabilistic lottery rule: In this type of noisy competition, the influence of the inequality will be less prominent; thus, the competition will be less biased toward the initially – and irrelevantly – advantaged contestant.

Competitions permeate many aspects of daily life. Competing isn't just something we do because – or when – we have to; competition seems to motivate us, and is often considered recreational. People compete for their enjoyment in sports – on the basketball courts or within a running application – in business and achievements, and in the silliest, Facebook-based (and billion-making) games. Many of the competitive situations we encounter inherently include one or more of the features studied in this work. The findings further our understanding of competitive situations in general, and of the influence of specific contextual features or facets in particular. The setting affects several aspects of behavior, namely, investment and participation rates, the degree of overinvestment and the corresponding earnings in the competition. At the same time, some aspects stay constant across competitions, namely, contestants' drive toward winning and its consequences.

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Appendix I

Theoretic Formulation

We denote the two contestants by A and B, each choosing their strategy of investment, which is a distribution of a nonnegative random variable (X and Y, respectively). In any given game, contestant A's investment will be x from distribution X, and contestant B's investment will be y from distribution Y. I define a,b ≥ 0 to be the contestants' respective mean investments in the contest game. Each contestant can invest only up to a certain amount of resources (their respective endowments), denoted by $\{r_A, r_B\}$. Each contestant also has a certain valuation for the prize, denoted by $\{v_A, v_B\}$.[22] The resource endowments and valuations are public information.

In the setting of Experiments 1A and 1B, the contestant who invested more wins the prize; if the two contestants tie, each gets half of the prize. All contestants, regardless of winning or losing, always pay their investment. This means that the payoff function for contestant A (the payoff function for contestant B is the same, substituting y for x and v_B for v_A) is as follows:

$$U_A(x, y) = \begin{cases} v_A - x & x > y \\ \frac{1}{2} v_A - x & x = y \\ -x & x < y \end{cases}$$

The best response to each investment of the opposing contestant is, of course, to invest just slightly above. This response leads to winning at the lowest cost. Best-responding in such a manner, however, leads to an escalation which could get to a maximum investment, at which point the best-response would be to invest nothing – which, in turn, would start the cycle again. The theoretic solution for various parameter values is therefore in mixed strategies. Moreover, for asymmetric contestants, the theoretic solution becomes even more complex and less intuitive.

I describe the strategies and equilibria separately for Experiment 1A (in which contestants differed in their resources) and Experiment 1B (in which contestants differed in the prize valuation) in the following respective sections, using the relevant notations and specific parameter values.[23]

[22] This notation follows that of S. Hart (2014). Similar notations are used by Baye et al. (1996), Hillman and Riley (1989), and Che and Gale (1998).

[23] It should be noted that the equilibrium strategies and mean investments I present are based on the assumption that the investments are continuous variables. In my setting, investments are discrete: Subjects invest a number of points. However, I take the continuous equilibria to be approximate solutions, as done in previous research, as, for example, regarding Colonel Blotto games (e.g., Chowdhury, Kovenock, & Sheremeta, 2013).

Experiment 1A: Theoretic predictions

In this experiment, the contestants' resources (denoted by r_A and r_B) are either equal – creating a symmetric contest – or unequal – creating an asymmetric contest. The prize valuations of the two contestants are equal, denoted by v_A=v_B=V. The game theoretic predictions of equilibrium strategies for this contest are derived in a paper by S. Hart (2014). The predicted strategies, predicted mean investments and gains for all conditions are presented in Table A1.

Table A1. Experiment 1A: Equilibrium strategies, predicted investments and gains

Prize Version	Resources	Equilibrium Strategy	Pred. Mean Invest	Pred. Gain
V-96	R-96 vs. R-96 (symmetric)	U[0,96]	48	0
	R-96 vs. R-72	0.75*U[0,72] + 0.25*1_{72}	45	24
	R-72 vs. R-96	0.25*1_0 + 0.75*U[0,72]	27	0
	R-72 vs. R-72 (symmetric)	0.5*U[0,48] + 0.5*1_{72}	48	0
V-72	R-96 vs. R-96 (symmetric)	U[0,72]	36	0
	R-96 vs. R-72	U[0,72]	36	0
	R-72 vs. R-96	U[0,72]	36	0
	R-72 vs. R-72 (symmetric)	U[0,72]	36	0

Note. The strategies and investments noted are for the first contestant in each pair.

The notation U[$\underline{e}$,$\bar{e}$] indicates a uniform distribution between $\underline{e}$ and $\bar{e}$; 1_e indicates the exact investment of *e* points.

To understand the equilibrium strategies, let us start with the simple case in which both contestants' resources equal 96 points, and the prize value is 96 points for both (r_A=r_B=96, V=96; i.e., the symmetric game between two R-96 types, in V-96). In this case, as aforementioned, each investment *y* is a best response to an investment of *(y-1)* points. Thus, one should give an equal weight to each of the possible options in the range of zero to 96 points. The equilibrium strategies are therefore: X=Y=U[0,96], and the mean investments are: a=b=48.

When the two contestants' resource endowments are equal but lower than the prize (r_A=r_B=72, V=96), each contestant randomizes with equal probability over the range [0,48] half of the time, and half of the time invests the entire resource endowment of 72. I denote this as: X=Y=0.5*U[0,48]+0.5*1_{72}. The mean investments are as above: a=b=48. It is worth noting that, whereas the intuition behind the 'uniform-distribution' part of the solution follows from the escalation in best responses described above, it is less intuitively clear why the solution calls for a considerable investment at a single focal point. As explained by Che and Gale (1998), the exact amount, and the probability with which it is to be invested, depends on an interplay between the prize and contestants' resources.

In asymmetric contests, in which the two contestants' resources are unequal (and V is still 96), the weaker contestant cannot invest more than 72 points. Thus, it is not worthwhile for the stronger contestant to invest more than 72 points (plus a little),[24] even though it is possible. In equilibrium, the weaker contestant sits out and invests zero points a quarter of the time, and randomizes over [0,72] three-quarters of the time: $Y=0.75*U[0,72]+0.25*1_0$, resulting in a mean investment of 27. The stronger contestant also randomizes over [0,72] three-quarters of the time, but in the remaining quarter invests 72 points: $X=0.75*U[0,72]+0.25*1_{72}$, for a mean investment of 45.[25]

When the prizes are worth 72 points to both contestants, it does not matter whether the contestants' resources are equal or not, because they are always higher than or equal to the prize value: All contestants, regardless of their resources or the symmetry of the contest, should invest only up to 72 points – and in fact, as in the first case described above, should always randomize with equal probability over the range [0,72], entailing a mean investment of 36 points by each contestant.

