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PREFERENCE REVERSAL AND NETWORKS

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To my mother

Without her, this would not have been possible...

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Studying in Barcelona for a PhD degree will always constitute a big chapter in my life. This thesis is a product of these past five years spent on this challenging path. Then again, it would be impossible to handle it all if it was not for those people that I am indebted to.

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Abstract

This thesis uses an experimental approach in understanding group decisions and interactions in networks and perceiving individual decisions causing preference reversal. Chapter 1 experimentally introduces different communication schemes to a production model of a costly good that is non-excludable among individuals linked within a network. Results show that one-way communication is not as efficient as in earlier literature; yet communication among maximal independent sets enhances coordination. Chapter 2 experimentally analyzes a model of multiple bilateral conflicts embedded in networks where opponents invest in conflict technology to win resources. It concludes on tendency to invest in excess of equilibrium predictions. Finally, Chapter 3 looks at whether preference reversal is driven by an endowment effect explanation originating from status quo bias. This is analyzed through questioning individuals' willingness to exchange their endowed lottery for another lottery or sure money. Contrary to the predictions, results show that individuals most often disclaim their endowments.

Resumen

Esta tesis utiliza un enfoque experimental para comprender las interacciones dentro de redes y percibir las decisiones causando inversión de preferencia (IP). El Capítulo 1 experimentalmente introduce comunicaciones no vinculantes a un modelo de producción de un bien costoso, que es no excluible entre personas vinculadas en una red. Los resultados muestran que la comunicación de dirección única no mejora coordinación tanto como la comunicación entre conjuntos máximos independientes. El Capítulo 2 analiza experimentalmente un modelo de conflictos bilaterales integrado en redes, donde los oponentes invierten para ganar recursos. Concluye sobre exceso de inversiones comparado a las predicciones de equilibrio. Por último, el Capítulo 3 mira si el efecto dotación inicial resultado de status quo conduce IP. Esto es analizado por la interrogación de la buena voluntad de cambiar una lotería dotada para otra o pago seguro. En contrario de las predicciones, resultados demuestra que dotaciones son renunciadas con frecuencia.

Preface

Among many factors that affect decisions, a very crucial one is uncertainty. In decision making scenarios, one can be involved with uncertainty in the form of strategic uncertainty while interacting with other decision makers or in the form of risk when taking individual decisions in stochastic environments.

Economies that exhibit strategic interdependence can be analyzed through deductive equilibrium analysis, yet most often this approach fails to determine a unique equilibrium. Chapter 1 of this thesis tries to resolve issues resulting from strategic uncertainty in the model of Bramoullé and Kranton (2007) that analyzes the production of a costly good non-excludable among individuals who are linked within a given network. The main analysis in this chapter is centered on two simple network structures - the star and the circle. My first results show that equilibrium play cannot replicated in experiments with repeated one shot games setup. Conjecturing that this discrepancy in theoretical and experimental results is attributable to the strategic uncertainty due to the existence of multiple equlibria, I introduce several different nonbinding communication possibilities before the actual decision stage in order to resolve coordination issues.

As an experimental analysis on the effectiveness of communication has not been studied earlier in network setups, three different communication mechanisms are made use of to test the efficacy of pre-play communication. The first scheme, referred to as the one-neighbor communication scheme, selects a random player to make an announcement on intention of play at the communication stage. Later this announcement is communicated within the network only to the direct neighbors of the communicator. The second mechanism, public communication, takes a randomly selected player to announce his intention of play which is to be communicated to all players in the network. This mechanism is equivalent to one-way communication proposed by Cooper, DeJong, Forsythe and Ross (1989) since information on intention of play is available to all players irrespective of network structure. Finally, the third mechanism, the independent communication scheme allows for non-binding pre-play communication among sets of disconnected players. In contrast to earlier literature of experiments with communication, results show that one-way communication does not necessarily improve upon coordination failures in the modified setup of Bramoullé and Kranton (2007). However, I show that they can be improved upon when allowing for communication among maximal independent sets in networks.

Meanwhile, Chapter 2 is related to the economic analysis of conflict situations concentrating on rent-seeking contest games, where individuals' probability of winning is a source of risk since it is proportional to one's investment relative to the total investment made by both parties. Chapter 2 addresses how networks differing in degree and size affect individual and total conflict investments. The experimental approach used in this chapter makes use of the theoretical model of Franke and Öztürk (2009) on conflict networks. In this model, multiple bilateral conflicts among individuals are integrated in a fixed network structure. For each bilateral conflict, i.e. for each link, an individual is involved in within the network; s/he can gain resources by investing. The contest game introduced by Tullock (1980) determines the winner of each conflict in accordance with investment decisions. The experimental design looks at two classes of networks, i.e. regular versus irregular. On one hand, complete and circle graphs are considered within the class of regular networks to assess the impact of differences in degrees; on the other hand, star networks are under focus in the class of irregular networks as they are exemplary of decentralized structures. Furthermore, for each graph under discussion a variation of between three and five nodes is implemented to encapsulate the effects of differences in size.

Results of this chapter demonstrate that although investment levels are closer to the equilibrium as networks become more regular; there is still a tendency of the subjects to over invest. Moreover, over investment behavior observed in conflict investments per link is also reflected into total conflict investment. As a second result, in contrast to the prediction that subjects should use an equal investment strategy for all links they are a part of, within the class of regular networks significant differences are observed in the investments per each link. As for star networks, in the treatment with five nodes, center players are better in using this equal strategy prediction in comparison to those subjects in the treatment with three players. Overall, these findings exhibit the influence of different networks structures in investment decision and also reveal the importance of network structures for peaceful conflict resolution.

Chapter 3 looks into the perplexing preference reversal phenomenon primarily observed when individuals are taking risky decisions within a stochastic environment. Preference reversal (PR) behavior was first demonstrated through the findings of Lichtenstein and Slovic (1971) where in a pair of lotteries subjects preferred one lottery to the other while placing a higher selling price on the "undesirable" lottery in the pair. In this chapter, this choice, contradicting with the expected utility theory predictions that preferences should be independent of the elicitation procedure, is analyzed to see whether it is driven by the behavioral explanation of an endowment effect in accordance with the theory of Masatlioglu and Ok (2005). In all PR experiments, within the task of elicitation of prices, individuals are given each lottery as an initial endowment. Keeping this as a motivation, this method might induce subjects to claim higher prices due to an endowment effect. Yet, these high prices driven by the endowment effect can comply with individuals' preferences within the revealed preference framework of Masatlioglu and Ok (2005) that allows for status quo bias. Hence, to conclude whether endowment effect is actually the driving force behind their decisions or not, there are two basic questions that motivate this chapter: whether individuals would be willing to exchange an initial endowment with an alternative lottery <u>and</u> whether individuals would be willing to give up their endowment towards earning a sure amount of money determined according to their minimum selling prices.

According to the predictions, independent of earlier choice among lotteries, decision of holding onto one's endowment should be optimal when offered a sure amount that is less than your valuation. However, as a first result in this chapter, findings show that a substantial amount of the observed decisions counteract to this argument. Still, the most striking result appears in analyzing the decisions of the task of switching lotteries. It is observed that participants have a very high tendency to give up their endowments as opposed to holding onto them as the theory predicts. Hence, it seems that a decision of adhering to your lottery is most often irrelevant of which lottery you preferred or which lottery you have priced higher.

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1. COMMUNICATING PUBLIC GOOD PROVISIONS IN NETWORKS

1.1. Introduction

Communicating information to friends, neighbors and colleagues is a common phenomenon. The acquired knowledge on experiences of friends and colleagues helps decisions related to purchase of a new product, investment in a new technology or launching a research project. This is why the analysis of social and economic networks in modeling this phenomenon has recently attained more importance in economics.

There is a vast literature that analyzes the effect of exchange of information in innovation. Foster and Rosenzweig (1995) analyze the effects of farmers' own experimentation along with learning from neighboring farmers on adoption of high-yielding seed varieties newly introduced during "Green Revolution" period in India. Their results show that the profitability of farmers is higher if they have access to experienced neighbors. Yet, they have the propensity to invest less in experimentation of this new technology as their neighbors experiment more, showing their tendency to free-ride on the information obtained by other farmers. Conley and Udry (2001) similarly analyze the role of dissemination of information in the implementation of a new agricultural technology in Ghana. They also show that farmers mimic the successful behavior of neighboring farmers.

People get access to new information through their own private research or collecting information from friends or colleagues that belong to their information neighborhood, i.e. network. Hence, this beneficial information is a public good among individuals that are linked and have a flow of information. Bramoullé and Kranton (2007) take these findings a basis to analyze the production of a costly good that is non-excludable among individuals who are linked to exchange information within a fixed social structure. Keeping this social/geographic structure among individuals fixed, they analyze the effect of these network structures on the level and pattern of public good provisions. As their first result, they characterize the Nash level of contributions. They find that for any network structure there are equilibria where some individuals contribute and others free ride. These specialized equilibria follow as a result of efforts being strategic substitutes. As they are faced with multiple equilibria, they later restrict these equilibria to stable ones. The notion of stability used corresponds to the convergence of contribution levels using a Nash adjustment process. They show that a stable Nash equilibrium for any given network structure has to involve some individuals contributing to the public good while others completely free ride.

Hence, the first question of this chapter is to see whether equilibrium predictions would hold in a laboratory environment. Since there are multiple equilibria to consider for most of the network structures, experimental results would also resolve the question whether stable or unstable equilibria are observed more often. Yet as Van Huyck, Battalio and Beil (1990) asserts “In economies with multiple equilibria, the rational decision maker … is uncertain which equilibrium strategy other decisions makers will use and …this uncertainty will influence the rational decision-maker’s behavior. Strategic uncertainty arises even in situations where objectives, feasible strategies, institutions, and equilibrium conventions are completely specified and are common knowledge." (p.234) Consequently, with the existence of multiple equilibria under this setup, it is quite likely that subjects will face problems of equilibrium selection. Moreover, the characterization of specialized equilibria in simple network structures (like the star and the circle) favors one set of disconnected subjects while disfavoring the other set of disconnected subjects. The resemblance of these specialized equilibria to those observed in a Battle-of-Sexes game is another reason why it is highly susceptible that agents will solve issues of coordination.

This provides an incentive to create a mechanism in the design to induce coordination. There is a wide literature that tries to resolve issues of coordination. One approach towards this end has been to introduce cheap talk or a nonbinding communication pre-stage before the actual decision stage. This approach was first experimented by Cooper et al. (1989) and Cooper, DeJong, Forsythe and Ross (1992). They find that in a Battle-of-Sexes game when communication is allowed for only one player, equilibrium play is achieved in 95 percent of the time. Yet, if simultaneous communication is allowed for both players, equilibrium play after equilibrium announcements is observed only 80 percent of the time, but this rate can be improved upon when allowing for communication for more than one round. In line with this literature, this chapter will also introduce a costless and non-binding pre-communication stage on the intention of play within the described network framework.

To my knowledge, communication under networks has not been considered experimentally in the earlier literature. Therefore, it will be necessary to further elaborate on the type of communication schemes under a network setup. There are three different mechanisms under consideration. As a first possibility, the communication stage selects a random player to make an announcement on his intention of play. Later this announcement is communicated within the network only to the direct neighbors of the communicator. The results with this additional communication stage demonstrate that this does not provide an improvement on the observed behavior in the laboratory. The second mechanism to test will consider the option of a public announcement. The announcement is again made by a randomly selected player but this time it is communicated to all players in the network. The results under this communication scheme do not improve upon the frequency of observed equilibria play, either. The third communication scheme, instead of picking one player at random to make an announcement, will consider one set of maximal independent players to make an announcement and communicate these announcements only to the direct neighbors of the announcers. Under this mechanism, equilibrium selection is more successful in the star network. The equilibrium in which the center player free rides on the contributions of periphery players is selected over the equilibrium in which peripheries free-ride on the contribution of center player.

1.2. Literature

Theoretical analysis of cheap talk has been considered under private and complete information. Crawford and Sobel (1982) introduced a cheap talk model where a sender communicates with a receiver who has similar but not identical preferences and is less informed. In this framework, babbling equilibria, where sender's message is uninformative and thus ignored by the receiver, always exist. Moreover, even when sender's message contains at least some information, their results establish multiplicity of equlibria. On the other hand, Farrell (1987, 1988) analyzed the situation where a communication stage on intentions of play precedes an underlying game. In this sequential game with complete information, they demonstrate that communication provides a chance to resolve coordination problems, though not at full efficiency.

Farrell and Rabin (1996) classify a message to be highly credible if it is self-signaling and self-committing. A message is self-signaling if the sender truly intends to play his signaled action as he prefers the receiver to best-respond to this signal. On the other hand, a self-committing message is one that is part of a Nash equilibrium strategy, creating an incentive for the speaker to fulfill it. On the other hand, Aumann (1990) argues that self-committing messages need not necessarily be credible, i.e. self-enforcing. Charness (2000) to test this disagreement among Farrell (1988) and Aumann (1990) experimentally, considers two treatments. In one treatment, senders signal their action and then decide on their actual play, while in the second the order of signaling and decision taking is reversed. In both treatments, receivers take actions after they learn senders' signals. His results also show that coordination is higher when one-way communication is allowed. However, when actions precede signals, results are not different from those without communication. Clark, Kay and Sefton (2001) also looks into Aumann (1990)'s conjecture that communication effectiveness will depend on the payoff structure. Their analysis also replicates the fact that communication improves coordination.

In the meanwhile, Duffy and Feltovich (2002, 2006) use Farrell and Rabin (1996)'s aforementioned nomenclature. They use communication and observations on past behavior for affecting cooperation. In their earlier work, they show that effectiveness of either of these two depends on the structure of the game under consideration. In their later study, apart from observing signals and past behavior, they also allow for observations on signals from one previous round. This extra treatment allows them to see how subjects weigh these two means of signaling, cheap talk and observations on previous actions. Their additional treatment leads to more cooperation, yet these rates are lower than those when only one of these means is available. Charness and Grosskopf (2004) also study the interaction of communication with observation on previous-round actions. They find that providing information about actions is a factor that substantially increases coordination when there is also the opportunity to communicate about intentions of play.

Burton and Sefton (2004) consider two games both with a unique Nash equilibrium. Both games have similar structure of payoffs, except for two outcomes. In one game, equilibrium strategy involves high strategic uncertainty because if coordination is not achieved on the equilibrium outcome, then a negative payoff is probable for either player. Their results show that without communication in the risky game, people play their maximin strategies while equilibrium play is more easily achieved under the less risky game. Yet one introduces communication to this setup, propensity to coordinate highly increases in the risky game. For a pure coordination game, Parkhurst, Shogren and Bastian (2004) analyze reputation effects in a repeated game (using fixed matching) in comparison to one-shot games (using random matching). For both scenarios they also allow for communication. They show that repetition without preplay communication enhances coordination, yet when preplay communication is allowed, efficiency of cheap talk in terms of coordinating is higher under random matching. Blume and Ortmann (2007) study the effect of preplay communication in median and minimum effort games with multiple Pareto-ranked equilibria – from the framework of Van Huyck et al. (1990) and Van Huyck, Battalio and Beil (1991) – with more than two players. Their results also support that strategic uncertainty, equilibrium selection and coordination is resolved with the help of costless messages on intentions of play.

Isaac and Walker (1988) was the first paper to show that face-to-face communication in a voluntary contribution mechanism decreases the free-riding behavior. Afterwards, in a repeated public goods setting Wilson and Sell (1997) analyzed the effect of preplay communication along with information on past behavior (reputation). In contrast to the work of Isaac and Walker (1988), their results on individual level showed that preplay communication hardly matches the actual contribution decisions and hence acts more like cheap talk. Bochet, Page and Putterman (2006) also study possibilities of communication in a voluntary contribution setting. This paper analyzes the effect of different means of communication – face to face, in a chat room and numerical. They also allow for punishment in each possible communication scheme. They showed that face-to-face communication is the most effective means of communicating in terms of increasing cooperation. Open-ended but anonymous verbal communication in an on-line chat room was also effective but not as much as face-to-face meetings. Moreover, the additional punishment possibility did not significantly alter cooperation levels. As numerical cheap talk did not improve cooperation levels, in a later study, Bochet and Putterman (2009) looked further into the possibility whether making promises on levels of contributions would result better than just announcing intentions of play. They note in this paper that earlier study's result on numerical cheap talk is mainly due to inter-group differences in the extent to which subjects made false announcements misleading other group members.