In sum, the game theoretic solution for the setup used in Experiments 1A predicts a large effect of the prize on investments. Regarding the effect of asymmetry on investments, it is predicted to appear only when the prize is high (V-96), and to impact mainly the mean investment of the R-72 contestants, who have fewer resources.

Experiment 1A: Results

Surprisingly, in contrast with the model prediction, there was no difference in investments between contests in which the prize was 96 points, and those in which the prize was 72 points ($M_{V\text{-}96}$=44.51, $M_{V\text{-}72}$=45.19, $t(94)=-0.19$, $p=.842$). Moreover, the pattern of investment in the different contests is similar across the two prize versions. This finding indicates different degrees of efficiency in the two contests. More importantly, it hints at a lesser importance of the prize in

[24] In the continuous case the maximum predicted investment is 72 points, because the probability of the low-type investing 72 points is negligible, and thus the high-type can always win by investing 72 points. In my discrete setting, the high-type may wish to invest more than 72 points in order to secure the prize.
[25] See S. Hart (2014) for the characterization of the equilibrium strategies and payoffs in the case of unequal resources; see also Amir (2014).

determining investments, as will be discussed below. Table A2 presents the observed and predicted average investments and gains. Whereas in the V-96 version the sum of investments did not significantly exceed the predicted investments, in the V-72 version there was substantial overinvestment relative to the predicted amounts in almost all conditions.

Relatedly, the observed gains are quite close to the predicted gains in V-96, but subjects gained significantly less in three of the four cases in V-72, as can be seen in Table A2. That is, investing more than the theoretic prediction led subjects to gain less than they could have.

The rate of sitting out the contest (investing zero points) was only somewhat in line with the predictions. The observed rate of sitting out was very similar to the predictions in V-96, yet was almost always higher than that predicted in V-72. Most interestingly, R-72 subjects tended to sit out about a quarter of the rounds when faced with R-96 subjects – fitting the prediction for the V-96 version, but much higher than the very low predicted rate of sitting out in the V-72 version.

Table A2. Experiment 1A: Predicted and observed investments and gains

Prize	**Resources**	**Invest**		**Gains**	
Version		**Pred.**	**Observed (SD)**	**Pred.**	**Observed (SD)**
V-96	R-96 vs. R-96 (symmetric)	48	51.9 (25.1)	0	-3.9 (16.1)
	R-96 vs. R-72	45	46.0 (22.3)	24	21.7 (15.4)
	R-72 vs. R-96	27	29.8 (22.6)	0	-1.5 (8.0)
	R-72 vs. R-72 (symmetric)	48	50.3 (21.8)	0	-2.3 (12.0)
V-72	R-96 vs. R-96 (symmetric)	36	51.0 (23.7)**	0	-15.0 (13.5)***
	R-96 vs. R-72	36	50.9 (20.8)**	0	-1.6 (13.1)
	R-72 vs. R-96	36	33.1 (21.2)	0	-10.4 (14.3)***
	R-72 vs. R-72 (symmetric)	36	45.8 (15.7)**	0	-9.8 (13.1)**

Note. The differences between the observed and predicted investments and gains are indicated as follows: * < 0.05; ** < 0.01; *** < 0.001

Experiment 1B: Theoretic predictions

In this experiment, both contestants' resources are equal ($r_A = r_B = R$), whereas their prize valuations (denoted as v_A, v_B) are either equal – creating a symmetric contest – or unequal –

creating an asymmetric contest.[26] The strategies and predicted mean investments and gains in these conditions are presented in Table A3.

Table A3. Experiment 1B: Equilibrium strategies, predicted investments and gains

Resource Version	Prize Values	Equilibrium Strategy	Pred. Mean	Pred. Gain
R-96	V-96 vs. V-96 (symmetric)	U[0,96]	48	0
	V-96 vs. V-72	U[0,72]	36	24
	V-72 vs. V-96	$0.25*1_0 + 0.75*U[0,72]$	27	0
	V-72 vs. V-72 (symmetric)	U[0,72]	36	0
R-72	V-96 vs. V-96 (symmetric)	$0.5*U[0,48]+0.5*1_{72}$	48	0
	V-96 vs. V-72	U[0,72]	36	24
	V-72 vs. V-96	$0.25*1_0 + 0.75*U[0,72]$	27	0
	V-72 vs. V-72 (symmetric)	U[0,72]	36	0

Note. The strategies and investments noted are for the first contestant in each pair.

The notation $U[\underline{e},\bar{e}]$ indicates a uniform distribution between $\underline{e}$ and $\bar{e}$; 1_e indicates the exact investment of *e* points.

The reader may notice that the symmetric contests are in fact the same as those in Experiment 1A, already described above: Contestants both have the same resources (either 72 or 96 points), and the same prize (72 or 96 points). I shall thus focus on describing the strategies and mean investments in the asymmetric contests. Without loss of generality, I take contestant B to hold a lower valuation of the prize than contestant A (i.e., $v_A > v_B$; $v_A = 96$, $v_B = 72$).

Note that in the asymmetric prize contests, the resource endowment (equal for both contestants) does not influence the equilibrium strategies nor the mean investments: The V-72 subjects would not invest more than their potential prize of 72 points, irrespective of whether they have 72 or 96 points; therefore, the V-96 subjects would also not invest more than 72 points. Hence, any resource endowment equal to or larger than the low prize value of 72 points would yield the same equilibrium. In the equilibrium of the asymmetric contest in both R-96 and R-72, the strategies are as follows: Contestant B, whose prize is 72 points, should randomize over the range [0,72] three-quarters of the time, and sit out (i.e., invest zero) a quarter of the time; contestant A, whose prize is 96 points, always randomizes over the range [0,72]. The mean

[26] The equilibrium strategies for these cases were described by Baye et al. (1996), Che and Gale (1998), and Hillman and Riley (1989).

investments in the asymmetric contests (in both the R-96 and R-72 versions) are: a=36 for contestant A, and b=27 for contestant B.