Although social networks have been of extensive interest and thus thoroughly analyzed through theoretical models, experimental work on networks is quite limited and is still in the path of progress. The line of research that has been under taken in terms of experiments on networks can be summarized in three categories.[1]

The first set of experiment focuses on the influence of different network structures on equilibrium selection. Keser, Ehrhart and Berninghaus (1998) analyze equilibrium selection in a 2x2 coordination game (with Pareto ranked equilibria) comparing interaction with everybody within the group to a local interaction possibility with direct neighbors in a circle network structure. They show that local interaction allows subjects to coordinate on the risk-dominant

[1] For more detailed discussion on experiments on networks, refer to Kosfeld (2004).

equilibrium whereas without local interaction coordination the play converges to the payoff-dominant equilibrium.[2] Berninghaus, Ehrhart and Keser (2002), on the other hand, analyze equilibrium selection within two different possible setups of local interaction: the circle and the lattice. Even though subjects are not aware of the kind of neighborhood structure they are involved in, their results show that coordination is more likely to focus on the risk-dominant equilibrium under the lattice than in the circle. They explain this observation as a result of the fact that subjects observe less individual decision changes under the circle than in the lattice.

Rosenkranz and Weitzel (2008), running an experiment under the setup of Bramoullé and Kranton (2007) mainly focus on the effects of global structures on the behavior on an individual level. They use a within subject design where groups of four subjects, which remains the same until the end of the experiment, take investment decisions under four different network structures. They also test whether there is any coordination on predicted equilibria. They find that this strongly depends on the network structure subjects are assigned to. Their results show that there is only a coordination of 0.4% in the circle and 4.7% in the star network. Hence, results of Rosenkranz and Weitzel (2008) also support my skepticism on coordination failures. Furthermore, in terms of convergence to a stable equilibrium, in the star network, convergence is observed for the equilibria where the center free rides on periphery investments. Additionally, results show

[2] Boun My, Willinger and Ziegelmeyer (1999) adapt the setting of Keser et al. (1998) by varying payoffs for the risk dominant and payoff dominant equilibrium in the 2x2 coordination games. As opposed to Keser et al. (1998), their results show that there is no significant difference in terms of convergence to the risk-dominant equilibrium under global and local interaction.

that convergence under the star network is more stable relative to other three network structures. Rosenkranz and Weitzel (2008) also argue that existence of multiple equlibria for all network structures adds to a strategic uncertainty in the investments of agents, thus they propose that personal risk attitudes may also explain investment decisions. Towards this end, their predictions propose that a risk-averse agent should contribute more, yet their results show to the contrary that relatively risk-averse individuals invest less.

The second category of experiments on networks is directed on cooperation. Kirchkamp and Nagel (2007) consider interaction through a repeated prisoner's dilemma game on a circle. They test to see if cooperation is more likely under this local interaction than in a global interaction setting since players can imitate successful behavior of their neighbors. Their results show that as opposed to the theoretical predictions, cooperation dies out a lot faster under the possibility of local interaction and that players' own successful strategies reinforce learning more rather than naïve imitation of neighbors' successful behavior. Cassar (2007) examines the influence of local, random and small-world networks on the sustainability of cooperation and coordination. Results show that though coordination is more likely on the payoff dominant equilibrium in all three networks, play of payoff dominant strategy is observed with significantly more frequency under small-world networks than in the other two structures. As for the prisoner's dilemma game, it is observed that cooperation is less likely to be achieved in all three networks, particularly with the lowest average cooperation rate in small-world networks. Riedl and Ule (2002) show that cooperation rates are at a more sustainable rate if players can determine who will belong to their neighborhood of play.

Another important line of research on experiments in networks tries to address a crucial question: how networks form. Falk and Kosfeld (2003) test the network formation model of Bala and Goyal (2000), and their results show that subjects are successful in forming strict Nash networks in the 1-way model, but these equilibrium predictions cannot be reproduced in the case of 2-way flow model. Callander and Plott (2005) analyze how networks emerge and what kind of individual decision making processes guide this procedure. Their main results show that emerging networks converge to a pattern that has traits consistent with Nash equilibrium. Rather than using a (Nash) best response model by Bala and Goyal (2000), individuals tend to use simple strategic responses. This paradox between the support for equilibrium in the model but not for the individual decisions leading to the equilibrium is explained through strategy commitment of some agents which may have initiated a means of learning "appropriate" behavior by others. Goeree, Riedl and Ule (2007) consider a network formation game allowing for heterogeneity of agents. They show that stars emerge among heterogeneous agents consistent with equilibrium predictions, which fail to be the case among homogeneous agents.

This chapter compared to this strand of literature will also address an equilibrium selection problem, but rather than a 2x2 coordination game, I will use a public goods setup where provisions are strategic substitutes. The equilibria are asymmetric as in a Battle-of-Sexes game, and they are Pareto optimal, but only one is socially optimal. Hence the purpose of this part of the thesis will be resolving coordination problems and focusing on individual cooperation behavior in the described setup. These issues will be tackled under exogenous networks rather than focusing on formation of these structures.

The chapter will be organized as follows. Section 2 will present an introduction to the model by Bramoullé and Kranton (2007). Section 3 will give the details of the design of the experiment along with the theoretical predictions. Section 4 will summarize the results while finally Section 5 will conclude and elaborate on possible further research.

1.3. Braumollé and Kranton's Model

a) The Model

The model of Bramoullé and Kranton (2007), henceforth denoted as BK, considers a group of individuals $N = \{1, 2, ..., n\}$ arranged in a network where benefits within a link flow in both directions. Each individual has to exert an effort level x_i, where marginal cost of exerting this effort is assumed to be constant and equal to c. The central assumption in the model is the substitutability of effort levels. Since benefits flow in both directions within a link, effort levels of each individual is a substitute of her neighbors, but not of her neighbors' neighbors. That is to say, an individual can benefit only from the effort levels of her direct links. Moreover, a neighbor's effort is also a perfect substitute of one's own. Thus, with these assumptions an individual i derives benefits from the total of her own and her neighbors' efforts.

The generic form of the benefit function considered is a strictly concave increasing benefit function $b(x)$ where $b(0) = 0$. Let $\mathbf{x} = (x_1, x_2, ..., x_n)$ denote the effort profile of all individuals. Hence with the earlier assumptions an agent's benefit is given by $b\left(x_i + \sum_{j \in N_i} x_j\right)$ where N_i denotes the set of direct neighbors an individual i has. Thus, an individual's payoff from profile $\mathbf{x}$ in a given network $\mathbf{g}$ is then

$$U_i(\mathbf{x}; \mathbf{g}) = b\left(x_i + \sum_{j \in N_i} x_j\right) - c \cdot x_i \tag{1.1}$$

b) Characterization of the Equilibria

The characterization of the Nash equilibrium level of efforts goes along in the following manner. Let $\mathbf{x}^*$ be the effort level at a single node where marginal benefits to an individual is equal to its marginal cost within a link, i.e. $b'(\mathbf{x}^*) = c$. Then profile $\mathbf{x}$ is a Nash equilibrium if and only if for every individual i either

(1) $x_i \geq \mathbf{x}^*$ and $x_i = 0$ or

(2) $\overline{x}_i \leq \mathbf{x}^*$ and $x_i = \mathbf{x}^* - \overline{x}_i$

where $\overline{x}_i$ is the total effort exerted by i's neighbors. Hence, an individual exerts effort as long as the total efforts exerted by her neighbours does not exceed $\mathbf{x}^*$. If total effort level of her neighbors is less than $\mathbf{x}^*$, then the individual will exert effort up to the point that will cover up for this shortage.

To elaborate on this characterization further, consider the following two network structures for four individuals given in Figure 1.1 which will be the main focus of this experimental study as well. The star network will have one individual in the center with the rest linked to the center. As for the circle network, all individuals will be linked to each other in a recursive manner.

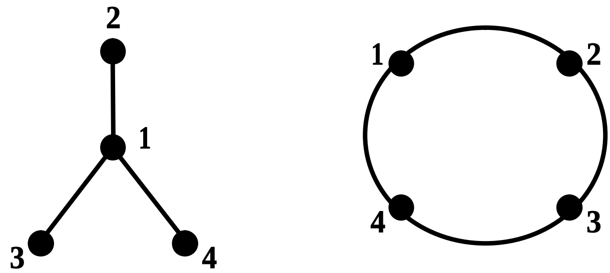

Figure 1.1. Star and Circle Networks

On the star network, there are two equilibria. The first equilibrium has the center that is linked to all other individuals in the society to exert all the effort, while the rest free rides on center's efforts. In the other equilibrium, peripheries, individuals linked only to the center and to nobody else, exert all the effort and the center free rides on their effort levels (Figure 1.2). These two equilibria will be referred to as specialized equilibria. In fact, any equilibrium profile where every individual either exerts the maximum amount of effort $\mathbf{x}^*$ or exerts no effort will be classified as a specialized equilibrium profile. Furthermore, individuals who provide this maximum effort level of $\mathbf{x}^*$ will be referred to as the specialists.

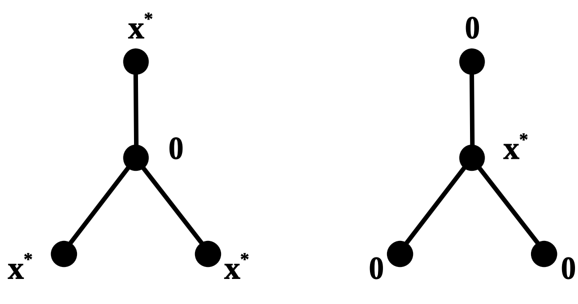

Figure 1.2. Equilibria in the Star Network

As for the circle there will again be two different equilibria. In one, the effort level will be distributed among all individuals, whereas in the other one a subset of individuals will exert effort; while the rest free rides (Figure 1.3). Hence, in this network structure, there again is a specialized equilibrium where half of the individuals are specialists whereas the other half is non-specialists.

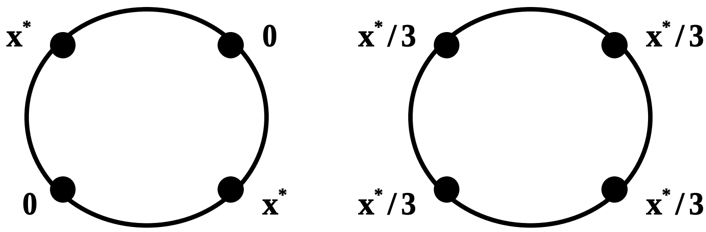

Figure 1.3. Equilibria in the Circle Network

1.4. Design of the Experiment

a) Experimental Game

In this experimental setup, theoretical model proposed and analyzed by BK is implemented. In all treatments, there are groups of four individuals, i.e. n = 4. To keep in line with the model analyzed and to keep the analysis as simple as possible, only the star and circle networks will be analyzed. Moreover, to make the results more comparable with that of a regular public good game, the game will be similar to that of a public goods provision game.

In a typical public good experiment, returns from the public good would be linear and same for everyone. Returns from the public good under this setup are no longer linear. On the contrary, as described in BK, they are increasing at a decreasing rate. The returns from total contributions, which will also be used in the experimental game, are given in Table 1.1.

Total contributions to one link	**Benefits to *i***	**Marginal Benefits to *i***	**Total contributions to one link**	**Benefits to *i***	**Marginal Benefits to *i***
0	0				
1	33	33	**7**	142	13
2	60	27	**8**	154	12
3	82	22	**9**	165	11
4	100	18	**10**	175	10
5	115	15	**11**	184	9
6	129	14	**12**	192	8

Table 1.1. Benefits from total contributions in a public account

As opposed to the total symmetry of a regular public good game, return on the public good in this setup is going to be symmetric only for those players with the same number of neighbors. This difference can be explained in the following manner. In a typical public good experiment, returns of the total contributions are divided equally among all individuals. In this game, this would have been the case if all individuals were in a complete network, where everyone is directly linked to each other. However, within a network structure different from that of the complete network, an individual does not necessarily have a direct link to all others. Thus, in the end, he can only benefit from the contributions of those individuals who he is directly connected to. Hence, most of the time, an individual with more links enjoys more benefits from the total contributions compared to the individuals with fewer direct links.

The subjects are given an endowment of **3** tokens in each round. Each subject is assigned to a position in a fixed network structure of a star or a circle. They have an option of putting their tokens in a public account or a private account. For every token they keep in their private account, they have a return of **21** per token. Hence, if they choose not to invest anything into the public account, at the end of one round, their payoff will be **63**.

First note that, as opposed to the direct cost introduced within the theory of BK, in this setup, this cost is introduced implicitly. That is to say, the cost of not investing into the public account is to keep tokens in the private account. Hence, the cost of not investing is c = **21**. To put it more formally, let x_i be the amount of tokens put in the public account by individual *i*, and x_{-i} be the amount of tokens invested into the public account by the direct neighbors of *i*. Then her payoff can be written as,

$$U(x;\mathbf{g}) = b(x_i + x_{-i}) + 21 \cdot (3 - x_i) \tag{1.2}$$

Hence, the first term refers to the benefits of the public good and the second term refers to the benefits of the private account.

b) Predictions for the Star Network

Note that the center player, player 1, apart from his own contribution, can get to benefit from a maximum of 9 tokens contributed by his direct neighbors, periphery players – players 2, 3 and 4 (Figure 1.1). Hence, with the mentioned form of payoffs (1.2) and given the total contributions of the peripheries, the payoff to the center is as shown in Table 1.2.[3]

---

3 For a better understanding on calculating the payoffs for each player, please refer to the example in Appendix A.

TOTAL CONTRIBUTION OF PERIPHERIES

CENTER's Contribution	0	1	2	3	4	5	6	7	8	9
0	63	96	123	145	163	178	192	205	217	228
1	75	102	124	142	157	171	184	196	207	217
2	81	103	121	136	150	163	175	186	196	205
3	82	100	115	129	142	154	165	175	184	192

Table 1.2. Payoff to the center given the total contributions of peripheries

In this table, highlighted cells correspond to the best responses of the center player. For example, if the total contributions of the center's periphery neighbors are equal to 0, then his best-reply is to contribute 3. On the other hand, if total contributions of the center's periphery neighbors are greater than or equal to 3, then his best-reply is to contribute 0. Note also that for a given level of the center's contribution, as a consequence of the given benefit function he earns more as his neighbors contribute more. However, the relationship in the other direction is not as immediate. Given the total contributions of the peripheries, the center player does not necessarily earn more the more he contributes. More specifically, if peripheries contribute a total of 3 or more tokens, then center player loses as he contributes more.

As for the peripheries, since their single neighbor is the center player, maximum number of contributions they can benefit from their single neighbor is equal to 3. Hence to calculate their final payoffs, one needs to consider a smaller version of Table 1.2, so as to say a table that includes only the first four columns. In this manner, the rows labeled from 0 to 3 will correspond to periphery's own contribution and columns again labeled from 0 to 3 will correspond to contributions of their unique neighbor, the center player. Explanations given earlier for Table 1.2 will also apply here.

Equilibrium Predictions

Now given the number of players, their strategy space, i.e. number of tokens to be invested in each round, and their payoffs, one can elaborate on the predicted equilibria in this game. The equilibrium number of total tokens to be contributed to the public account is determined by the point where the marginal benefit of contributing an extra token to the public project is greater than or equal to the marginal cost of it. In BK, the benefit function under consideration is continuous. Thus, the equilibrium level is the point with marginal benefits exactly equal to the marginal cost. However, in this setup, as a discrete version is considered, the optimal point is the point where marginal cost does not exceed marginal benefit of contributing an extra token. As the marginal cost of not contributing is **21**, the highest level of total contributions where this cost does not exceed marginal benefits is at a level of 3 tokens.[4] This tells that in the equilibrium every individual has to have access to a total minimum of 3 tokens in the public account they can benefit from. Hence, there are two possible Nash equilibria demonstrated in Figure 1.4. In the figure, the Nash equilibrium on the left will be referred to as the periphery-sponsored equilibrium since only peripheries contribute to the public accounts. On the other hand, since it is only the center contributing to the public accounts, the equilibrium on the right will be referred to as the center-sponsored equilibrium.

[4] **3** tokens have a marginal benefit of 22 while **4** tokens have a marginal benefit of 18 according to the benefit table given in Table 1.1.

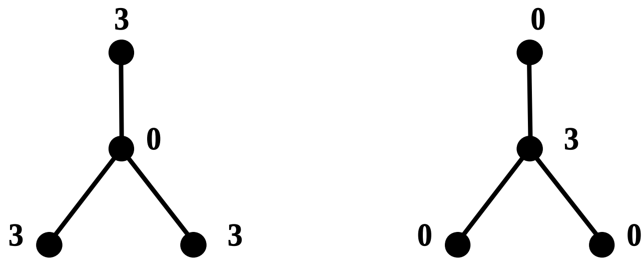

Figure 1.4. Nash Equilibria in the star network under the described game

Efficient contributions

The next concern is to determine the efficient level of contributions. First one needs to define the efficient level of contributions. As in BK, a utilitarian approach will be utilized to express the welfare of a profile of contributions **x** in the fixed network structure **g**. Hence the total welfare $W(\mathbf{x};\mathbf{g})$ is equal to the sum of payoffs of the individuals:

$$W(\mathbf{x};\mathbf{g}) = \sum_{i\in N} b(x_i + \bar{x}_i) - c\sum_{i\in N} x_i \qquad (1.3)$$

where $\bar{x}_i$ is the sum of contributions of *i*'s neighbors. Thus, a profile of contributions **x** is be *efficient* if and only if there is no other profile **x'** such that $W(\mathbf{x}';\mathbf{g}) > W(\mathbf{x};\mathbf{g})$.