Experiment 1B: Results

Across all contests, the average investment was 48.95 points: 53.41 in R-96, in which subjects' resource endowments were 96 points, and 44.49 in R-72, in which they had 72 points. The former is significantly higher than the latter ($t(94)=1.97$, $p=.051$). This demonstrates a first deviation from the theoretic predictions: The mean investments in the different contest conditions should not have been influenced by the subjects' resources, i.e., the contest version.

Let us now look at the efficiency of investments, by comparing to the predicted values in the different conditions. Table A4 presents the predicted and observed averages.

Table A4. Experiment 1B: Predicted and observed investments and gains

Resource Version	**Prize Value**	**Invest**		**Gains**	
		Pred.	**Observed (SD)**	**Pred.**	**Observed (SD)**
R-96	V-96 vs. V-96 (symmetric)	48	57.3 (24.7)	0	-9.3 (18.7)*
	V-96 vs. V-72	36	56.2 (26.6)***	24	-4.5 (20.1)***
	V-72 vs. V-96	27	48.3 (29.6)**	0	-15.1 (13.5)***
	V-72 vs. V-72 (symmetric)	36	51.9 (29.1)*	0	-15.9 (12.7)***
R-72	V-96 vs. V-96 (symmetric)	48	49.9 (22.6)	0	-1.9 (16.4)
	V-96 vs. V-72	36	52.8 (18.6)***	24	13.2 (15.8)**
	V-72 vs. V-96	27	33.7 (22.4)	0	-11.2 (15.7)**
	V-72 vs. V-72 (symmetric)	36	41.5 (22.0)	0	-5.5 (9.7)*

Note. The differences between the observed and predicted investments and gains are indicated as follows: * < 0.05; ** < 0.01; *** < 0.001

In symmetric contests, V-96 subjects (with prizes of 96 points) did not exhibit overinvestment in R-96 or in R-72. V-72 subjects (with prizes of 72 points) exhibited overinvestment in R-96, but not in R-72. In asymmetric contests, V-96 subjects substantially overinvested compared to the theoretic benchmark in both the R-96 and the R-72 versions. In contrast, V-72 subjects demonstrated overinvestment only in R-96, and not in R-72. In sum, in both symmetric and asymmetric contests, when subjects had 72 points (R-72), there was almost no overinvestment. When subjects had 96 points to invest (R-96), there was overinvestment in most contests. In addition, subjects' average gains reveal that in almost all of the conditions they gained significantly less than predicted by the game theoretic solution.

Here, as in Experiment 1A, the observed rates of sitting out were somewhat higher than those predicted. However, the qualitative results were in line with the prediction. Most importantly, in contests between low valuation V-72 subjects and the high valuation V-96 subjects, the rate of sitting out did not significantly differ from the 25% rate predicted by theory (both p's>.49).

Experiment 2: Theoretic predictions

I am aware only of theoretic predictions regarding the SURE and PROB conditions (and not for either of the ERR conditions), and so will present only a partial prediction for the experiment conditions. Notably, the game theoretic solution for the SURE condition is given above, as the solution for version V-96 of Experiment 1A.

The theoretic prediction for the PROB condition is presented in Tullock (1980), and is as follows: In competitions with a probabilistic resolution rule as I employed, there exists a pure strategy equilibrium; that is, contestants' best action in equilibrium is to invest a specific amount with certainty. Taking the parameters used in the game, namely that V=96 and the cost of investments is their worth, the pure strategy is to invest V/4, which equals 24 points. This is irrespective of the contestants' resource endowments, or those of their opponents (and correspondingly, symmetry or asymmetry of the competition).

As all contestants are predicted to invest 24 points, each will win the prize with a probability of one half. Thus, on average all contestants win an expected prize of 48 points by investing 24 points: Earning each contestant 24 points from competing (as noted, irrespective of resources and symmetry or asymmetry). The predicted mean investments and gains are presented in Table A5, as are the observed investments and earnings, which will be described in the next section.

Experiment 2: Results

The invested amounts in the SURE condition did not statistically differ from the predicted amounts, similar to the findings in the (equivalent) V-96 condition of Experiment 1A. However, in the PROB condition there were large, significant, differences between predicted and observed investments: As can be seen in Table A5, there was substantial overinvestment relative to the predicted amounts in all conditions.

A similar pattern can be seen in contestants' gains. In the SURE condition earnings were quite close to the theoretic predictions, yet being somewhat lower than predicted in the symmetric competitions. Conversely, in the PROB condition, in all competitions earnings were significantly lower than the predicted gain of 24 points. That is, by investing more than the predicted 24 points, contestants substantially decreased their gains compared to the prediction.[27]

Table A5. Experiment 2: Predicted and observed investments and gains

Resolution	Resources	Invest		Gains	
		Pred.	**Observed (SD)**	**Pred.**	**Observed (SD)**
SURE	R-96 vs. R-96 (symmetric)	48	58.7 (32.2)	0	-11.3 (14.1)*
	R-96 vs. R-72	45	52.3 (20.2)	24	27.6 (15.8)
	R-72 vs. R-96	27	18.6 (19.5)	0	-2.5 (11.4)
	R-72 vs. R-72 (symmetric)	48	42.6 (22.3)	0	5.4 (10.1)*
PROB	R-96 vs. R-96 (symmetric)	24	43.9 (21.4)***	24	4.1 (18.7)***
	R-96 vs. R-72	24	42.1 (18.5)***	24	16.4 (16.0)*
	R-72 vs. R-96	24	31.0 (16.6)*	24	6.5 (15.4)***
	R-72 vs. R-72 (symmetric)	24	40.8 (17.1)***	24	7.2 (13.3)***

Note. The differences between the observed and predicted investments and gains are indicated as follows: * < 0.05; ** < 0.01; *** < 0.001

Experiment 3: Theoretic predictions

Baye et al. (2011) present the game theoretic model and equilibria of a contest similar to that used in Experiment 3, which allows for various dependencies (termed "spillovers") of the prize on the contestants' investments. In principle, from this model one could derive all the equilibria, predicted mean investments and payoffs for all six conditions of Experiment 3. However, one important difference between the experimental conditions and the Baye et al. model conditions is that in my game, subjects could not invest more than 96 points in any condition; in the Baye et al. model with the relevant parameters, subjects in some conditions are predicted to invest much more than 96. Thus, I present only the predictions for the two conditions in which the predicted investment remains in the range of zero to 96 points, namely, the Winner(0)*Loser(-) and Winner(0)*Loser(0) conditions (the latter is similar to the symmetric R-96 V-96 game presented

[27] Note that while subjects gained less than predicted in the PROB condition, and similar to predictions in the SURE conditions, overall gains in the PROB condition were still higher than those in the SURE condition.

for Experiments 1A and 1B, and to the SURE condition in Experiment 2). The equilibrium strategies, predicted investments and gains for these two conditions are presented in Table A6.

Table A6. Experiment 3: Equilibrium strategies, predicted investments and gains

Winner Impact	Loser Impact	Equilibrium Strategy	Pred. Mean	Pred. Gain
Winner(0)	Loser(-)	F(x)=-4*ln(1-0.25*x/96) for x∈[0,84.94)	40.7	0
	Loser(0)	U[0,96]	48	0

Note. The strategies and investments noted are for the first contestant in each pair.

The notation U[e̲,ē] indicates a uniform distribution between e̲ and ē; 1_e indicates the exact investment of *e* points.

Experiment 3: Results

As for the previous experiments, in the two conditions for which I know the game theoretic prediction – namely, Winner(0)*Loser(-) and Winner(0)*Loser(0) – I compared the observed investments and gains to those predicted. As presented in Table A7, in investing 45.6 points, subjects' investments in the Winner(0)*Loser(-) condition were quite similar to the predicted investment of 40.7 points. In contrast, the investments in the Winner(0)*Loser(0) condition, at 65.6 points, significantly exceeded the predicted amount of 48 points; that is, there was significant overinvestment in this condition.

In both of the above conditions, according to theoretic predictions subjects should not gain nor lose from competing. However, this was observed only in the Winner(0)*Loser(-) condition: Whereas gains in the Winner(0)*Loser(-) condition followed the game theoretic prediction, gains in the Winner(0)*Loser(0) did not – subjects significantly decreased their gains compared to what they would have had, had they invested only 48 points (rather than 65.6), as predicted.

Table A7. Experiment 3: Predicted and observed investments and gains

Winner Impact	Loser Impact	Invest		Gains	
		Pred.	**Observed (SD)**	**Pred.**	**Observed (SD)**
Winner(0)	Loser(-)	40.7	45.6 (19.8)	0	-1.2 (12.5)
	Loser(0)	48	65.6 (28.4)*	0	-17.6 (19.1)**

Note. The differences between the observed and predicted investments and gains are indicated as follows: * < 0.05; ** < 0.01; *** < 0.001

Conclusions

In line with previous findings, contestants earned less than the game-theoretic prediction in the majority of the conditions. Yet, in contrast with previous research, I observed overinvestment (compared to the theoretic benchmark) only in approximately half of the conditions, distributed equally across symmetric and asymmetric contests.

In Experiments 1A and 1B, the different sources of asymmetry had different effects on behavior: Inequality in contestant strength (resources, in Experiment 1A) mattered more than inequality in motivation (prize value, in Experiment 1B). The small effect of the motivation – prize value – was smaller than that predicted by theory; it was not observed in several cases in which theory predicts it, in both experiments. In contrast, the significant impact of contestants' strength – the resource endowments – was observed even when it was not predicted by theory, in Experiment 1B and in the V-72 condition in Experiment 1A. Importantly, and incompatible with the theory, only in the case of unequal resources did subjects invest less in asymmetric contests than in symmetric contests. That is, contestants' strengths – and especially differences in strength – were not ignored even when they should have been according to theory.

In Experiment 2, the resolution rule – a deterministic rule or a probabilistic one – did not affect investments. This was in contrast with the theoretic prediction of lower investments in the probabilistic contest. Whereas investments followed the theoretic predictions in the deterministic contest, subjects significantly overinvested in the probabilistic contest – leading to lower observed gains than those predicted. Yet, the smaller difference between investments in symmetric and asymmetric contests in the probabilistic condition compared to the deterministic one is in line with the theory, albeit weaker than predicted.

In Experiment 3, in one of the conditions, namely that in which the prize was fixed and did not depend on subjects' investments, subjects significantly overinvested compared to the theoretic prediction (and thus gained less); in the other condition, in which the loser decreases the winner's prize, investments (and gains) were similar to the theoretic predictions.

In sum, across all experiments, there is a correspondence between the theoretic predictions and the observed investment patterns, but this correspodence is far from complete.

Appendix II

Experiments 1A and 1B instructions[28]

You will now participate in a game in which each of two players decides how much to invest in a contest, in multiple rounds. In each round, the contest winner gets a prize.

The amount you will receive at the end of the experiment is determined by your decisions and those of the other participants.

Please read the instructions carefully.

After reading the instructions, and during the entire experiment – if you have any questions, please raise your hand and one of the experimenters will approach you. Please keep quiet during the entire experiment.

The game will go as follows:

The game includes 16 rounds.

In each round, each of you has a box and a fixed number of points.

[EXPERIMENT 1A: *Half of the players will have 72 points at their disposal in each round, and half of the players will have 96 points in each round.]*

<u>You will have 72 (96) points in each round.</u>

You may invest in the box any number between 0 and 72 (96). The number you type will constitute your investment. Uninvested points will remain yours.

The player who invested more in the box, will win that round's contest and wins the prize.

If the two players invested the same amount – each will receive half of the prize.

[EXPERIMENT 1B: *For half of the players the prize is worth 72 points, and for half of the players the prize is worth 96 points.]*

<u>Your prize is worth 72 (96) points.</u>

Note that investments are non-refundable – whether you win or lose the contest.

In each round the computer will randomly select your opponent from the participating players.

[28] The instructions for all experiments were originally in Hebrew.

Half of the rounds will constitute of contests between players with an equal number of points, and the other half of the rounds will be between players with a different number of points (not necessarily in this order).

Your characteristics and those of the opposing player will appear on each screen in which you have to make a decision.

And the payment?

The computer will calculate the number of points you have left and add the prize – if you received it – in this round.

At the end of every round you will see the round summary: Your determining investment, whether you invested more or less than the other player, and whether you got a prize – and so, your corresponding total for this round.

At the end of the game, the computer will sum up the totals for all rounds, and points will be exchanged for shekels according to the following exchange rate: Every 50 points equals one shekel.

Appendix III

Experiment 2 instructions

You will now participate in a game in which each of two players decides how much to invest in a contest, in multiple rounds. In each round, the contest winner gets a prize.

The amount you will receive at the end of the experiment is determined by your decisions and those of the other participants.

Please read the instructions carefully.