In the first place, welfare of the Nash equilibrium profiles will be determined. In the periphery-sponsored equilibrium, the center benefits from a total of **9** tokens and according to Table 1.2 has a total payoff of **228** whereas each periphery benefits from only **3** tokens and hence each has a payoff of **82**. Hence, the total welfare of a periphery-sponsored star is $W(\text{periphery-sponsored; star}) = 228 + 3\cdot 82 = \mathbf{474}$. On the other hand, in the center-sponsored equilibrium, both the center and the peripheries benefit from a total of **3** tokens. According to Table 1.2, this gives a total payoff of **82** to the center and a total payoff of **145** to each periphery. Hence, total welfare of a center-sponsored star is $W(\text{center-sponsored; star}) = 82 + 3 \cdot 145 = \mathbf{517}$. Thus, the equilibrium level of contributions in the periphery-sponsored star is inferior to those in the center-sponsored star in terms of efficiency.

Yet, more importantly, the equilibrium level of contributions in the center-sponsored star is not the efficient level of contributions. The efficient level of contributions is where all individuals contribute all of their tokens to the public account. In that case, center benefits from a total of **12** tokens and has a total payoff of **192** according to Table 1.2. As for the peripheries, each benefits from a total of **6** tokens and has a total payoff of **129.** Thus, the highest attainable welfare in a star network is given by. $W_{\max}(\mathbf{x}; \text{star}) = 192 + 3 \cdot 129 = \mathbf{579}$.

c) Predictions for the Circle Network

The analysis provided for the star network will be very similar to the one to be made for the circle network. Subjects are again given an endowment of 3 tokens in each round. They again either invest these tokens into a public account or a private account. The benefits are similar to those given in Table 1.1, with the only difference that the maximum level of tokens that a subject can benefit from is 9 instead of the total 12 tokens in the star network. Hence in Table 1.1, one needs to consider only up till the column corresponding to contribution 9 (included).[5]

As the number of neighbors each subject has is the same, one can summarize the payoffs to each subject in the circle as in Table 1.3:

5 An elaboration on calculation of payoffs in the circle network is provided in Appendix A.

TOTAL CONTRIBUTIONS OF DIRECT NEIGHBOURS

Individual's own Contribution	0	1	2	3	4	5	6
0	63	96	123	145	163	178	192
1	75	102	124	142	157	171	184
2	81	103	121	136	150	163	175
3	82	100	115	129	142	154	165

Table 1.3. Payoff to any individual given contributions of her direct neighbors in the circle network[6]

Equilibrium Predictions

As the analysis of equilibria provided for the star network does not depend on the network structure, predictions for the circle network will follow in a similar fashion. That is to say, at the equilibrium every subject again has to have access to a minimum of **3** tokens in the public account they can benefit from. This will give way to two different particular equilibria under this structure. Nash equilibrium on the left in Figure 1.5 will be referred to as the distributed equilibrium as all individuals contribute to the public accounts. In comparison, as only a subset of individuals provides contributions to the public account, the equilibrium on the right will be referred to as the specialized equilibrium.

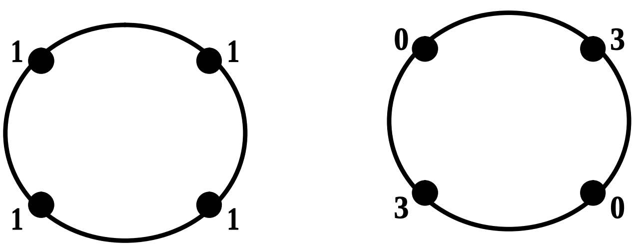

Figure 1.5. Nash Equilibria in the circle network under the described game

[6] The highlighted cells again correspond to the best-reply function of a player given the contributions of his neighbors

Efficient Contributions

As done with star networks, first an analysis on the welfare of Nash equilibrium profiles will be provided. In the distributed equilibrium profile, every individual puts **1** token and hence enjoys benefits from **3** tokens. Thus, every individual has a final payoff of **124** and the welfare of this profile is $W\left(\text{distributed; circle}\right) = 4 \cdot 124 = \mathbf{496}$.

As for the specialized equilibrium, with the existence of individuals who free-ride on the contributions of others, payoffs in this equilibrium profile is uneven compared to the distributed equilibrium. For the specialists, who can only benefit from the **3** tokens they themselves contributed to the public account, their final payoff is **82**. As for the non-specialists, who contribute nothing and free ride on the total of **6** tokens contributed by their specialist neighbors, they have a final payoff of **192.** Therefore, the welfare of the specialized equilibrium is $W\left(\text{specialized; circle}\right) = 2 \cdot 82 + 2 \cdot 192 = \mathbf{548}$. As a result, for the circle network, the level of contributions in the distributed equilibrium is inferior to those in the specialized equilibrium in terms of efficiency.

Similar to the results obtained for the star network; neither of the Nash equilibrium level of contributions is efficient. The efficient level of contributions is where all individuals again contribute all of their tokens to the public account. In that case, every individual gets to benefit from a total of **9** tokens and according to Table 1.3 has a total payoff of **165.** Thus, the highest attainable welfare in a circle network is given by $W_{\max}\left(\mathbf{x}\text{; circle}\right) = 4 \cdot 165 = \mathbf{660}$.

d) Treatments

There are three different treatments along with a control treatment. The control treatment essentially mimics the setup of the analyzed theory paper. That is to say it considers a random matching within the star and circle networks. For each network, at the beginning of the experiment, 16 subjects are randomly assigned to groups of four. In the case of the star network, subjects are – again randomly – assigned a label A or B in this network (see Figure 1.6). To avoid further complications in the understanding of the design, subjects maintain their assigned labels throughout the experiment. If they are assigned label A in order to be a center player in the first period, they act as a center player for the rest of the experiment. Same goes through for players with label B, i.e. periphery players. In order to collect statistically independent observations, the random matching is done within cohorts of eight subjects. That is to say, in each session 16 subjects are divided into two cohorts; and, within each cohort of eight, there are two center players (label A) playing against three periphery players (label B) out of the remaining six. Hence, the group of four they are playing in is reassigned at the beginning of each period within this group of eight people.[7] As for the circle network of this treatment, like in the star network, subjects are again divided into two cohorts of eight to determine the different groups of four in every period. Note that with the circle network as everybody is in a symmetric situation, it does not really matter what label you get. Hence in the instructions, rather than using labels, subjects are told that they will be benefiting from subjects to their “right” and to their “left” in their assigned

[7] The instructions for this treatment are provided in Appendix A.

group.[8] Once subjects are informed about the structure of the network and their payoffs, they need to take contribution decisions of 0, 1, 2 or 3 for 20 periods. The results from this random matching treatment are used to determine the equilibria played by the subjects without communication.

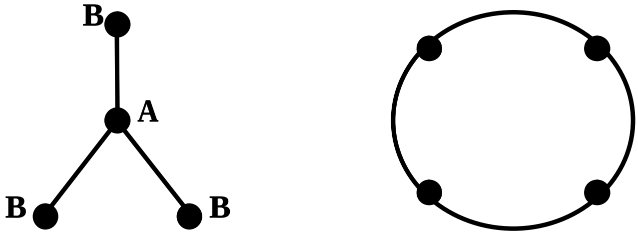

Figure 1.6 – Labels used in the experiment

As there are multiple equilibria in both network structures, subjects will face problems of coordination. The approach of introducing cheap talk as a nonbinding communication pre-stage before the actual decision stage as to resolve coordination issues was first experimented by Cooper et al. (1989) and Cooper et al. (1992).

Cooper et al. (1992) allowed for two different communication schemes in two different simultaneous coordination games each with a Pareto-dominant equilibrium. In the first communication scheme one player is chosen to announce his intention of playing a certain pure strategy with the knowledge that this announcement is not necessarily binding for the decision stage. This is referred to as one-way communication while the second communication scheme, referred to as two-way communication, involves both players making simultaneous announcements on their intentions of pure strategy play.

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[8] The instructions specify to the subjects that individuals to their “left” and “right” are not necessarily sitting next to them but rather they are connected to them through the computer.

Results show that allowing for one-way communication in a game that is similar to a prisoner's dilemma game including a dominated strategy for both players increases the frequency of the play of the Pareto-dominant equilibrium. Yet this does not resolve the coordination problem fully. As for a simple coordination game, results show that allowing for two-way communication, when both players announce the play of the Pareto-dominant equilibrium; actual decisions follow these announcements at a rate of 91 percent. Cooper et al. (1989) used the same methodology this time for a Battle-of-Sexes game. Their results showed one-way communication resulted in equilibrium play 95 percent of the time. In contrast, two-way communication is not as efficient, yet this scheme of communication can be improved upon if players are allowed to communicate with each other in more than one round.

Note that in the setup under consideration both network structures have the problem of multiple equilibria. Moreover, the specialized equlibria in each network structure favors a certain subset of players. In the star, the periphery-sponsored equilibrium favors the center player and the center-sponsored equilibrium favors the periphery players. As for the circle structure, the specialized equilibrium favors one set of disconnected subjects while disfavoring the other set of disconnected subjects. This is very similar to the structure of the coordination problem in a Battle-of-Sexes game. This is why it is highly susceptible that agents will face issues of coordination facing an equilibrium selection problem. Hence, taking results from Cooper et al. (1989) and Cooper et al. (1992) into consideration, further treatments in the experimental design will introduce a costless and non-binding communication stage into the game and hence the described first treatment will act as a control treatment on these communication possibilities. Yet this communication stage needs further elaboration since a network setup is under consideration.

There are three different mechanisms under consideration corresponding to three different treatments: one-neighbor, public and independent set communication. For all communication schemes, there are two sessions – one for each network structure. The subjects' assignments to positions in the network structure and into groups to form those networks are exactly the same as in the control treatment. In comparison to the control treatment's sequence of play, prior to their decisions on contribution levels, subjects are informed either to make a non-binding announcement of their intention of play or wait for announcement(s) of selected player(s) according to communication structure. These announcement(s) are communicated to the relevant subjects again in accordance with the communication scheme in hand and are accessible while subjects are making their decisions on how much to contribute.

One – Neighbor Communication **(*One-Neigh Comm*)**

As a first mechanism, one-neighbor communication scheme selects a random player to make an announcement on his intention of play at the communication stage. Later this announcement is communicated within the network only to the direct neighbors of the communicator. In this one-neighbor communication, players who send the announcement and players who receive this announcement are informed that the announcement is non-binding. Hence, any player who is chosen to make an announcement is not forced to follow her announcement in the decision stage. The most important difference of this announcement stage to the earlier described one-way communication used in the literature is the restriction on the set of players who is going to receive this announcement. As the game under consideration entails networks, the announcement of a player is communicated only to his direct neighbors.

In the case of the star network, if a center player is chosen to make an announcement, all periphery players are informed about this announcement. However, if a periphery player is chosen to make an announcement, only the center player learns the announcement while the other peripheries remain uninformed as they do not have a connection with any of the other periphery players. On the other hand, in the circle network, when a randomly chosen player makes an announcement, this announcement is communicated to players to her "right" and to her "left", but not to the player that is not connected to her. [9]

__Public Communication__ **(*Public Comm*)**

The second mechanism to test considers the option of a public communication, i.e. all players of the network are informed about the announcement. In this mechanism, at the communication stage, again a randomly selected player announces his nonbinding intention of play; and this time this announcement is communicated to all players in the network. Hence, in the case of the star network, if a periphery player is chosen to announce, his announcement is not available only to the center player but also to all other periphery players. In contrast,

[9] Instructions for this treatment are also available in Appendix A. In comparison to the first treatment, the only difference appears as an additional communication stage under the section "Your Decision".

if a center player is chosen to announce in the star, this communication mechanism is equivalent to the first mechanism in the sense that center's announcement is again communicated to all periphery players. As for the circle network, announcement of the randomly selected player is available not only to his neighbors but also to the third player in the network that he does not have a direct link with. This mechanism is equivalent to the earlier one-way communication proposed by Cooper et al. (1989) since information on intention of play is available to all players irrespective of network structure. Hence it is crucial in terms of comparability to earlier results discussed in the literature.

Independent Set Communication **(*Indep-Set Comm*)**

The last communication scheme to consider, the independent set communication, makes use of a specific structure, maximal independent sets, embedded in networks.[10] An independent set of a network is a set of agents such that no two agents who belong to this independent set have a direct link between each other. An independent set is maximal when it is not a proper subset of any other independent set. In a network given a maximal independent set, every agent either belongs to this set or is connected to an agent who belongs to it. The communication scheme to be discussed entails communication across maximal independent sets within the star and the circle.

For the star network, there are two independent sets. One is the set of all periphery agents and the other set is the center player alone. Hence,

[10] Several results on maximal independent sets have been derived by mathematicians and computer scientists. (see e.g. Gutin (2004))

in the experiment instead of picking at random a player to make an announcement, the mechanism selects one of these two maximal independent sets. If the center player is chosen, his announcement is available information to all periphery players. Note that, this aspect of the mechanism is again equivalent to the other communication mechanisms discussed. Alternatively, if the maximal independent set of periphery players is chosen, then each of the three periphery players makes an announcement simultaneously which is to be communicated only to the center player. Thus the periphery players do not know what each of them is communicating to the center player.

As for the circle network, there are again two disjoint maximal independent sets. Each of the maximal independent sets includes players that have no direct link with each other. More formally, according to Figure 1.1, players 1 and 3 constitute one maximal independent set and players 2 and 4 constitute the other. Hence, if the maximal independent set of players 1 and 3 are selected, they make their announcements which are to be delivered to players 2 and 4, and vice versa in case the maximal independent set of players 2 and 4 are picked to announce.

The treatments have been programmed and conducted in Laboratori d'Economia Experimental (LeeX) with the software z-Tree (Fischbacher (2007). The participants were undergraduate students from different areas at Universitat Pompeu Fabra. There were two sessions for the control treatment without communication and one session for all other treatments for each considered network structure.

1.5. Results

This section will summarize the results obtained for all treatments. To keep the discussion simple, as in the discussion of the theoretical predictions, results will be provided separately for each network structure. Results will focus on observed contributions, (individually and as a group), announcements in treatments allowed for communication and payoffs.

a) Star Network

The participants were a total of 80 undergraduate students Universitat Pompeu Fabra. There were two sessions for the control treatment without communication and one session for all other treatments.

	Control (No Comm)	**One-Neigh Comm**	**Public Comm**	**Indep-Set Comm**
OVERALL	1.463 (.968)	1.353 (1.084)	1.456 (1.085)	1.4125 (1.177)
CENTER	.875 (.976)	1.025 (1.147)	.6875 (1.001)	.4125 (.774)
PERIPHERY	1.658 (.884)	1.463 (1.042)	1.713 (.988)	1.746 (1.097)
H_0: mean(center) = mean(periphery)	0.0000	0.0000	0.0149	0.0000

Table 1.4. Average Contribution Levels in the Star Network
Note: Numbers in parentheses are standard deviations.

As a part of the results, first an analysis of contributions observed in all treatments is provided. Table 1.4 summarizes the observed average contributions in all treatments for the star network. Note that the main observation from Table 1.4 is the fact that center players on average contribute less than periphery players.