After reading the instructions, and during the entire experiment – if you have any questions, please raise your hand and one of the experimenters will approach you. Please keep quiet during the entire experiment.

The game will go as follows:

The game includes 32 rounds.

In each round, each of you has a box and a fixed number of points.

Half of the players will have 72 points at their disposal in each round, and half of the players will have 96 points in each round.

<u>You will have 72 (96) points in each round.</u>

You may invest in the box any number between 0 and 72 (96). The number you type will constitute your investment. Uninvested points will remain yours.

[SURE CONDITION:

The player who invested more in the box, will win that round's contest and wins the prize.

If the two players invested the same amount – each will receive half of the prize.]

[PROB CONDITION:

Every point you invest will become a lottery ticket, and so will the points invested by the other player. In order to determine who wins that round's contest and wins the prize, the computer will draw one winning ticket out of the total amount of tickets.

That is, your chance of winning = your investment / the sum of your and the other player's investment.]

[ERR CONDITIONS: ERR8 {ERR 16}

"Noise" will be added or subtracted from each of the investments, independently. That is, for each player the computer will draw a random noise, which is independent from the noise drawn for the other players.

The noise for each player will be a random number between -8 {-16} and +8 {+16}, with an equal chance for every number in that range.

The sum of the investment and noise will constitute the determining investment for the contest.

The computer will compare these sums (= investment plus/minus noise), and whoever has the larger sum, wins that round's contest and wins the prize.

If the two players' sums are equal – each will receive half of the prize.

Important: Your investment is the number you chose, without the noise – the noise influences only your chance of winning.]

The prize is worth 96 points.

Note that investment are non-refundable – whether you win or lose the contest.

Therefore, in a round in which you won, your total will be 72 (96) minus your investment plus 96.

In a round in which you did not win, your total will be 72 (96) minus your investment.

In each round the computer will randomly select your opponent from the participating players.

Half of the rounds will constitute of contests between players with an equal number of points, and the other half of the rounds will be between players with a different number of points (not necessarily in this order).

Your characteristics and those of the opposing player will appear on each screen in which you have to make a decision.

And the payment?

The computer will calculate the number of points you have left and add the prize – if you received it – in this round.

At the end of every round you will see the round summary: Your determining investment, the determining investment of the other player, and whether you got a prize – and so, your corresponding total for this round.

At the end of the game, the computer will sum up the totals for all rounds, and points will be exchanged for shekels according to the following exchange rate: Every 40 points equals one shekel.

Appendix IV

Experiments 3 instructions

You will now participate in a game in which each of two players decides how much to invest in a contest, in multiple rounds. In each round, the contest winner getsa prize.

The amount you will receive at the end of the experiment is determined by your decisions and those of the other participants.

Please read the instructions carefully.

After reading the instructions, and during the entire experiment – if you have any questions, please raise your hand and one of the experimenters will approach you. Please keep quiet during the entire experiment.

The game will go as follows:

The game includes 16 rounds.

In each round, each of you has a box and a fixed number of points.

Each player will have 96 points in each round.

You may invest in the box any number between 0 and 96. The number you type will constitute your investment. Uninvested points will remain yours.

The player who invested more in the box, will win that round's contest and wins the prize.

If the two players invested the same amount – each will receive half of the prize.

<u>The size of the prize you will get if you win depends on your investment and the other player's investment as follows:</u>

The initial size of the prize is 96 points.

[**Winner(+):**

Each point you invest will <u>add</u> 0.25 points (a quarter of a point) to the prize.]

[**Loser(+) / Loser(-):**

Each point the other player invests will <u>add / subtract</u> 0.25 points (a quarter of a point) to the prize.]

Note that investment are non-refundable – whether you win or lose the contest.

Therefore, in a round in which you did not win, your total will be 96 minus your investment.
In a round in which you won, your total will be 96 minus your investment plus the prize as described above.

In each round the computer will randomly select your opponent from the participating players.
Your characteristics and those of the opposing player will appear on each screen in which you have to make a decision.

And the payment?

The computer will calculate the number of points you have left and add the prize – if you received it – in this round.
At the end of every round you will see the round summary: Your determining investment, the determining investment of the other player, and whether you got a prize – and so, your corresponding total for this round.
At the end of the game, the computer will sum up the totals for all rounds, and points will be exchanged for shekels according to the following exchange rate: Every 70 points equals one shekel.

Appendix V

Regression Tables

Chapter I: Experiment 1A - average investment

	Coefficient	S.E.	*T*	*p*-value
self	0.427	0.143	2.99	0.004
opp	-0.282	0.115	-2.46	0.016
symmetric	9.827	2.754	3.57	0.001
Prize version	0.043	0.214	0.20	0.842
Prize*self	0.007	0.018	0.38	0.708
Prize*opp	0.003	0.014	0.18	0.857
Prize*symm	-0.001	0.001	-1.22	0.224
round	-0.046	0.293	-0.16	0.875

N=1536; S.E. adjusted for 96 clusters.
$F(8,95)=3.91$, $p<.001$; Model $R^2=0.064$, RMSE=30.928

Chapter I: Experiment 1A - investment relative to resource endowment

	Coefficient	S.E.	*t*	*p*-value
self	-0.0013	0.002	-0.76	0.451
opp	-0.0041	0.001	-2.97	0.004
symmetric	0.1312	0.033	3.92	0.000
Prize version	0.0004	0.003	0.15	0.883
Prize*self	0.0001	0.000	0.35	0.727
Prize*opp	0.0001	0.000	0.36	0.723
Prize*symm	0.0000	0.000	-1.25	0.215
round	-0.0002	0.004	-0.06	0.954

N=1536; S.E. adjusted for 96 clusters.
$F(8,95)=3.19$, $p<.001$; Model $R^2=0.052$, RMSE=0.374

Chapter I: Experiment 1A - rate of sitting out

	Coefficient	S.E.	*t*	*p*-value
self	-0.005	0.002	-3.21	0.002
opp	0.005	0.001	3.75	0.000
symmetric	-0.074	0.029	-2.58	0.012
Prize version	0.001	0.002	0.56	0.575
Prize*self	0.000	0.000	1.89	0.062
Prize*opp	0.000	0.000	-0.14	0.892
Prize*symm	0.000	0.000	0.59	0.558
round	0.004	0.003	1.42	0.159

N=1536; S.E. adjusted for 96 clusters.
$F(8,95)=5.15$, $p<.001$; Model $R^2=0.089$, RMSE=0.324

Chapter I: Experiment 1A - average earnings

	Coefficient	S.E.	*T*	*p*-value
self	1.262	0.071	17.71	0.000
opp	-0.407	0.087	-4.69	0.000
symmetric	-9.827	2.080	-4.73	0.000
Prize version	-0.793	0.107	-7.42	0.000
Prize*self	-0.023	0.009	-2.63	0.010
Prize*opp	0.014	0.011	1.31	0.194
Prize*symm	0.001	0.001	1.62	0.109
round	0.046	0.212	0.22	0.827

N=1536; S.E. adjusted for 96 clusters.
$F(8,95)=50.13$, $p<.001$; Model $R^2=0.231$, RMSE=33.055

Chapter I: Experiment 1A - round-to-round dynamics

	Coefficient	S.E.	*t*	*p*-value
Previous	-0.397	0.043	-9.25	0.000
win	-13.939	3.174	-4.39	0.000
Prev*win	0.230	0.068	3.40	0.001
self	0.221	0.119	1.87	0.065
opp	0.043	0.129	0.33	0.741
symmetric	2.844	3.119	0.91	0.364
self*win	-0.549	0.131	-4.21	0.000
opp*win	0.165	0.122	1.35	0.181
symm*win	-0.002	0.010	-0.23	0.815
Prize version	0.015	0.110	0.14	0.893
Prize*self	0.001	0.009	0.09	0.927
Prize*opp	0.002	0.007	0.27	0.788
Prize*symm	-0.001	0.001	-1.45	0.152
Round	1.543	1.664	0.93	0.356
Round*self	-0.009	0.013	-0.71	0.479
Round*opp	-0.013	0.015	-0.91	0.366
Round*symm	0.019	0.354	0.05	0.958
_cons	3.617	15.174	0.24	0.812

N=1348; S.E. adjusted for 96 clusters.
$F(17,95)=11.06$, $p<.001$; Model $R^2=0.248$, RMSE=25.483

Chapter I: Experiment 1B - average investment

	Coefficient	S.E.	*t*	*p*-value
self	0.425	0.182	2.34	0.021
opp	-0.138	0.098	-1.40	0.164
symmetric	2.363	2.356	1.00	0.318
Resource version	-0.557	0.273	-2.04	0.044
Resource*self	0.018	0.023	0.81	0.420
Resource*opp	-0.011	0.012	-0.87	0.387
Resource*symm	0.000	0.001	0.01	0.990
round	-0.513	0.279	-1.84	0.069

N=1536; S.E. adjusted for 96 clusters.
$F(8,95)=2.52$, $p=.002$; Model $R^2=0.054$, RMSE=32.590

Chapter I: Experiment 1B - rate of sitting out

	Coefficient	S.E.	*t*	*p*-value
self	-0.003	0.002	-1.52	0.131
opp	0.003	0.001	2.99	0.004
symmetric	-0.016	0.023	-0.69	0.492
Resource version	0.000	0.003	-0.18	0.855
Resource*self	0.000	0.000	1.65	0.103
Resource*opp	0.000	0.000	2.30	0.024
Resource*symm	0.000	0.000	-0.46	0.647
round	0.010	0.003	3.49	0.001

N=1536; S.E. adjusted for 96 clusters.
$F(8,95)=2.92$, $p<.001$; Model $R^2=0.051$, RMSE=0.341

Chapter I: Experiment 1B - average earnings

	Coefficient	S.E.	*t*	*p*-value
self	0.471	0.098	4.79	0.000
opp	-0.259	0.085	-3.06	0.003
symmetric	-3.723	2.029	-1.83	0.070
Resource version	-0.887	0.147	-6.01	0.000
Resource*self	0.014	0.012	1.14	0.256
Resource*opp	-0.022	0.011	-2.06	0.042
Resource*symm	0.000	0.001	-0.45	0.651
round	0.544	0.231	2.35	0.021

N=1536; S.E. adjusted for 96 clusters.
$F(8,95)=11.01$, $p<.001$; Model $R^2=0.087$, RMSE=33.821

Chapter I: Experiment 1B - round-to-round dynamics

	Coefficient	S.E.	*t*	*p*-value
Previous	-0.364	0.045	-8.09	0.000
win	-18.426	2.946	-6.26	0.000
Prev*win	0.353	0.071	4.97	0.000
self	0.174	0.109	1.59	0.115
opp	0.298	0.125	2.39	0.019
symmetric	3.682	2.970	1.24	0.218
self*win	-0.201	0.163	-1.23	0.222
opp*win	-0.082	0.122	-0.67	0.503
symm*win	0.002	0.010	0.24	0.810
Resource version	-0.123	0.116	-1.06	0.292
Resource*self	0.003	0.010	0.34	0.733
Resource*opp	-0.006	0.006	-0.96	0.339
Resource*symm	0.000	0.001	-0.61	0.544
Round	1.026	1.710	0.60	0.550
Round*self	0.011	0.012	0.90	0.372
Round*opp	-0.033	0.016	-2.09	0.039
Round*symm	-0.266	0.373	-0.71	0.478
_cons	-10.042	13.433	-0.75	0.457

N=1274; S.E. adjusted for 96 clusters.
$F(17,95)=9.83$, $p<.001$; Model $R^2=0.238$, RMSE=25.279

Chapter II: Average investment

	Coefficient	S.E.	*t*	*p*-value
self	12.947	4.272	3.03	0.003
opp	-7.023	1.953	-3.60	0.000
symmetric	4.933	1.951	2.53	0.012
PROB	-3.631	3.805	-0.95	0.341
PROB*self	-8.895	3.805	-2.34	0.021
PROB*opp	2.398	2.266	1.06	0.291
PROB*symm	-4.705	2.267	-2.08	0.039
ERR	12.905	3.757	3.43	0.001
ERR*self	1.402	3.757	0.37	0.709
ERR*opp	-0.774	2.751	-0.28	0.779
ERR*symm	-2.275	2.750	-0.83	0.409
ERR16	-2.594	4.229	-0.61	0.540
ERR16*self	-4.451	4.229	-1.05	0.294
ERR16*opp	0.169	2.499	0.07	0.946
ERR16*symm	-3.267	2.501	-1.31	0.193
round	-0.059	0.071	-0.84	0.404
_cons	47.831	8.784	5.45	0.000

N=5376; S.E. adjusted for 168 clusters.
$F(16,167)=12.94$, $p<.001$; Model $R^2=0.186$, RMSE=29.637