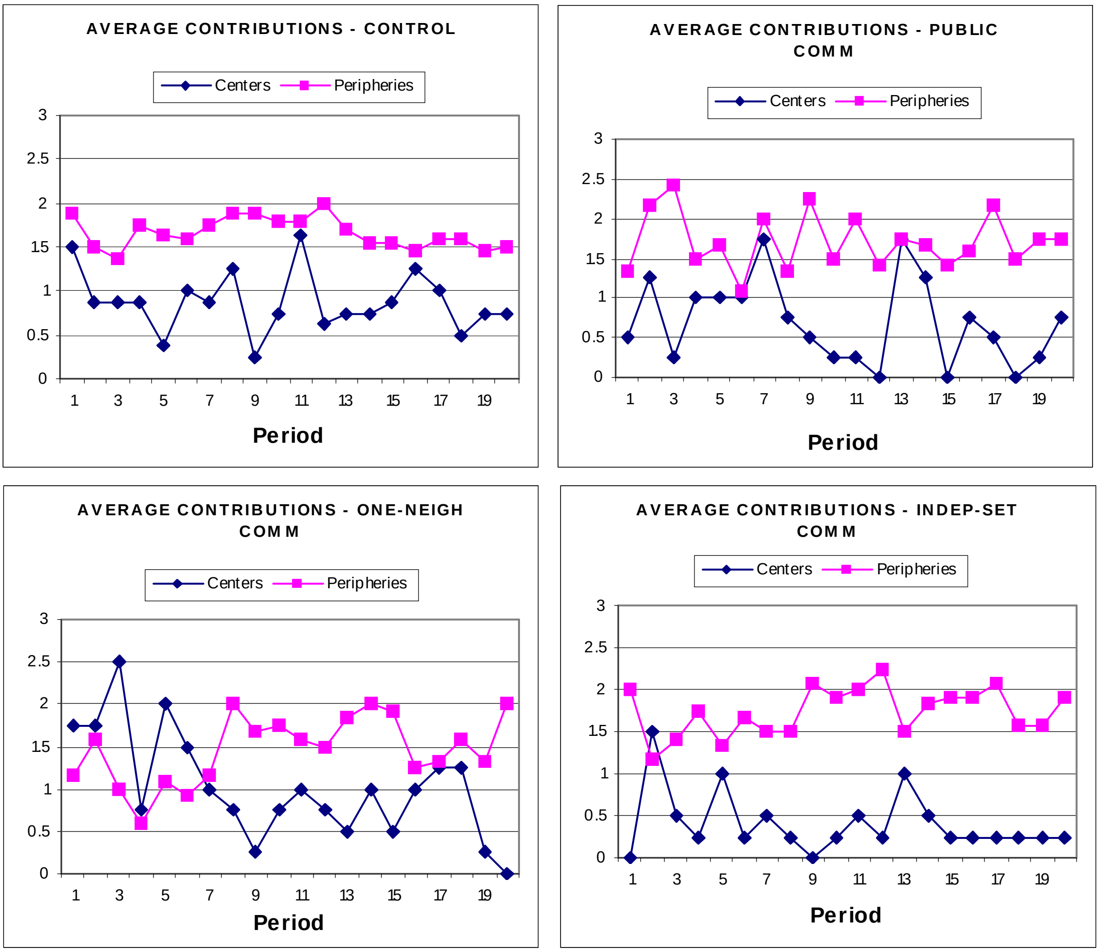

Figure 1.7. Average Contributions in each treatment

Indeed, within the randomly matched cohort of 8 subjects, pairing the average contributions of 2 center players with the average contributions of six periphery players they are playing against, the paired Wilcoxon-sign test shows that the difference of average contributions between center and periphery players are statistically significant in all treatments (last row of Table 1.4 summarizes the relevant p-values). This result can also be observed in Table 1.4, which gives a summary of average contributions of centers and peripheries in each treatment.

		CONTRIBUTION LEVELS				
		0	**1**	**2**	**3**	**No of Observation**
Control (No Comm)	Center	46.9%	26.3%	19.4%	7.5%	**160**
	Periphery	11.5%	27.5%	44.8%	16.3%	**480**
	Total	**20.3%**	**27.2%**	**38.4%**	**14.1%**	**640**
One-Neigh Comm	Center	50.0%	11.3%	25.0%	13.8%	**80**
	Periphery	20.0%	35.4%	22.9%	21.7%	**240**
	Total	**27.5%**	**29.4%**	**23.4%**	**19.7%**	**320**
Public Comm	Center	60.0%	21.3%	8.8%	10.0%	**80**
	Periphery	14.2%	24.6%	37.1%	24.2%	**240**
	Total	**25.6%**	**23.8%**	**30.0%**	**20.6%**	**320**
Indep-Set Comm	Center	72.%5	17.5%	6.3%	3.8%	**80**
	Periphery	16.%3	27.1%	22.5%	34.2%	**240**
	Total	**30.3%**	**24.7%**	**18.4%**	**26.6%**	**320**

Table 1.5. Distribution of Contributions in the Star

Given this, it is interesting to see the actual distribution of contributions made by each type of player in each treatment. Table 1.5 gives a summary of the percentage of observed contribution levels in each treatment for the star network to get a better understanding of the distribution of contributions. From this table, one can observe that in the star network center players have higher tendencies to contribute 0 and 1 while periphery players have a higher tendency to contribute 1 or 2.

To test for these tendencies, a binomial test for the relevant probabilities of contributions is used. To start with, for center players the probability of contributing 0 is compared to the probability of contributing 1, 2 or 3. Hence to start with the null hypothesis on the probability of contributing 0 was set to be equal to ¼. The null hypothesis was rejected for all communication schemes as well as for control treatment with no communication. When this probability is changed from 0.25 to 0.5, the null hypothesis could not be rejected at a 5% significance level for public and one- neighbor communication schemes along with no communication control treatment. For the independent communication scheme, the null hypothesis could not be rejected when the probability of contributing 0 was set to be 0.8. Next test was on whether the probability of contributing 3 was ¼ for center players again. This hypothesis was also rejected for all communication schemes.

As for comparing whether center players tend to contribute more 0 and 1's in comparison to 2 and 3's, the null hypothesis of contributing 0 or 1 with a probability of ½ was rejected for all communications except for the one neighbor communication. When the probability was set to be equal to 0.85 in the null, one could not reject the null for the public and independent set communications. For the one-neighbor communication scheme and control treatments, one had to fix this probability to 0.7 where the null hypothesis could not be rejected. On the other hand, the null hypothesis that the probability of contributing 0 and 3 is equal to the probability of contributing 1 and 2 for the center players was rejected for all treatments of communication, yet failed to be rejected for the control treatment without communication. All of these observations are summarized in the following, Table 1.6.

		p values for CENTER PLAYERS			
	H_0: p=	**Control**	**One-Neigh Comm**	**Public Comm**	**Indep-Set Comm**
0 vs 1,2,3	**0.25**	0.0000	0.0000	0.0000	0.0000
	0.4	0.0898	0.0862	0.0862	0.0000
	0.5	0.4769	1.0000	1.0000	0.0000
	0.8	0.0000	0.0000	0.0000	0.0947
3 vs 0,1,2	**0.05**	0.1452	0.0021	0.0021	0.7996
	0.1	0.3558	0.2614	0.2614	0.0621
	0.25	0.0000	0.0196	0.0196	0.0000
0,1 vs 2,3	**0.5**	0.0000	0.5666	0.5666	0.0000
	0.65	0.0312	0.4836	0.4836	0.0000
	0.8	0.0373	0.0001	0.0001	0.0245
	0.85	0.0001	0.0000	0.0000	0.2718
0,3 vs 1,2	**0.5**	0.3041	0.0183	0.0183	0.0000
	0.6	0.1473	0.5686	0.5686	0.0028
	0.7	0.0000	0.2240	0.2240	0.2719
	0.8	0.0000	0.0007	0.0007	0.4020

Table 1.6. p-values for Binomial Tests on Contributions of Centers

Similar tests were also run for peripheries. Again I started off with testing whether peripheries contribute 0 with a probability of ¼. Except for one-neighbor communication scheme, this null hypothesis was rejected for all treatments. One could not reject the null when the probability was fixed to 0.15 for independent set and public communication schemes and 0.1 for the control treatment. Meanwhile, when the probability of peripheries contributing 3 was tested to be equal to ¼; the null could not be rejected for the public and one-neighbor communication schemes.

	p values for PERIPHERY PLAYERS				
	H_0: p=	**Control**	**One-Neigh Comm**	**Public Comm**	**Indep-Set Comm**
0 vs 1,2,3	**0.1**	0.2865	0.0000	0.3998	0.0024
	0.15	0.0296	0.0370	0.7865	0.5874
	0.2	0.0000	1.0000	0.0237	0.1696
	0.25	0.0000	0.0740	0.0000	0.0013
3 vs 0,1,2	**0.2**	0.0399	0.5187	0.1070	0.0000
	0.25	0.0000	0.2634	0.8232	0.0017
	0.3	0.0000	0.0047	0.0487	0.1594
	0.4	0.0000	0.0000	0.0000	0.0654
0,1 vs 2,3	**0.35**	0.0765	0.0000	0.0038	0.0082
	0.4	0.6751	0.0000	0.7419	0.2926
	0.45	0.0078	0.0014	0.0519	0.6498
	0.5	0.0000	0.1064	0.0006	0.0451
0,3 vs 1,2	**0.25**	0.1708	0.0000	0.0000	0.0000
	0.3	0.2956	0.0001	0.0059	0.0000
	0.4	0.0000	0.5988	0.6448	0.0012
	0.5	0.0000	0.0117	0.0003	0.9486

Table 1.7. p-values for Binomial Tests on Contributions of Peripheries

As done with center players, to check whether the tendency of contributions were more on the side of 0 and 1, the null hypothesis that sets this probability to 0.5 was rejected for all treatments apart from one-neighbor communication. One had to set this probability to 0.4 for all other three treatments in order to get a p-value that favors the null hypothesis. Finally to make a similar check on comparing these tendencies of contributing 0 and 3 more than 1 and 2, initially the null probability of contributing 0 and 3 was set to ½. I observed that apart from the independent set communication treatment that the null was rejected for all other three treatments. When this probability was allowed to drop down to 0.4, one failed to reject it for public and one-neighbor communication schemes, while to obtain a similar result for the control treatment without communication this probability had to be dropped to 0.25. Please refer to Table 1.7 for an overview of all these results.

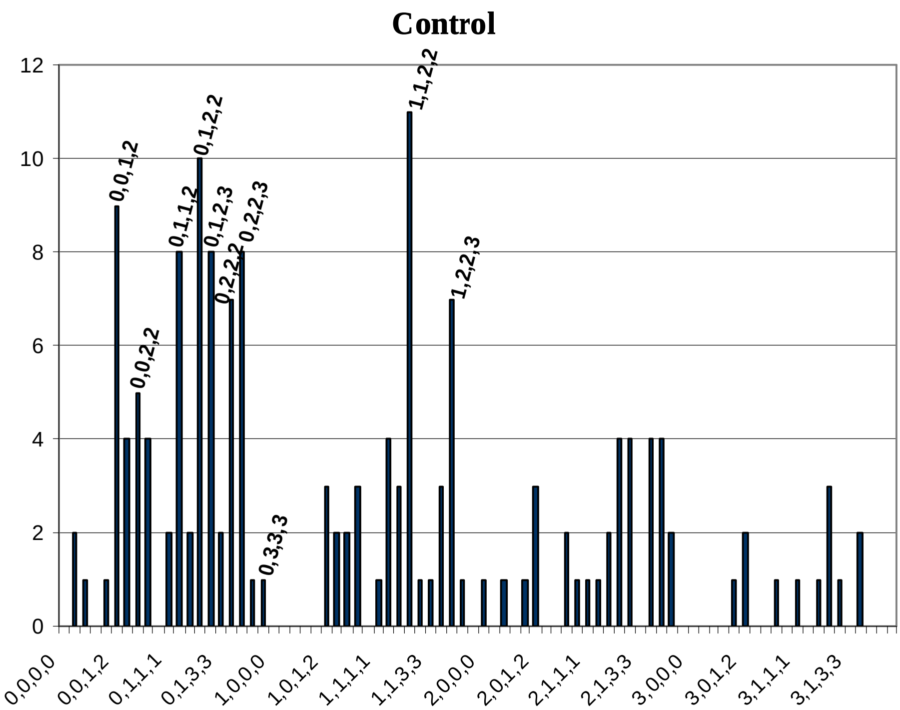

Figure 1.8. Observed Contribution Profiles in Star without Communication

Given these observations on the distribution of contributions made by the subjects, it is quite likely that equilibrium predictions for the analyzed network structures will not be observed with a lot of frequency. Therefore, it is another important aspect to analyze what kind of contribution profiles emerged under the considered network structures.

Figure 1.8 summarizes the observed contribution profiles under the star structure for the control treatment without communication. The horizontal axis spans all 80 different possibilities for public good provisions. Each possible contribution profile has the contribution of the center player as the first entry with contributions of the peripheries in the following three entries. Profiles are ordered in an ascending manner first according to center's contribution. Then the last three entries of contributions observed for peripheries are also ordered increasingly within themselves. As a result of this reordering, observations on contribution profiles such as (0,0,1,1), (0,1,0,1) and (0,1,1,0) are all summarized under the profile (0,0,1,1). So, overall as an example, a contribution profile given as (0,1,1,3) corresponds to the case where the center contributes 0, while two peripheries contribute 1 and one periphery contributes 3.

Hence, from Figure 1.8, one can immediately note that the center-sponsored equilibrium where the center contributes 3 and the peripheries free-ride on his contribution (3,0,0,0) has not been observed at all in neither of the sessions. On the other hand, the periphery-sponsored equilibrium where peripheries contribute 3 and the center free-rides on their contributions (0,0,3,3) has been observed only once in the first session and has not been observed at all in the second session. Finally the socially efficient outcome, where all agents contribute 3, has not been observed at all in neither of the sessions. In line with the discussion on the distribution of contributions, in the first session 55% of the observed contribution profiles (44 out of 80) involve center players contributing 0. Hence as predicted subjects failed to coordinate on the possible equilibria.

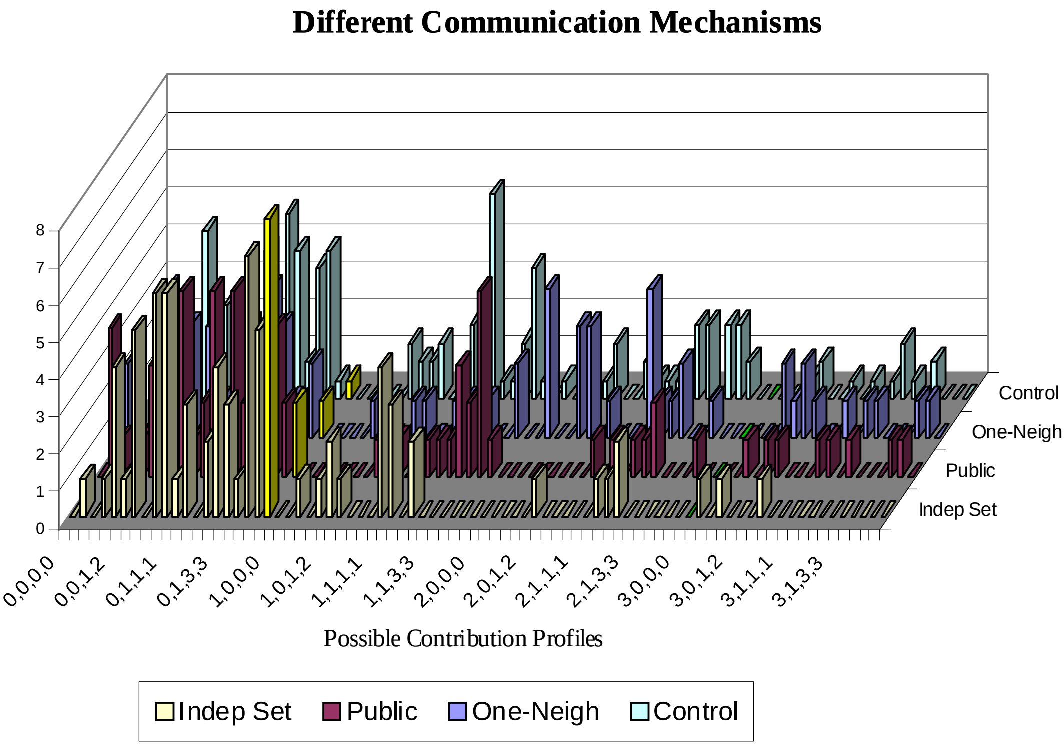

Figure 1.9. Observed contribution profiles in the star

Given the observation that under the control treatment subjects fail to coordinate on equilibrium, a further elaboration is provided on the observed contribution profiles when different schemes of communication were allowed. Figure 1.9 summarizes the observed contribution profiles under all treatments. In the figure, labels “Indep Set”, “Public”, “One-Neigh” and “Control” respectively stand for independent set communication, public communication, one-neighbor communication and control treatment without communication.

The horizontal axis again corresponds to the 80 different possible contribution profiles as in Figure 1.8. To be able to compare one session for each communication treatment with the two sessions of control treatment, relative frequencies of the observations in the control treatment have been used. In the figure, columns highlighted with a yellow color stand for the frequency observations where the equilibrium profile (3,0,0,0) was observed. As one can see, the only treatment where there is a significant observation on this equilibrium is under the possibility of independent set communication. Moreover, for all treatments, there does not exist any observation neither for the center-sponsored equilibrium (0,3,3,3) nor for the efficient outcome (3,3,3,3).