Chapter II: Rate of sitting out

	Coefficient	S.E.	*t*	*p*-value
self	-0.074	0.041	-1.78	0.077
opp	0.084	0.020	4.21	0.000
symmetric	-0.031	0.020	-1.56	0.121
PROB	-0.109	0.030	-3.59	0.000
PROB*self	0.077	0.030	2.54	0.012
PROB*opp	-0.077	0.024	-3.18	0.002
PROB*symm	0.029	0.024	1.20	0.231
ERR	0.007	0.037	0.18	0.854
ERR*self	-0.006	0.037	-0.17	0.863
ERR*opp	-0.015	0.029	-0.52	0.603
ERR*symm	0.015	0.029	0.51	0.613
ERR16	0.000	0.047	-0.01	0.996
ERR16*self	0.048	0.047	1.02	0.310
ERR16*opp	-0.024	0.025	-0.93	0.352
ERR16*symm	0.021	0.025	0.84	0.401
round	0.002	0.001	3.40	0.001
_cons	-0.083	0.067	1.25	0.214

N=5376; S.E. adjusted for 168 clusters.
$F(16,167)=6.18$, $p<.001$; Model $R^2=0.1439$, RMSE=0.300

Chapter II: Average earnings

	Coefficient	S.E.	*t*	*p*-value
self	26.969	2.527	10.67	0.000
opp	-8.893	2.005	-4.44	0.000
symmetric	-4.933	2.011	-2.45	0.015
PROB	3.631	2.347	1.55	0.124
PROB*self	-1.810	2.347	-0.77	0.442
PROB*opp	8.307	1.833	4.53	0.000
PROB*symm	4.705	1.835	2.56	0.011
ERR	-12.905	1.940	-6.65	0.000
ERR*self	-1.907	1.940	-0.98	0.327
ERR*opp	1.278	1.787	0.72	0.475
ERR*symm	2.275	1.786	1.27	0.205
ERR16	2.594	2.155	1.20	0.230
ERR16*self	-0.332	2.155	-0.15	0.878
ERR16*opp	4.614	1.963	2.35	0.020
ERR16*symm	3.267	1.971	1.66	0.099
round	0.059	0.070	0.84	0.403
_cons	71.194	5.237	13.59	0.000

N=5376; S.E. adjusted for 168 clusters.
$F(16,167)=41.43$, $p<.001$; Model $R^2=0.178$, RMSE=39.858

Chapter II: Round-to-round dynamics

	Coefficient	S.E.	*t*	*p*-value
previous	-0.308	0.028	-11.11	0.000
win	0.279	0.039	7.22	0.000
Prev*win	-14.482	1.951	-7.42	0.000
PROB	-0.311	2.198	-0.14	0.888
PROB*previous	-0.050	0.055	-0.90	0.367
PROB*win	-3.278	1.740	-1.88	0.061
PROB*prev*win	0.264	0.083	3.19	0.002
ERR	4.427	2.773	1.60	0.112
ERR*previous	-0.064	0.055	-1.16	0.249
ERR*win	-3.201	1.989	-1.61	0.109
ERR*prev*win	0.180	0.080	2.25	0.026
round	-0.083	0.026	-3.15	0.002
_cons	21.362	2.652	8.06	0.000

N=5060; S.E. adjusted for 168 clusters.
$F(12,167)=18.65$, $p<.001$; Model $R^2=0.186$, RMSE=23.770

Chapter III: Average investment

	Coefficient	S.E.	*t*	*p*-value
Wself	43.023	15.765	2.73	0.007
Wopp	27.035	8.722	3.10	0.002
Wself*Wopp	-141.668	69.777	-2.03	0.045
round	1.754	0.241	7.28	0.000
_cons	50.342	2.855	17.63	0.000

N=1728; S.E. adjusted for 108 clusters.
$F(4,107)=21.63$, $p<.001$.
Model $R^2=0.122$, RMSE=31.750

Chapter III: Average earnings

	Coefficient	S.E.	*t*	*p*-value
Wself	-3.149	10.600	-0.30	0.767
Wopp	-2.593	5.903	-0.46	0.661
Wself*Wopp	172.042	47.223	3.64	0.000
round	-1.638	0.227	-7.21	0.000
_cons	2.862	2.265	1.26	0.209

N=1728; S.E. adjusted for 108 clusters.
$F(4,107)=17.10$, $p<.001$; Model $R^2=0.044$, RMSE=41.353

Chapter III: Round-to-round dynamics

	Coefficient	S.E.	*t*	*p*-value
Previous	-0.384	0.065	-5.87	0.000
win	-2.821	0.814	-3.46	0.001
Prev*win	0.100	0.041	2.46	0.016
Wself	18.360	7.670	2.39	0.018
Wopp	12.200	4.527	2.69	0.008
Wself*Wopp	-69.711	34.022	-2.05	0.043
Wself*win	5.074	10.166	0.50	0.619
Wopp*win	2.847	6.577	0.43	0.666
Wself*Wopp*win	40.785	49.745	0.82	0.414
round	0.318	0.169	1.89	0.062
_cons	0.634	1.442	0.44	0.661

N=1356; S.E. adjusted for 108 clusters.
$F(10,107)=11.95$, $p<.001$; Model $R^2=0.265$, RMSE=25.098

בפרק III אני בוחנת השקעה בתחרויות בהן הפרס מושפע מן ההשקעות של המתחרים. כלומר, מתחרה יכול להרוויח יותר ככל שירבו משקיע יותר, או להרוויח פחות כתוצאה מכך. גם המתחרה עצמו עשוי להשפיע על גודל זכייתו. מצאתי כי ההשקעה הייתה גבוהה יותר כאשר השקעת המפסיד בתחרות הגדילה את הפרס שקיבל המנצח, ונמוכה יותר כאשר השקעת המפסיד הקטינה את פרס המנצח. בנוסף, ההשקעות היו גבוהות יותר כאשר השקעת המנצח עצמו הגדילה את הפרס. מעניין לראות כי במצבים מסוימים, נטיות אלו הובילו דווקא לרווח פחות: המשתתפים הרוויחו פחות בכמה מהתחרויות בהן הפרס תלוי בהשקעות המתחרים מאשר בתחרויות בהן הפרס קבוע מראש.