Treatment / Difference	CENTER One-Neigh	CENTER Public	CENTER Indep-Set	PERIPHERY One-Neigh	PERIPHERY Public	PERIPHERY Indep-Set
-3	4	2	0	5	3	4
-2	0	5	3	7	3	16
-1	5	5	7	13	9	18
0	11	8	27	20	18	49
1	1	1	1	10	10	13
2	0	1	0	2	5	12
3	0	1	0	2	9	17
	21	**23**	**38**	**59**	**57**	**129**

Table 1.8. Difference between Actual and Announced Contributions
Note: Positive (negative) values of the difference correspond to contributing more (less) than announced

One important explanation as to why treatments with communication did not improve the observed contributions can be explained with the truthfulness of the announcements. As the announcements were not binding, it was common knowledge to all players that a player need not announce her intention of play truthfully. Indeed, Table 1.8 summarizes the frequency of differences in the announcements and the actual plays.

Table 1.8 shows that in the star network, out of the 21 times a center player was chosen to make an announcement in the one-neighbor communication scheme, 11 of them were truthful while 10 of them were different than their announcements. Out of these 10 announcements, four of them were when center players announced they would play 3 and actually played 0.[11] Only once one of the center players ended contributing one more than their original announcement. Note that truthfulness of the announcements is a lot stronger for the independent set communication scheme. 71% of the time center players complied with their announcements. The following table specifically elaborates for this case the mapping between announcements and contributions of center players.

		CONTRIBUTION			
		0	1	2	3
Announcement	0	22	-	-	-
	1	3	3	1	-
	2	1	3	-	-
	3	-	2	1	1

Table 1.9. Mapping of Announcements into Contributions for Center Players (Independent Set Communication)

Again in the star network, the periphery players were chosen 59 times to make an announcement in the one-neighbor announcement scheme. 20 of these announcements were truthful while 39 of them were not. Out of these 39 non-truthful announcements 25 of them were announcements bigger than their actual plays while 14 of them were smaller announcements of their actual plays. The rate of truthful announcements for periphery players in all communication treatments were really close to each other (33.9% for one-neighbor communication, 31.6% for public communication and 38% for

[11] This announcement of 3 and actual plays of 0 causes the difference of -3 between the announcement and the actual play.

independent set communication). Yet to give the contrast of periphery players in the independent set communication scheme, following table gives the results on the mapping between announcements and contributions for periphery players.

		CONTRIBUTION			
		0	**1**	**2**	**3**
Announcement	**0**	14	10	9	17
	1	1	12	1	3
	2	6	9	14	2
	3	4	10	8	7

Table 1.10. Mapping of Announcements into Contributions for Peripheries (Independent Set Communication)

After this discussion on observed contributions in all treatments, let us compare the earnings of subjects in all treatments. Table 1.11 summarizes the average payoffs within each treatment along with focusing on average earnings of center and periphery players. As one can observe from this table, in all treatments center players earn more on average than periphery players. This statistically significant difference according to the Wilcoxon-sign test, run in a similar fashion as in the case of average contributions, is reported in the last row of Table 1.11.

The next important question is to see whether treatments have any effect on earnings of players. The rank-sum (Mann-Whitney-Wilcoxon test) is used to test for the null hypothesis that distributions of payoffs across treatments are equal. One fails to reject this null hypothesis, if the p-value of the associated test statistic is greater than 0.05. Table 1.12 summarizes these p-values.

	Control (No Comm)	One-Neigh Comm	Public Comm	Indep-Set Comm
OVERALL	114.855 (38.452)	113.847 (38.07)	111.75 (42.169)	109.1625 (44.998)
CENTER	169.4125 (24.218)	158.75 (33.75)	171.7 (29.477)	175.875 (34.484)
PERIPHERY	96.668 (21.264)	98.879 (25.661)	91.767 (21.96)	86.925 (17.977)
H_0: mean(center) = mean(periphery)	0.0000	0.0000	0.0000	0.0000

Table 1.11. Average Payoffs in the Star Network in each treatment
Note: numbers in parentheses are standard deviations

In the first column of the following table, the pairwise comparison of treatments is given. Mann-Whitney test is run for overall average values of payoffs along with average values for center and periphery players. According to Table 1.12, considering average payoffs independent of players' types, the only significant difference is for the pairwise comparison of control treatment and independent set communication along with one-neighbor treatment versus independent set treatment. Meanwhile, keeping the focus on only center players, Mann-Whitney test supports a significant difference when comparing control treatment with one-neighbor treatment. Moreover, this test also provides proof of a significant difference in average payoffs of centers comparing one-neighbor communication treatment with public and independent set communication treatments. Finally keeping the focus on periphery players, one fails to reject a significant difference in average payoffs of periphery players only when comparing control treatment versus one-neighbor communication scheme along with public versus independent set communication schemes.

Treatments Compared	Prob > |z| Centers	Peripheries	Overall
No Communication vs. One-Neighbor	0.0226**	0.3199	0.9906
No Communication vs. Public	0.2696	0.0028**	0.0527
No Communication vs. Independent Set	0.1434	0.0000**	0.0035**
One Neighbor vs. Public	0.0105**	0.0070**	0.2087
One Neighbor vs. Independent Set	0.0040**	0.0001**	0.0341**
Public vs. Independent Set	0.5523	0.3669	0.5661

Table 1.12. p-values for Mann-Whitney-Wilcoxon test comparing treatments in terms of average earnings in the star network[12]

b) Circle Network

There were again two sessions for the control treatment without communication and one session for the one-neighbor communication treatment. 48 undergraduate students from Universitat Pompeu Fabra participated to this part. Sessions for public communication and independent set communication are still to be conducted.

	Contribution Levels 0	1	2	3	No of Observation	Average
Control (No Comm)	31.7%	31.7%	24.5%	12.0%	640	1.169 (1.008)
One-Neigh Comm	34.1%	31.9%	20.3%	13.8%	320	1.138 (1.038)

Table 1.13. Distribution of Contributions in the Circle

[12] In Table 1.12, ** is used to show significance at a 5% level. Throughout, the thesis the standard abbreviation of * for 10%, ** for 5% and *** for 1% significance levels will be used.

Table 1.13 summarizes the observed average contributions in the conducted treatments for the circle structure. The most prominent observation one could make for this network is the tendency of the players to contribute 3, the efficient level of contributions, with the least likelihood.

To test for contribution tendencies, as in the case of the star network, a binomial test was used. As explained in the star network, first the null hypothesis of contributing was set to be equal to ¼. The p-values being less than 0.01 for both treatments resulted in rejection of the null. However, once the probability of contributing was set to 0.35, one failed to reject the hypothesis that players in a center network use a contribution of 0 with a probability of 0.35. In the meanwhile, applying the same procedure this time for the probability of contributing 3, the null hypothesis that fixed this probability to ¼ was again rejected in both treatments. The binomial test did not provide evidence on rejecting the null hypothesis when this probability of contributing 3 is set to be 0.15.

Looking further into Table 1.14, one observes that the null hypothesis that observing contributions 0 and 1 equally probable to observing contributions 2 and 3 is rejected. Indeed, with the binomial test results one only fails to reject when this probability of contributing 0 and 1 is equal to 0.65. Finally, to check whether players use contributions 0 and 3 more often than 1 and 2, one can actually observe from the given p-values in the above table that this probability is somewhere between 0.4 and 0.5.

		p values for CIRCLE	
	H_0: p=	**ONE-NEIGH**	**NO COMM**
0 vs 1,2,3	**0.25**	0.0003	0.0001
	0.3	0.1131	0.3429
	0.35	0.7696	0.0820
	0.4	0.0302	0.0000
3 vs 0,1,2	**0.1**	0.0315	0.0869
	0.15	0.5839	0.0353
	0.2	0.0041	0.0000
	0.25	0.0000	0.0000
0,1 vs 2,3	**0.5**	0.0000	0.0000
	0.6	0.0302	0.0760
	0.65	0.7696	0.4075
	0.7	0.1131	0.0004
	0.75	0.0002	0.0000
0,3 vs 1,2	**0.35**	0.0051	0.0000
	0.4	0.3125	0.0580
	0.45	0.4675	0.5513
	0.5	0.0113	0.0018

Table 1.14. p-values for Binomial Tests on Contributions in the Circle

The observed contribution profiles without communication within the circle appear in Figure 1.10. In this network structure, there are 55 different possible contribution profiles. On the horizontal axis, for any contribution profile first two entries correspond to the contributions of one set of maximal independent set while the last two entries correspond to contributions from the other set maximal independent set. The contributions in each independent set are ordered in ascending order within themselves and then the contributions from these two separate independent sets are again put together in an ascending manner. Thus, for example, a contribution profile (0,0,2,2) corresponds to the case where players of one of these maximal independent sets both contribute 0 while players in the other maximal independent set both contribute 2. Looking at Figure 1.10, it follows immediately that distributed equilibrium where all agents contribute 1 token (1,1,1,1) has only been observed twice, once in each session. On the other hand, the specialized equilibrium (0,0,3,3) has not been observed at all in neither of the sessions. Finally, the socially efficient outcome where everybody contributes 3 has not been observed at all.

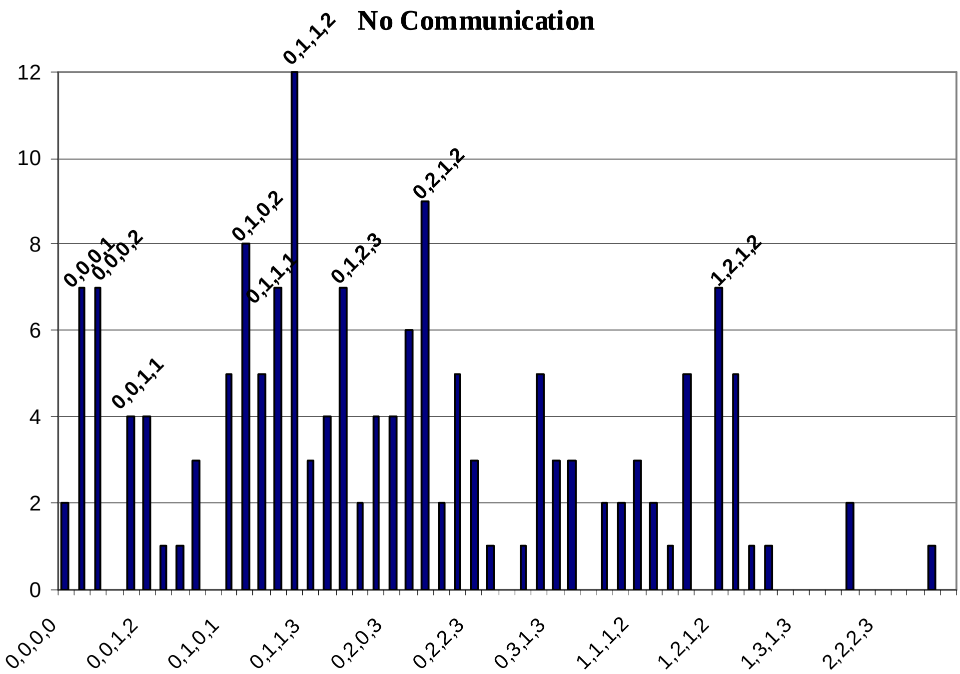

Figure 1.10. Observed Contribution Profiles in the Circle

Finally, the observed contribution profiles for the circle when one-neighbor communication was allowed are summarized in Figure 1.11. As in Figure 1.10, the horizontal axis corresponds to 55 different possible contribution profiles. Construction of these different profiles is exactly done in the same manner as explained earlier. The data series labeled with "Control" corresponds to the observed data from the first treatment replicating the original theoretical framework with the circle structure. In this treatment, neither the distributed nor the specialized equilibrium was observed. Furthermore, there was no observation on the efficient contribution profile where every subject fully cooperated. There was no major change in the relative contribution frequencies of the players in the circle.

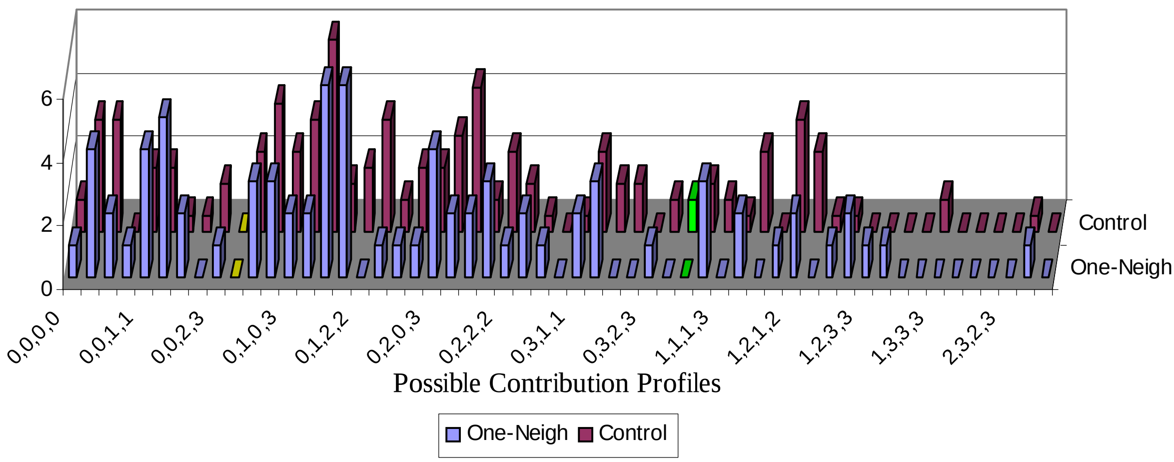

Figure 1.11. Observed contribution profiles in the circle with communication

Once again, similar to the analysis given for the star, one can take a closer look at the truthfulness of the announcements made by subjects. Table 1.15 summarizes the frequency of differences in the announcements and the actual plays.

Difference	**-3**	**-2**	**-1**	**0**	**1**	**2**	**3**
Circle	8	6	13	41	9	1	2

Table 1.15. Difference between Actual and Announced Contributions (One-Neighbor Communication)

Finally in the circle structure, out of the 80 announcements made by the subjects 41 of them were truthful while 39 of them were not.

Moreover, out of these 39 non-truthful announcements 27 of them were announcements higher than their actual plays while 12 of them were smaller announcements of their actual plays. When communication was an improvement to induce players to coordinate on equilibrium for two person coordination games as in Cooper et al. (1989) and Cooper et al. (1992), the major reasoning behind this observation was the fact that a large majority of the announcements made by the players were truthful. However, in this setup this no longer is this case. Hence there is no substantial improvement on the equilibrium play of subjects. This can be observed more closely in Table 1.16 that describes the mapping between announcements and contributions.

		CONTRIBUTION			
		0	**1**	**2**	**3**
Announcement	**0**	21	6	-	2
	1	2	7	-	1
	2	4	8	10	3
	3	8	2	3	3

Table 1.16. Mapping of Announcements into Contributions in the Circle (One-neighbor Communication)

Finally, for the comparison of earnings of subjects in the circle network, the average payoff in the control treatment was 125.07 with a standard deviation of 27.95 while in the one-neighbor communication treatment the average was 123.54 with a standard deviation of 29.526. As to see whether there were any treatment effects in terms of earnings, when the one-neighbor communication scheme is compared to the control treatment, Mann-Whitney-Wilcoxon test gives a p-value of 0.5366. Hence, this gives evidence to conclude that there is no statistically significant difference in average payoffs among the two treatments.

1.6. Conclusions and Further Research

These experiments provide an interesting analysis on the effectiveness of pre-play communication under a network environment. As opposed to the earlier literature, results show that pre-play communication does not necessarily improve upon coordination failures. More specifically, due to the strong strategic uncertainty of the game, results as expected show that equilibrium predictions do not hold in experiments with repeated one shot game setup without communication. In contrast, for the star network, when one-neighbor and public communication were allowed, there was no significant difference in the observations of equilibrium play. Yet, when allowing for communication among maximal independent sets coordination was improved upon focusing on the center-sponsored equilibrium play though not as strong as in the case of two person games analyzed in the literature. These observations I believe are strongly due to the asymmetric structure of the star which adds in a further strategic uncertainty especially for the peripheries. Peripheries that interact with the center player alone are not informed about other peripheries' actions which actually in turn determine center's actions. Hence, any communication scheme that is not powerful enough to cancel this effect does not enhance coordination. In the independent set communication scheme, allowing for all peripheries to announce their intent of play, these players have the opportunity to inflict their desired equilibrium.

However, center players are always well aware of their advantageous position in the network and hence are more successful in free-riding on peripheries contributions. This is strongly observed under the discussion for different contributions levels. Results show that players do not use a random strategy but rather center players tend to contribute more 0's while periphery players give 1 or 2 as their contributions. Given all these findings, I conclude that one-way communication schemes suggested earlier for two person games is not enough for network setups and thus there is a puzzle out there to resolve in terms of providing alternative schemes in order to enhance coordination under networks.

As further research, to restrict the strategic uncertainty in hand, I aim to analyze the behavior of players as well as the observations on the equilibrium play when strategy space for all players is restricted to the option of efficient contribution or free-riding. In the experiments of this study, the positions in a star network are imposed exogenously on subjects. Hence, subjects who get to be center players sustaining this position throughout the experiment are quite advantageous in comparison to other subjects. Thus, a further extension to this research project to eliminate this imposition could be offer positions in networks as a reward of a preceding game where subjects get to earn their positions rather than being assigned to it.

2. CONTEST EXPERIMENT IN CONFLICT NETWORKS

2.1. Introduction

In many social and political settings, rivalry can frequently become a serious problem as it often leads to violent conflicts and consequently a substantial waste of resources. Therefore, conflict resolution and management along with the analysis of conflicts have been among the main interests of social scientists. More recently, game theorists and experimentalists also focus on conflict situations, usually analyzing them as rent-seeking and contest games. However, relevant literature generally studies these rent-seeking situations as bilateral or multilateral contest games without taking into account network structures.

The purpose of this chapter is to experimentally test the effects of network structures, differing in degree and size, on total conflict intensity and individual conflict investments. It is plausible to provide useful insights for conflict resolution by testing the relationship between network structures and total conflict intensity along with the amount of investment realized by each party. The experimental design of this chapter is inspired by a theoretical model of conflict networks, Franke and Öztürk (2009). A version of Tullock (1980) contest game is implemented where two parties compete for an indivisible prize by investing in contest tokens, i.e. conflict funds. The number of prizes available to each party, i.e. the resources that can be obtained through each conflict, is determined by the network structure the individual is in, as one prize can be won for each link. The main consideration is on two classes of networks, i.e. regular versus irregular. More specifically, in the experimental design, among regular networks, complete and circle graphs are implemented to highlight the difference in degrees, and a variation between three and five nodes is used to highlight the difference in size. Accordingly, among irregular networks, two star graphs with three or five nodes are utilized as they constitute a good example for decentralized structures and the difference of the number of nodes between the two star graphs capture the effect of size.[13]

The analysis of network structures in economics started with Myerson (1977) and explaining many of the social and economic relationships through networks gained further importance with the contributions of Jackson and Wolinsky (1996). The experimental design of this chapter takes the network structure for each session as fixed and given, however, individual decisions are link specific. Therefore, on the one hand, the analysis to be provided is related to the works of Bramoullé and Kranton (2007), Ballester, Calvó-Armengol and Zenou (2006), Calvó-Armengol and Zenou (2004) and Goyal and Moraga-González (2001) in terms of keeping the network fixed and given. On the other hand, it differs from this literature as it allows individuals to decide separately for each link, whereas, previous literature mainly concentrates on individual strategies that are unidimensional, i.e. common for all the links.

[13] For example, the degree for the circle structures is always equal to 2 as each party is linked with 2 others; whereas, the degree for the complete network of 5 people is equal to 4. There is no degree of symmetry in a star network as there is one center player and *n-1* peripheries.

In spite of the rapid advancement of theoretical models analyzing social networks, experimental studies in networks are still in the path of progress.[14] The first set of experiments on this topic concentrate on the influence of different network structures on equilibrium selection. Equilibrium selection in a 2x2 coordination game (with Pareto ranked equilibria) is analyzed by Keser et al. (1998) through comparing interactions in a complete network to local interactions in a circle network. They show that play converges to the payoff-dominant equilibrium when everybody interacts with everyone else while risk-dominant equilibrium prevails under local interaction.[15] Berninghaus et al. (2002), on the other hand, analyze equilibrium selection under the local interaction of two different structures; the circle and the lattice. Even though subjects are unaware of the network they are involved in, their findings demonstrate that coordination is more likely to focus on the risk-dominant equilibrium under the lattice than in the circle.

The second category of experiments on networks is directed on cooperation. Kirchkamp and Nagel (2007) make use of a repeated prisoner's dilemma game under the possibility of local and global interaction. In contrast to their theoretical predictions that cooperation is more likely under local interaction, their results show that cooperation is sustained longer under global interaction. Cassar (2007) examines the influence of local, random and small-world networks on the sustainability of cooperation and coordination.

[14] For a more detailed discussion on the experiments on networks, refer to Kosfeld (2004).

[15] Boun My et al. (1999) adapt the setting of Keser et al. (1998) by varying payoffs for the risk dominant and payoff dominant equilibrium in the 2x2 coordination games. As opposed to Keser et al. (1998), their results show that there is no significant difference in terms of convergence to the risk-dominant equilibrium under global and local interaction.

Results show that play of payoff dominant strategy is observed significantly more often under small-world networks than in the other two structures. Moreover, cooperation in a prisoner's dilemma game, under all these network structures, is observed to be less likely in all three networks. Riedl and Ule (2002) show that cooperation rates are more sustainable if players can choose who will belong to their network.

Another important line of research in experiments with networks tries to address a crucial question: how networks form. Falk and Kosfeld (2003) test the network formation model of Bala and Goyal (2000), and their results show that subjects are successful in forming strict Nash networks in the 1-way model, but in 2-way flow models these equilibrium predictions cannot be reproduced. Conclusions of Callander and Plott (2005) establish that emerging networks converge to a pattern that has traits consistent with Nash equilibrium. Rather than using a (Nash) best response model, individuals tend to use simple strategic responses. Study of Goeree et al. (2007) allows for heterogeneity of agents in a network formation game. In accordance with their equilibrium predictions, stars are observed to emerge among heterogeneous agents and fail among homogeneous agents.

As mentioned before, literature on economic analysis of conflict situations concentrates on rent seeking games; and, experimental analysis on these rent seeking games has initially focused on the single stage game replications of the contest game by Tullock (1980). The study by Millner and Pratt (1989) is the first paper analyzing experimentally a Tullock contest game and testing the effects of allowing for different probabilities of winning the contest game. Assuming risk neutral agents, their results show a tendency of over investment. Hence, Millner and Pratt (1991) incorporate the theoretical work of Hillman and Katz (1984) the analysis while examining the possibilities of risk aversion in explaining their previous results. In contrast to Hillman and Katz (1984), the authors find that for the relatively less risk-averse group, mean individual expenditures significantly exceeds the Cournot-Nash risk neutral predictions while there is no significant difference for the more risk-averse group. However, suggesting that the results of Millner and Pratt (1989) are due to complex instructions and bounded rationality of subjects, Shogren and Baik (1991) improve the earlier design to report the resulting behavior of rent-seekers consistent with theoretical predictions in terms of mean expenditure and mean dissipation.

As all-pay auctions correspond to the perfectly discriminatory case of the Tullock (1980) contest game, experimental research analyzing all-pay auctions is comparable to the rent-seeking games. Davis and Reilly (1998) design an experiment in order to compare behavior in several different settings of repeated contests and all-pay auctions. They introduce a rent-defending buyer and demonstrate that this has an effect on reducing dissipation. Yet, across all auctions variants, dissipation and bidding behavior exceeds predicted Nash equilibrium levels, which also persists in their later study, Davis and Reilly (2000), where they allow for the possibility of more than one rent defending buyer. Potters, de Vries and Van Winden (1998) similarly compare all-pay auctions with rent-seeking contests where probability of winning is proportional. They also find over dissipation and over expenditure relative to the equilibrium predictions under the setup with proportional probabilities while the dissipation is as predicted under all-pay auctions. Two other studies that consider all-pay auctions are by Barut, Kovenock and Noussair (2002) and Gneezy and Smorodinsky (2006). The former study compares multiple-unit all-pay and winner-pay auctions while the latter study concentrates on a simple form of all-pay auction (complete information, perfect recall and common value) to abstract from the real world complications of the mechanism. Results of Gneezy and Smorodinsky (2006) confirm that even the simplest form of the mechanism alone is enough to induce irrational behavior in terms of excessive expenditures while the results of Barut et al. (2002) show that over-bidding behavior also prevails in both multiple-unit winner-pay and all-pay auctions. Lastly, to test the theoretical paper of Moldovanu and Sela (2001), Müller and Schotter (Forthcoming) consider an all-pay auction setting where groups of four contestants compete for two possible prizes. In their experimental setting where each contestant has a different ability level affecting the cost of exerting effort, predictions on efforts continuously increasing with ability levels are followed only in aggregated average results while observations on individual efforts show drop in efforts to zero after a cutoff ability level.

There are also studies considering rent-seeking contests under dynamic setups. In order to mimic the infinite-horizon model of Leininger and Yang (1994), Vogt, Weimann and Yang (2002) allow for contestants to react to each other's moves until either both players chose not to increase their bids or a random-stopping procedure intervenes the game. In comparison to the observed coordination failure in the two-stage game results of Weimann, Yang and Vogt (2000), subjects in this open-ended rent-seeking game learn how to evade escalations in rent-seeking expenditures. Meanwhile, Schmitt, Shupp, Swope and Cadigan (2004) analyze a model of multi-period rent seeking contest environment with carry-over. Theoretical predictions of the forward shift of expenditures from the last period to the first with no change in total expenditures are in line with their experimental results, even though they also report an over-investment behavior relative to the equilibrium predictions.

Öncüler and Croson (2005) is another study that also analyzes a two-stage rent seeking game but with a risky rent. The first stage of the game is a rent-seeking contest in groups of two or four for a risky rent whose actual value is determined in the second stage when the winner of the first stage is playing against nature. As earlier literature, their results also illustrate evidence of expenditure levels in excess of equilibrium predictions. Moreover, in their findings they also observe increases in expenditures as the group size increases. In the two-stage contest game of Parco, Rapoport and Amaldoss (2005), subjects first compete within their groups subject to an initial amount of resources and in the second stage winners of the first stage compete against each other where their budget constraint is restricted by their initial resources minus their first stage expenditures. Due to the observed over-expenditure behavior in the first stage, results are in the direction of rejecting their equilibrium model.

Schmidt, Shupp and Walker (2006) compare three different contest environments with different prize schemes. First scheme involves contestants competing for a single common prize while in the second environment there are three prizes whose total value is set equal to the value of the single prize offered in the first treatment. Finally, in the third mechanism each contestant's share of the prize is determined according to his share of expenditure relative to the total. In all three mechanisms, their results show that rent seeking expenditures are less than the predicted Nash equilibrium levels.

Bullock and Rutström (2007) study a transfer-seeking model that links the theoretical papers of Becker (1983) to the Tullock (1980) contest game. In symmetric games with two contestants, theoretical predictions imply either over-dissipation with equal but positive expenditures or zero expenditure and no transfers, depending on the specification of the model. Experimental results show strong support for over-dissipation along with excessive median expenditures in comparison to equilibrium predictions.

Anderson and Stafford (2003) design an experimental test on the theoretical model of Gradstein (1995) by varying cost heterogeneity of players, entry fee and group size. Mean group expenditure exceeds the predicted levels as well as the existing evidence of over dissipation in majority of the treatments. In line with the theory, group expenditures increase (decrease) with group size (adding an entry fee), but contrary to the theory, they do not decrease in the degree of cost heterogeneity. The influence of having groups rather than individuals competing against each other is examined by Abbink, Brandts, Herrmann and Orzen (2009). Their analysis is a version of the Tullock (1980) contest game where rivalry in consumption and excludability is at the level of conflict parties while there is non- rivalry in consumption and non-excludability *within* each conflict party. Their results show over expenditure behavior both when rival parties are individuals and groups. Specifically, total expenditures when teams are competing against each other are significantly higher than the total expenditures when competing parties are individuals. Moreover, total expenditures, when subjects have the opportunity to punish their own group's members, are significantly higher than when there is no such possibility.

The rest of this chapter is structured as follows. Next section will give a brief introduction to the theoretical model, while Section 3 will present the experimental design and procedures used in this study. Section 4 will elaborate on the experimental results and finally Section 5 will conclude and discuss further possible research.

2.2. Theoretical Model

This section introduces the model of Franke and Öztürk (2009) along with the modifications introduced into the model. Consider N agents embedded in a fixed network structure. Each agent $i \in \{1, 2, ..., N\}$ is involved in bilateral conflicts with a set of rivals, which is denoted by N_i.. Put differently, the structure of these $n_i = |N_i|$ bilateral conflicts each agent is engaged in determines the fixed network structure. Hence, in this fixed network, two agents have no link with each other as long as they do not have any conflicting relation with each other.

For each bilateral conflict, agents have to invest in a conflict specific technology. The outcome of each bilateral conflict is determined probabilistically according to the investments of respective rivals. The conflict spending of agent *i* against rival $j \in N_i$ is denoted by $e_{ij} \in \mathbb{R}_+$ and the n_i-dimensional vector of investments of agent *i* against all her rivals is denoted by $\mathbf{e_i} = \left(e_{ij}\right)_{j \in N_i}$. Hence, the aggregated conflict investment of agent *i* against all his rivals is given by $E_i = \sum_{j \in N_i} e_{ij}$, which will be referred to as the overall conflict intensity of agent *i*. Finally the vector of conflict spending directed against agent *i* by all of his respective rivals is denoted by $\mathbf{e_{-i}} = \left(e_{ji}\right)_{j \in N_i}$. All of this spending comes at a cost in accordance with a continuous, increasing and convex cost function c ($\mathbf{e_i}$) with c (0, …, 0) = 0. More specifically, in this study the cost function c ($\mathbf{e_i}$) under consideration follows the quadratic form:

$$c(\mathbf{e_i}) = c\left(E_i\right) = \left(E_i\right)^2 = \left(\sum_{j \in N_i} e_{ij}\right)^2 \qquad (2.1)$$

The outcome of each bilateral conflict is determined according to the proportional probability function proposed by Tullock (1980). The probability of an agent winning a conflict, $p_{ij} = p\left(e_{ij}, e_{ji}\right) \in [0,1]$, depends on the proportion of his investment relative to the total spending of respective rivals on that conflict. Hence, if two direct rivals' investments are the same, then their probability of winning the conflict is equal. Moreover, to take care of the discontinuity at the point where neither of the two makes no spending on the corresponding bilateral conflict, i.e. $e_{ij} = e_{ji} = 0$, both agents again have equal chances of winning the prize. Overall, these are summarized by the following functional form:

$$p_{ij}\left(e_{ij},e_{ji}\right)=\begin{cases}\dfrac{e_{ij}}{e_{ij}+e_{ji}} & \text{if } \mathrm{e}_{ij}+e_{ji}>0\\ 1/2 & \text{if } \mathrm{e}_{ij}+e_{ji}=0\end{cases} \tag{2.2}$$

In the study of Franke and Öztürk (2009), the outcome of the conflict is considered as a transfer. In other words, in any bilateral conflict, if agent *i* wins against any of his rivals *j*, agent *i* gets an amount of V of agent *j*'s resources while if agent *i* loses against any of his rivals *j*, then an amount of V of his resources is transferred to agent *j*. Hence, the expected payoff of agent *i* is additively separable in costs and expected wins and losses of all bilateral conflicts he is involved in and can be written in the following manner:

$$\begin{aligned} p_i(\mathbf{e_i},\mathbf{e_{-i}}) &= \sum_{j\in N_i} p_{ij}V-\sum_{j\in N_i} p_{ji}V-c(\mathbf{e_i})\\ &= \sum_{j\in N_i}\left(p_{ij}-p_{ji}\right)V-c(\mathbf{e_i})\\ &= \sum_{j\in N_i}\left(p_{ij}-(1-p_{ij})\right)V-c(\mathbf{e_i})\\ &= \sum_{j\in N_i} p_{ij}2V-\sum_{j\in N_i} V-c(\mathbf{e_i}) \end{aligned} \tag{2.3}$$

Note that the second term $\sum_{j\in N_i} V$ in the last line of (2.3) has no strategic impact on agent *i*'s choice of investment. Hence, rather than using this transfer game where the loser has to fully compensate the winner, the strategically equivalent version, where for any bilateral conflict the winner receives $2V$ while those who lose receive 0, will be utilized in the experimental design of this chapter. This eliminates the term $\sum_{j\in N_i} V$ and reduces the expected payoff function of agent *i* to the following form:

$$p_i(\mathbf{e_i}, \mathbf{e_{-i}}) = \sum_{j \in N_i} p_{ij} 2V - c(\mathbf{e_i})$$

$$= 2V \sum_{j \in N_i} \frac{e_{ij}}{e_{ij} + e_{ji}} - (E_i)^2 \qquad (2.4)$$

2.3. Equilibrium Analysis

In the conflict network game Franke and Öztürk (2009) propose, the authors demonstrate the existence of a unique equilibrium. Moreover, they show that this equilibrium is also interior. Hence, the interiority result implies that given the fixed network structure **g**, the equilibrium solves the following system of equations:

$$\frac{e^*_{ki}(\mathbf{g})}{(e^*_{ki}(\mathbf{g}) + e^*_{ik}(\mathbf{g}))^2} V = E^*_i, \quad \text{for all } k \in N_i \text{ and all } i \in N. \qquad (2.5)$$

where E^*_i is the overall conflict intensity for agent *i* at the equilibrium.