בכל התחרויות, בחנתי את השינויים בין השקעות בתחרויות עוקבות, כדי לבדוק אם השקעה לאחר ניצחון שונה משמעותית מזו הבאה לאחר הפסד. אכן מצאתי כי מעבר לכל התחרויות ולכל התנאים, הדינמיקה של ההשקעות מסיבוב לסיבוב יכולה להיות מוסברת באמצעות תגובה לתוצאת הסיבוב הקודם (ניצחון או הפסד): לאחר ניצחון, משתתפים נטו להוריד את ההשקעה העוקבת שלהם; לאחר הפסד, משתתפים נטו להעלות את ההשקעה. הבדל זה בין ניצחון והפסד נצפה לאורך כל סיבובי התחרות, מה שמרמז על כך שהדינמיקה אינה משקפת למידה או התאמה לכיוון השקעה אופטימלית, אלא משקפת תגובתיות לניצחון לעומת הפסד.

הממצאים מרחיבים את הידע שלנו לגבי מצבים תחרותיים בכלל, ולגבי השפעה של ההקשר על התנהגות השקעה בפרט. מבנה התחרות משפיע על מספר היבטים של ההתנהגות: על סך ההשקעה, על הנטייה להשתתף בתחרות ועל סך הרווחים מהתחרות. עם זאת, היבטים אחרים של ההתנהגות נשארים בעינם מעבר לתחרויות השונות: השאיפה לנצח ותוצאותיה.

תקציר

אינטראקציות תחרותיות מהוות חלק גדול מכלל האינטראקציות שלנו כבני אדם, ונפוצות מאוד גם בקרב בעלי חיים וצמחים – פרטים מתחרים על מזון, מרחב מחייה, בני זוג; תחרויות נפוצות בבתי ספר, במקומות עבודה, בספורט, במחקר ובפיתוח, במירוצים פוליטיים ובקונפליקטים בתוך ובין מדינות. בתחרויות אלו מושקעים משאבים רבים – זמן, מאמץ וכסף – והשקעות אלו אינן מוחזרות למתחרים, בין אם ניצחו ובין אם הפסידו בתחרות. המשאבים המושקעים בתחרות יכולים להועיל למתחרים ולחברה ככלל, למשל בתחרויות הנוגעות ליצירתיות או המעודדות פיתוח והמצאות; עם זאת, במגוון מצבים אחרים, השקעת משאבים בתחרות הינה בזבוז – כאשר התחרות גוברת אך לא נוצר שום הון חדש כתוצאה מההשקעות. כיוון שכך, הבנת המשתנים וההיבטים המשפיעים על כמות ההשקעה בתחרויות הינה בעלת חשיבות ועניין רב.

שלושת המחקרים בעבודה זו בוחנים התנהגות השקעה בתחרויות בהן ההשקעות לא מוחזרות. אני מציגה משחק ניסויי, "משחק ההשקעה", בו המשתתפים מקבלים החלטות השקעה במספר סיבובים (החלטות חוזרות). אני משנה את מאפייני התחרויות בניסויים השונים, על מנת לבדוק אם –וכיצד– השקעות מושפעות ממגוון משתנים פסיכולוגיים וכלכליים. אני בוחנת מספר היבטים של התנהגות השקעה תחת תנאים שונים: סך ההשקעה בתחרות; רווח (או הפסד) של המתחרים כתוצאה מהתחרות, ובהשוואה למשאבים ההתחלתיים; דינמיקת ההשקעה לאורך זמן, האם כרוכה בהסלמה או דעיכה של התחרות; וכן שינויים בהשקעה מסיבוב לסיבוב, ביחס לתוצאה (ניצחון או הפסד) בתחרות הקודמת.

בפרק I, אני בוחנת איך התנהגות מושפעת מאסימטריה (אי-שוויון) בין המתחרים. תחרויות הן לעתים קרובות לא סימטריות, כאשר למתחרים כמות שונה של משאבים או ערך שונה לזכיה בתחרות. בשני ניסויים בחנתי התנהגות השקעה בתחרויות אסימטריות, כאשר המתחרים שונים או בכוחם – כלומר בסך המשאבים שלרשותם – או במוטיבציה שלהם – כלומר בערך הפרס עבורם. המשתתפים התחרו הן בתחרויות סימטריות והן בתחרויות אסימטריות, כך שניתן היה להשוות בתוך-משתתף. אם אסימטריה מרתיעה את המתחרים החלשים יותר, ואם אכן כך, אם המתחרים החזקים לוקחים זאת בחשבון ומשקיעים פחות אף הם? ואולי השאיפה לנצח גוברת על ההבדלים בין המתחרים? אני מראה שאסימטריה במשאבים הובילה להשקעות נמוכות יותר לעומת תחרויות סימטריות, בפרט על ידי השחקנים החלשים; לעומת זאת, אסימטריה במוטיבציה לא השפיעה על ההשקעה.

בפרק II, אני בודקת איך הוספת רעש לכלל הקובע את המנצח בתחרות משפיעה על השקעה הן בתחרויות סימטריות והן בתחרויות אסימטריות, כאשר האסימטריה מתבטאת בהבדל במשאבים. מנצח התחרות נקבע לפי כללים שונים: כלל הסתברותי, כלל הכולל רעש מקרי, או כלל דטרמיניסטי לפיו המנצח הוא המתחרה שהשקיע יותר. השאלה המרכזית הייתה אם כאשר אנשים בעלי משאבים שונים מחליטים כמה להשקיע בתחרות, כי אז רעש בהערכת ההשקעות משפיע על החלטותיהם? ההשקעה הייתה גבוהה יותר בתחרויות הכוללות רעש מקרי, בהשוואה לתחרויות הסתברותיות או דטרמיניסטיות. כמו בניסוי הקודם, גם כאן אסימטריה במשאבים הובילה להשקעות פחותות, אבל השפעה זו הייתה מתונה יותר בתחרות ההסתברותית. התוצאות מרמזות על כך שרעש – אשר נמצא ברוב התחרויות – יכול לעתים להיות מועיל; למשל, סוג מסוים של רעש יכול להפחית את ההשפעה של אי-שוויון בין המתחרים; סוג אחר של רעש עשוי לעודד השקעה.

עבודה זו נעשתה בהדרכתם של:

יעקב קריב ויהודית אברהמי

״עלות התחרות ודחף הניצחון״

חיבור לשם קבלת תואר דוקטור לפילוסופיה

מאת

עינב הרט

הוגש לסנאט האוניברסיטה העברית בירושלים

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