Given this general result, the analysis introduced in this chapter will involve two classes of networks: regular and irregular, more specifically, star networks.

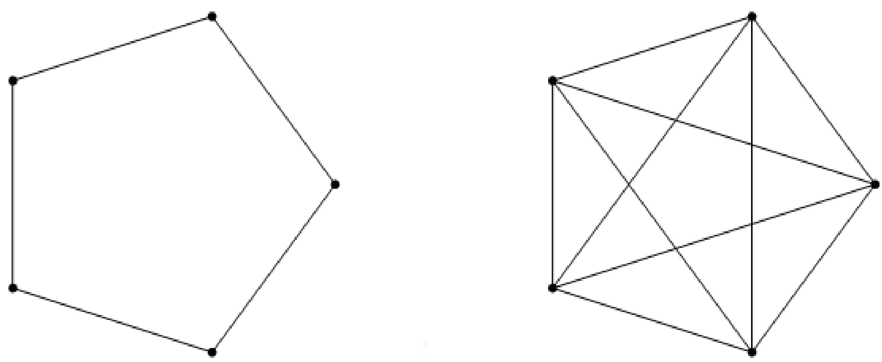

Figure 2.1. Regular Networks with n = 5, Circle Network on the left and Complete Network on the right

a) Regular Networks

A regular network is characterized by its high symmetry. Formally, a regular network is called to have degree d if every agent $i \in N$ has the same number d of opponents, i.e. $n_i = d$. Hence, a regular network is characterized by its degree d and the total number n of agents. In the class of regular networks, denoted by $\mathbf{g}^R$, two special cases will be analyzed: the complete networks where everybody is in conflict with everyone else, i.e. $d = n$ -1, and the circle networks where every agent has two rivals, i.e. $d = 2$.

In the case of regular networks, the symmetric conflict investment $e^* \equiv e^*_{ij}$ for all $i \neq j$ solves the system of first order conditions given in (2.5), , and thus the unique equilibrium is given by:

$$e^*\left(\mathbf{g}^R\right) = \frac{1}{2}\sqrt{\frac{V}{d}} \tag{2.6}$$

Consequently, at the equilibrium total investment of any agent depends only on the degree of the network d and is predicted to increase as the degree d decreases. Moreover, total conflict intensity of the network is then given by the total investment of all agents:

$$E^*\left(\mathbf{g}^R\right) = \sum_{i\in N}\sum_{j\in N_i} e^*\left(\mathbf{g}^R\right) = nde^*\left(\mathbf{g}^R\right) = \frac{n}{2}\sqrt{dV} \tag{2.7}$$

With these findings, in the class of regular networks, total conflict intensity is predicted to increase as the number of agents or the degree increases. Finally, at the equilibrium, the payoffs are given by $p^* = \frac{3}{4}dV$ and so the equilibrium payoffs increase only as the degree of the network increases and have no relation with the total number of agents.[16]

b) Star-Shaped Networks

Compared to the symmetry of regular networks, star networks are highly asymmetric. In these network structures, one agent is in conflict with all the remaining agents while these remaining agents are not in conflict with each other (Please see Figure 2.2).

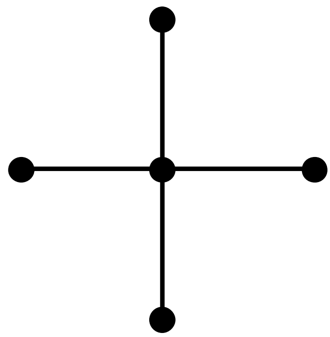

Figure 2.2. Star-shaped Network with n = 5

Strictly speaking, a star-shaped conflict network, denoted by $\mathbf{g}^S$, consists of a center agent c who is in conflict with all other agents such that $N_c = N \setminus \{c\}$. All agents belonging to the set N_c are called periphery players *p*. All periphery players that are in conflict with the center agent c are not in conflict with each other implying $n_i = 1$ for all $i \in N_c$. Therefore, a total of n -1 bilateral conflicts characterizes a star-shaped network with $n_c = n - 1$. Given these the payoffs of the center player c and the periphery players p can be written respectively in the following manner:

---

16 Note that if instead the transfer game where the loser compensates the winner as in Franke and Öztürk (2009) was used, then equilibrium payoffs would be given by $p^* = \frac{-dV}{4}$ in which case equilibrium payoffs would be decreasing in degree *d*.

$$p_c\left(\mathbf{e_c},\mathbf{e_i};\mathbf{g}^S\right)=\sum_{i\in N_c}\frac{e_{ci}}{e_{ci}+e_{ic}}2V-\left(E_c\right)^2$$

$$p_p\left(e_{pc},e_{cp};\mathbf{g}^S\right)=\frac{e_{pc}}{e_{pc}+e_{cp}}2V-\left(e_{pc}\right)^2 \tag{2.8}$$

As the equilibrium is unique and interior, the first order conditions derived in (2.5) entail that the center agent invests the same amount for all the periphery players, i.e. $e_c^*\left(\mathbf{g}^S\right)\equiv e_{ci}^*\left(\mathbf{g}^S\right)$ for all $i\in N_c$. The same argument follows also for periphery players, i.e. $e_p^*\left(\mathbf{g}^S\right)\equiv e_{jc}^*\left(\mathbf{g}^S\right)$ for all $j\in N_c$. Using these, the equilibrium investments and conflict intensities for the center and the periphery players are derived to be as follows:

$$e_c^*\left(\mathbf{g}^S\right)=\frac{1}{1+\sqrt{n_c}}\sqrt{\frac{V}{\sqrt{n_c}}}\text{ with }E_c^*\left(\mathbf{g}^S\right)=\frac{n_c^{3/4}}{1+\sqrt{n_c}}\sqrt{V}$$

$$e_p^*\left(\mathbf{g}^S\right)=E_p^*\left(\mathbf{g}^S\right)=\frac{\sqrt{n_c}}{1+\sqrt{n_c}}\sqrt{\frac{V}{\sqrt{n_c}}} \tag{2.9}$$

Note that at the equilibrium, probability of the center player winning each bilateral conflict is given by $1/(1+\sqrt{n_c})$ which is decreasing in n_c; while the same probability for periphery players is $\sqrt{n_c}/\left(1+\sqrt{n_c}\right)$ which, in contrast, is increasing in n_c. As a result, the total conflict intensity of a star-shaped network can be calculated as in (2.10) and is increasing in n_c.

$$E^*\left(\mathbf{g}^S\right)=n_c\left[e_c^*\left(\mathbf{g}^S\right)+e_i^*\left(\mathbf{g}^S\right)\right]=n_c\sqrt{\frac{V}{\sqrt{n_c}}}=n_c^{3/4}\sqrt{V} \tag{2.10}$$

Finally, equilibrium payoffs of the center and periphery players are as in equation (2.11).[17] Note that for both the center and periphery player, equilibrium expected payoffs are increasing in n_c.

$$
\begin{aligned}
p_c\left(\mathbf{e}_c^*,\mathbf{e}_p^*;\mathbf{g}^S\right) &= \frac{n_c(2+\sqrt{n_c})}{\left(1+\sqrt{n_c}\right)^2}V \\
p_p\left(e_p^*,e_c^*;\mathbf{g}^S\right) &= \frac{\left(2n_c+\sqrt{n_c}\right)}{\left(1+\sqrt{n_c}\right)^2}V
\end{aligned}
\qquad (2.11)
$$

c) Predictions

In this chapter, the theoretical equilibrium predictions of Franke and Öztürk (2009) is tested examining networks with 3 or 5 nodes, i.e. agents. For each possibility, the complete, circle and star-shaped networks are under consideration.[18]

As earlier literature where discussions are focused on risk aversion possibly driving the over-expenditure behavior; a contest game where agents won $2V$ or 0 is used rather than the contest game with transfers. The main intention of this approach is to avoid inducing further complications of risk aversion when agents have to lose their resources.

As in the theoretical results introduced in Section 2.1, the costs of investment is quadratic over the total expenditures as given in (2.1) and the probability to win each bilateral conflict is in accordance with

[17] Like in the case of regular networks, not using the transfer game results in obtaining different expected payoffs from those of Franke and Öztürk (2009), in which equilibrium expected payoff of center (periphery) player is decreasing (increasing) in n_c.

[18] Note that in the case of networks with 3 agents, the complete network is equivalent to the circle network.

the proportional probability function introduced in (2.2). Given the network structure along with the functional forms of the cost function and probability of winning, in each bilateral conflict the value V is set to be 150. Hence, in each bilateral conflict, agents are competing for a prize of value $2V = 300$.

Given these, equations (2.6) and (2.7) characterize the equilibrium individual investment decisions per conflict and in total for regular networks, while equation (2.9) characterizes the equilibrium both for center and periphery players in star-shaped networks. Using $V = 150$, these equations reduce to the approximate values given in third and fourth columns of Table 2.1.

			Theoretical Approximations for each agent		**Experimental Predictions for each agent**	
Network	**Description**	**Type**	**per Conflict**	**Total**	**per Conflict**	**Total**
complete-3 (circle-3)	n = 3 d = 2	- -	4.33	8.66	4	8
complete-5	n = 5 d = 4	- -	3.06	12.25	3	12
circle-5	n = 5 d = 2	- -	4.33	8.66	4	8
star-3	n = 3	center	4.27	8.53	4	8
	$n_c = 2$	periphery	6.03	6.03	6	6
star-5	n = 5	center	2.89	11.55	3	12
	$n_c = 4$	periphery	5.77	5.77	6	6

Table 2.1. Theoretical predictions and their approximations in the discrete case with 2*V* = 300

It is important to notice that all these approximate predictions are valid under the assumption that agents have continuous strategy spaces. However, providing subjects with continuous strategy spaces in experimental environments is likely to result in biases due to calculation limitations of subjects. In view of this, the case where agents have a discrete strategy space is to be analyzed. To assure that unique equilibrium predictions are valid even with a discrete strategy space; simulations have been run for each possible network. Results of these simulations, summarized in the fifth and sixth columns of Table 2.1, show that given the network structure these theoretical predictions are assuredly the unique equilibrium predictions in this version.

Complete Networks

Quantitatively: Investment per bilateral conflict by each agent should be 4 when total number of agents is 3. Hence, the predicted conflict intensity per agent is 8 and predicted overall conflict intensity is 24. In contrast, when there are a total of 5 agents and hence 4 bilateral conflicts per agent, agents' expenditure per bilateral conflict should fall down to 3 which will result in a conflict intensity of 12 per agent and a total conflict intensity of the network of 60.

Qualitatively: When number of agents increase from 3 to 5, individual investment is expected to decrease and total conflict intensity of the network to increase. As for equilibrium payoffs, they should increase as well since the degree of the network increases from 2 to 4 when number of agents increase from 3 to 5.

Circle Networks

Quantitatively: As mentioned earlier, when there are only 3 agents in the network, this is equivalent to the case of a complete network. Hence, theoretically individual investment per bilateral conflict is predicted to be equal to 4. Moreover, since this investment level is independent of the number of agents in the network, it is expected to stay at the same level of 4 when number of agents in the network increases to 5. As for the total conflict intensity of the network, an increase from 24 to 40 is predicted since total number of agents increases from 3 to 5.

Qualitatively: As explained above, independent of the total number of agents, the individual investment level should stay fixed while the total conflict intensity of the network to increase. Regarding the equilibrium expected payoffs, as they are theoretically independent of the number of agents in the network, the prediction is that they will stay at the same level when number of agents increase from 3 to 5.

Star-shaped Networks

Quantitatively: When number of peripheries is equal to 2 in the network, center players should invest 4 per periphery at the equilibrium while their investment should drop 3 per periphery when there are a total of 4 peripheries. In the meanwhile, investment of each periphery in both cases should be equal to 6. Total conflict intensity should be 20 when there are 3 agents and 36 when there are 5 agents.

Qualitatively: When the number of bilateral conflicts the center player faces increases from 2 to 4, his individual expenditure per periphery should decrease whereas the peripheries' individual investment level should stay the same. An increase in the number of peripheries should also result in an increase in the total conflict intensity. As the number of peripheries increase with the increase in total number of agents, equilibrium expected payoffs of all agents are predicted to increase.

2.4. Experimental Design and Procedures

One hundred and ninety two undergraduate students participated in a total of 10 sessions. Each participant took part in only one session and thus only in one treatment. All 10 sessions were conducted at the Laboratori d'Economia Experimental (LeeX) of Universitat Pompeu Fabra in Barcelona that contains 20 networked computer workstations at separate cubicles. Students were seated in random order at PCs and they were not allowed to communicate with one another by any means. All sessions were programmed and conducted with the z-Tree software, Fischbacher (2007). Average payment in all 10 sessions was 12.03€. For each session of networks with 3 agents, there were 18 subjects per session and average payoff in these sessions was 11.76€. In the meanwhile, there were 20 subjects per session for treatments with networks of 5 agents and in these sessions average payment per subject was 12.20€.

All sessions consisted of two stages. The instructions[19] gave the structure of the game in full detail to the subjects. Instructions of the second stage were distributed once the subjects were done with the first stage. All instructions were read aloud at the beginning of the corresponding stage. Before starting the second stage of the experiment, subjects had to answer a series of computerized questions to make sure that instructions were well understood. Moreover, subjects filled a questionnaire at the end of the experiment in order for us to get data on gender, age, studies as well as their opinions of the experiment and strategies used.

19 Please refer to the Appendix B for the instructions.

As there is strategic uncertainty in winning each bilateral conflict, the first stage of each session was towards eliciting the risk preferences of each subject. In this first stage, subjects faced 45 independent decision situations arranged in 3 blocks of 15. In each situation, subjects had to decide between two options, X and Y. Option X gave a secure payoff (in points) while option Y was a lottery. The first two blocks contained lotteries that at maximum would pay 300 points, the value of a single prize from one bilateral conflict. The third block contained lotteries that would either pay at maximum 600 or 1200 points, the maximum total value of prizes one can obtain given the fixed network structure.[20]

In the first block, the secure payoff X for the first 10 decision situations varied from 0 to 100 points in increments of 10; while for the last 5 decision situations of the same block, secure payoff X varied from 150 to 300 points in increments of 50. Option Y in this first block was a lottery that gave 300 points with probability of 1/6. In contrast, the second block of decision situations used as Option Y, a lottery that gave 300 points with a probability of 1/2. In this second block, the secure payoff X was given in increments of 50 in the first three situations varying from 0 to 100 points and in the last three situations varying from 200 to 300 points. The remaining nine decision situations in between were in increments of 10 varying from 110 to 190 points.

[20] In case of complete networks, all agents are involved in 4 bilateral conflicts with all other players in their group. Hence, they can win up to 4 prizes giving a sum of 1200 points. This is similarly the case for subjects when they have the center role in star-shaped networks of 5 agents. For all other network variations considered in this study, each subject at maximum has 2 bilateral conflicts, which give the possibility of winning up to 2 prizes at a value of 600 points.

Two different variations were used for the third block of decision situations. For those subjects participating in sessions of complete and star networks of 5 agents, the lottery option Y offered 1200 points with a probability 1/2. In this version of the third block, the safe option X was altered from 0 to 1200 points in increments of 100. On the other hand, for subjects participating in all other networks excluding the aforementioned two, option Y was a lottery that gave 600 points with a probability of 1/2. The secure payoff X in this case varied from 0 to 200 points in the first five decision situations and from 400 to 600 points in the last five decision situations in increments of 50. The remaining five decision situations in between were in increments of 25 from 250 to 350 points.

In the second stage of the experiment, a 3-by-2 design was followed. Three different structures of networks, consisting of complete, circle and star networks were under consideration. For each class of networks, the total number of agents was also varied with 3 and 5. For each variation of total agents, two sessions were conducted. As the case of a complete network with 3 agents was equivalent to the case of a circle, the design includes a total of 5 different networks. For all networks of 3 agents, there were a total of 18 subjects per session while for all networks of 5 agents there were 20 subjects per session. All sessions were run for 40 periods apart from the session of star-shaped network with 3 agents, which lasted for a total of 24 periods. (Please refer to Table 2.2 for a detailed summary of the treatments.)

Treatment	Description	No. of Subjects	No. of Periods	Type	Predicted Investment per Bilateral Conflict	Predicted Conflict Intensity per Agent	Predicted Conflict Intensity Network Total
complete-3 (circle-3)	n = 3 d = 2	36	40	_	4	12	24
complete-5	n = 5 d = 4	40	40	_	3	12	60
circle-5	n = 5 d = 2	40	40	_	4	16	40
star-3	n = 3 n_c = 2	36	24	center	4	8	20
				periphery	6	6	
star-5	n = 5 n_c = 4	40	40	center	3	12	36
				periphery	6	6	

Table 2.2. Treatments for Conflict Networks

At the beginning of the second stage of the experiment, subjects in each session of networks of 5 agents were divided into two independent cohorts, each including two groups of 5 players. On the other hand, subjects in each session of networks of 3 agents were divided into three independent cohorts, each including two groups of 3 players. At the beginning of each round, depending on the variation of total agents, participants were randomly reassigned into groups of 3 or 5 within their fixed cohorts. In the case of the star network, subjects were assigned a label A or B at random in each period (see Figure 2.3). Hence, center players obtained label A and periphery players label B. Once a participant received label A, he retained the role of center player for eight consecutive periods. Thus, in a star of 5 agents each participant played the role of a center player for 8 periods and the role of a periphery player for 32 periods. To fix the experience of each subject with the role of a center player at 8 periods, the treatment for the star network with 3 agents was run for a total of 24 periods in comparison to the 40 periods in all other treatments. As a result, subjects in these sessions were center players for 8 periods and periphery players for 16 periods. Moreover, to check whether there was any order effect in taking the role of a center player, in star networks of 3 agents, 6 subjects were center players in the first 8 periods, 6 other subjects in the last 6 periods and the remaining 6 subjects in periods from 9 to 16.[21]

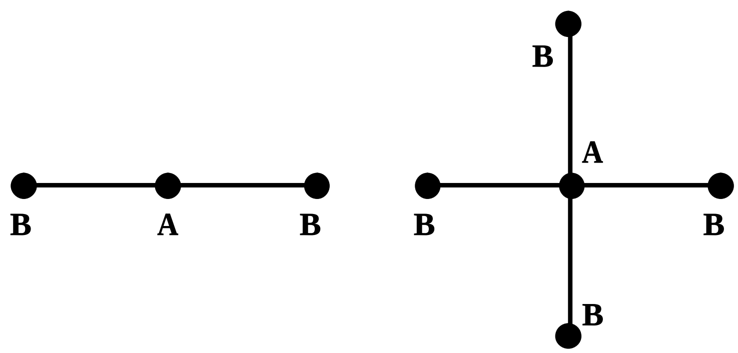

Figure 2.3. Labels used in the experiment for the star-shaped network

Once the subjects were informed about the structure of their network (and their label in case they were a part of a star-shaped network), for each bilateral conflict, they simultaneously had to make their investment decisions in the form of buying "contest tokens". Subjects were instructed that their total purchase of contest tokens would incur "decision costs".[22] At the beginning of each round, each participant

[21] In star networks of 5 agents, in each session, 20 subjects were divided into sets of 5 subjects. One set had the center label in the first 8 periods, another set of 5 subjects during periods 9-16, another set from period 17 till 24, another set in between periods 25 and 32; finally, the last set of subjects had the center role in the last 8 periods.

[22] Note that the incurred cost is not calculated separately for each bilateral conflict but rather for the total investment. In line with the theory, investment decisions for

had an initial endowment of 400 points which they could use to pay for these costs (in each session, an exchange rate of 200 points = 1€ determined the actual payment of each round.) Subjects were informed that the form of these costs was quadratic and any points that were left over from their initial endowment after paying for the costs would be added to their final points in that round. All this information was explained both verbally in the instructions and in the form of a separate cost table sheet. The separate cost table sheet was provided in order to assure that there would be no bias due to the subjects' limited computational capabilities. With the initial 400 points participants could buy a total maximum of 20 "contest tokens". Note that in any given network, these 20 tokens were well above the highest possible predicted total conflict expenditure of a single agent.[23]

Once all participants made their decisions, an on-screen lottery wheel for each bilateral conflict determined which of the two agents involved in that conflict won the prize. For every bilateral conflict an agent won, he received a prize of 300 points. The probability of an agent winning any bilateral conflict was equal to the number of tokens he invested in that bilateral conflict divided by the sum of tokens invested by both parties in the respective conflict. Accordingly, each lottery wheel was divided into two parts in line with the winning probabilities of the two parties. Therefore, the computer selected the winner of each bilateral conflict by implementing Tullock's proportional contest success function. After the lottery, each participant was informed

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each bilateral conflict are summed up to find the total investment over which subjects have to pay a cost.

23 Please refer to Table 2.2 for the predictions of total expenditure per agent in each network.

whether he won or lost for all bilateral conflicts he was involved in within his network. The points of that round was then determined by adding the total points he received from the prizes he won to his points left over after paying the costs from his initial endowment.

At the end of each round, subjects had information about the actual round and the previous rounds in terms of the tokens they purchased (per conflict and in total), cost of these tokens, number of prizes won along with the total points received from those prizes and the total points earned. Subjects were informed that after the completion of this second stage of the experiment, two periods would be selected randomly towards monetary earnings. In the case of a star-shaped network, one of these two periods was chosen from the 8 periods the subject had the role of a center and the other was chosen from the remaining periods where he had played the role of a periphery player. Finally, total payment of the experiment was calculated by adding the converted sum of points earned in the first and second stage to the fixed participation fee given at the beginning of the experiment.

2.5. Results

The analysis to be presented consists of two parts corresponding to the study of the results from the two stages of the experiment. The first part of the analysis checks if subjects make consistent choices between riskless and risky situations of X and Y, respectively. Moreover, the certainty equivalent of each lottery chosen by the subjects is checked within consistent choices. For the second part, the query is whether, on average, network structures affect individual and thus total conflict investment and if results differ from equilibrium predictions.

a) Results for Part I

As mentioned before, in this part of the experiment, subjects have to choose between the secure payoff X and a lottery Y for each situation. For situations 1-30, the secure payoff varies between 0 and 300, whereas on the one hand, option Y is a lottery that gives 300 points with probability of 1/6 for situations 1-15 and, on the other hand, for situations 16-30, option Y is a lottery that gives 0 or 300 points with a probability of 1/2. Moreover, for decision situations 31 to 45, depending on the treatment, the secure payment is either between 0 and 600[24] or between 0 and 1200.[25] The option Y is a lottery that gives 0 with probability 1/2 and respectively, 600 or 1200 with a probability 1/2.

For each block of decision situations, a risk neutral agent calculates the expected value of the lottery and plays the lottery up to that point and switches the secure strategy after the lottery's certainty equivalence. In order to determine if there are any inconsistent subjects in this experiment in terms of their decisions under these circumstances, for all subjects, it is measured when there is a switch from the risky option Y to the riskless option X or vice versa. A risk-averse individual would switch to the secure payoff X at a point lower than the certainty equivalent of the lottery; whereas, a risk-loving subject would switch at a payoff higher than this certainty equivalence. The assumption that any subject with consistent choices would only switch once (or

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[24] For circle-3, circle-5 and star-3 treatments

[25] For complete-5 and star-5 treatments

never)[26] from the risky option Y to the riskless option X will be in order in this part. Tables 2.3 to 2.5 below report the percentages of consistent versus inconsistent choices in the data. For situations 1-15, the second row of Table 2.3 demonstrates that there are subjects who chose not to switch from Y to X or vice versa. According to the aforesaid definition, the data for the treatments circle-3 and circle-5 belongs to subjects who are extremely risk-averse, whereas, the subject in star-3 is extremely risk-loving.

Decision Situations 1-15

	circle-3	circle-5	complete-5	star-3	star-5
switch = 1	80.56%	80.00%	85.00%	83.33%	87.50%
no switch	2.78%	2.50%	-	2.78%	-
inconsistent	16.67%	17.50%	15.00%	13.89%	12.50%

Table 2.3. Percentage of subjects' decisions consistency

Decision Situations 16-30

	circle-3	circle-5	complete-5	star-3	star-5
switch = 1	55.56%	75.00%	65.00%	63.89%	77.50%
inconsistent	44.44%	25.00%	35.00%	36.11%	22.50%

Table 2.4. Percentage of subjects' decisions consistency

Decision Situations 31-45

	Max Secure Payoff 600			*Max Secure Payoff 1200*	
	circle-3	circle-5	star-3	complete-5	star-5
switch = 1	75.00%	80.00%	80.56%	80.00%	80.00%
inconsistent	25.00%	20.00%	19.44%	20.00%	20.00%

Table 2.5. Percentage of subjects' decisions consistency[27]

[26] Depending on their risk attitudes the subject can choose X from the beginning if s/he is extremely risk-averse or always choose the lottery if s/he is extremely risk-loving.

[27] Among the inconsistent ones, subject 17 from 2nd session of circle-5 and subject 7 from 2nd session of complete-5 choose secure payoff until situation 38 (payoff 600) and choose lottery then on. And subject 2 from 2nd session of star-5 chooses safe payment for situation 31 (payoff of 0) and chooses lottery then on. These

Subsequently, in order to determine the risk attitudes of the subjects, the inquiry for each subject is at which secure payoff the switch occurs from Y to X. Tables 2.6 to 2.8 show what percentage of the consistent subjects switch from the lottery to the sure payment for each decision situation. Each row gives the information corresponding to the sure payoff indicated at the second column of the table. The data given in these tables are combining the information for both of the sessions of each treatment. The rows belonging to the certainty equivalent of the lottery for each block of decision situation are highlighted in gray.

Decision Situations 1-15

Situation	Payoffs	circle-3	circle-5	complete-5	star-3	star-5
1	0	3.45%	3.13%	2.94%	6.67%	14.29%
2	10	3.45%	6.25%	2.94%	-	-
3	20	6.90%	15.63%	-	6.67%	-
4	30	13.79%	-	5.88%	10.00%	-
5	40	24.14%	6.25%	8.82%	16.67%	40.00%
6	50	6.90%	28.13%	26.47%	13.33%	8.57%
7	60	3.45%	9.38%	8.82%	-	2.86%
8	70	6.90%	9.38%	14.71%	6.67%	11.43%
9	80	3.45%	9.38%	2.94%	-	2.86%
10	90	10.34%	-	8.82%	16.67%	8.57%
11	100	6.90%	9.38%	8.82%	13.33%	2.86%
12	150	10.34%	3.13%	5.88%	10.00%	8.57%
13	200	-	-	-	-	-
14	250	-	-	-	-	-
15	300	-	-	2.94%	-	-

Table 2.6. Subjects' switching behavior

subjects were also included in the inconsistent ones however, after the experiment they have mentioned that they actually confused the options X and Y; hence, made a mistake during the experiment. Therefore, in reality, the percentage of inconsistent subjects should be lower.

Decision Situations 16-30

Situation	Payoffs	circle-3	circle-5	complete-5	star-3	star-5
16	0	5.00%	6.67%	-	-	-
17	50	5.00%	3.33%	3.85%	4.35%	12.90%
18	100	-	6.67%	3.85%	8.70%	6.45%
19	110	5.00%	-	15.38%	4.35%	-
20	120	5.00%	3.33%	3.85%	4.35%	3.23%
21	130	30.00%	13.33%	11.54%	8.70%	9.68%
22	140	35.00%	16.67%	30.77%	47.83%	29.03%
23	150	10.00%	16.67%	19.23%	13.04%	12.90%
24	160	5.00%	30.00%	11.54%	8.70%	25.81%
25	170	-	3.33%	-	-	-
26	180	-	-	-	-	-
27	190	-	-	-	-	-
28	200	-	-	-	-	-
29	250	-	-	-	-	-
30	300	-	-	-	-	-

Table 2.7. Subjects' switching behavior

Decision Situations 31-45

Situation	Payoffs	circle-3	circle-5	star-3	Payoffs	complete-5	star-5
31	0	-	3.13%	-	0	-	-
32	50	3.70%	-	3.45%	100	-	12.50%
33	100	-	-	3.45%	200	3.13%	6.25%
34	150	14.81%	3.13%	10.34%	300	9.38%	3.13%
35	200	3.70%	21.88%	6.90%	400	6.25%	9.38%
36	225	7.41%	15.63%	10.34%	500	12.50%	3.13%
37	250	25.93%	18.75%	27.59%	550	34.38%	28.13%
38	275	11.11%	18.75%	3.45%	600	9.38%	12.50%
39	300	3.70%	12.50%	3.45%	650	6.25%	3.13%
40	350	18.52%	-	20.69%	700	12.50%	9.38%
41	400	3.70%	6.25%	3.45%	800	3.13%	3.13%
42	450	7.41%	-	3.45%	900	3.13%	9.38%
43	500	-	-	-	1000	-	-
44	550	-	-	3.45%	1100	-	-
45	600	-	-	-	1200	-	-

Table 2.8. Subjects' switching behavior

b) Results for Part II

Before starting on the analysis for the second part, it is necessary to check if there is any irrational play in the game. Irrationality in this game is defined by comparing the cost and the benefit of investing in one link. Given that the prize that can be won is 300 points per link, investing a number of tokens that are more costly than this into one single link is irrational, i.e. investing 18 or more tokens since the cost of 18 tokens is already equal to 324 points. Therefore, one needs to check the number of players who decided to invest 18 or more tokens for only one link and in order to measure the frequency one also needs to look at the number of periods a certain subjects plays irrationally. Token 1, token 2, token 3 and token 4 define the tokens invested in link 1 to 4 respectively. It is important to note that for the treatments of circle-3, and circle-5, players invest in two separate links and thus the data at hand is only for token 1 and token 2, whereas for complete-5, all subjects have four links available and thus the choices of token 1 to 4 will be checked. Moreover, for star treatments, the peripheries have only one link whereas the center has link as many as the number of peripheries.[28] Therefore, there are different number of data points for each token type, for example 7104 data points for token 1, whereas 5248 observations for token 2. According to the definition of irrational play for this game, at Table 2.9 one can see that for token 1, out of 7104 choices available there are 53 choices that are irrational, whereas out of 5248 choices available there are 9 inconsistent choices for token 2. The second column of this table shows the frequency of irrationality happening for a certain subject.

[28] 2 links and thus 2 tokens for Star-3, and 4 links and thus 4 choices of tokens in Star-5

For example, one can observe that 17 subjects that invested more than 17 token for a single link but later corrected their behavior.

	# of Periods	# of Irrational Subjects	Total # of Irrational Choices
Token 1	1	17	17
	2	3	6
	3	1	3
	4	1	4
	7	1	7
	16	1	16
Total	**-**	**24**	**53 (out of 7104)** [29]
Token 2	1	3	3
	3	2	6
Total	**-**	**5**	**9 (out of 5248)**[30]
Token 3	0	**0**	**0**
Token 4	0	**0**	**0**

Table 2.9. Irrational Subjects

In the following page, in Figures 2.4 to 2.10, the analysis will start by presenting average investments per period in each session. For the regular networks, averages are presented as the average investment of all subjects per period. For the star shaped networks, two graphs are presented for each treatment corresponding to the per period investment averages of the center players of both sessions and the periphery players of both sessions.

Figures 2.4 to 2.6 correspond to sessions for regular networks. The graphs show the average investment of all subjects per period. As one can see from Figure 2.4 average investments of subjects in complete-5 treatment are close to equilibrium levels whereas for the other sessions

[29] i.e. out of 7104 available cases
[30] i.e. out of 5248 available cases

average investments are above equilibrium predictions. Hence, in general, as aforementioned literature, over-investment is observed in the contest game, i.e. in each conflict situation.

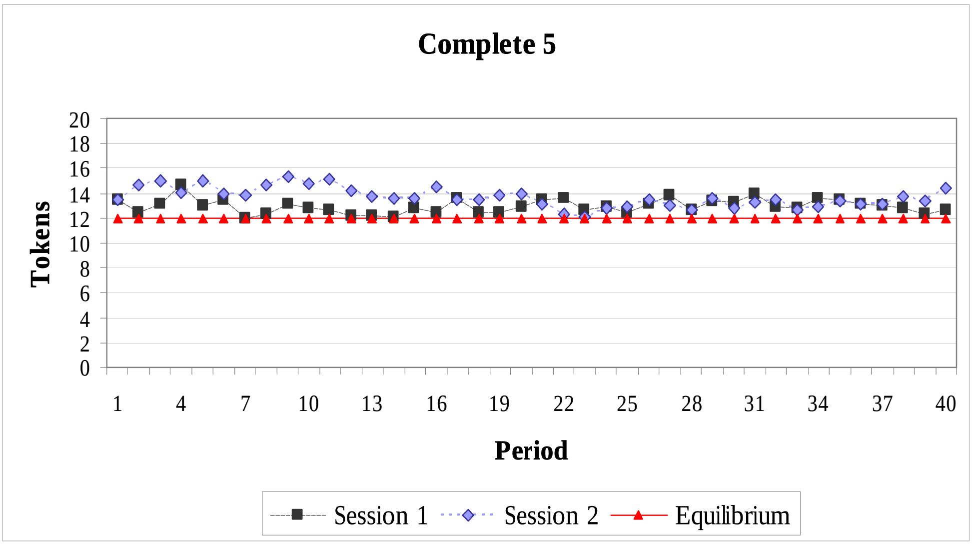

Figure 2.4. Investment Decisions in Complete-5 treatment

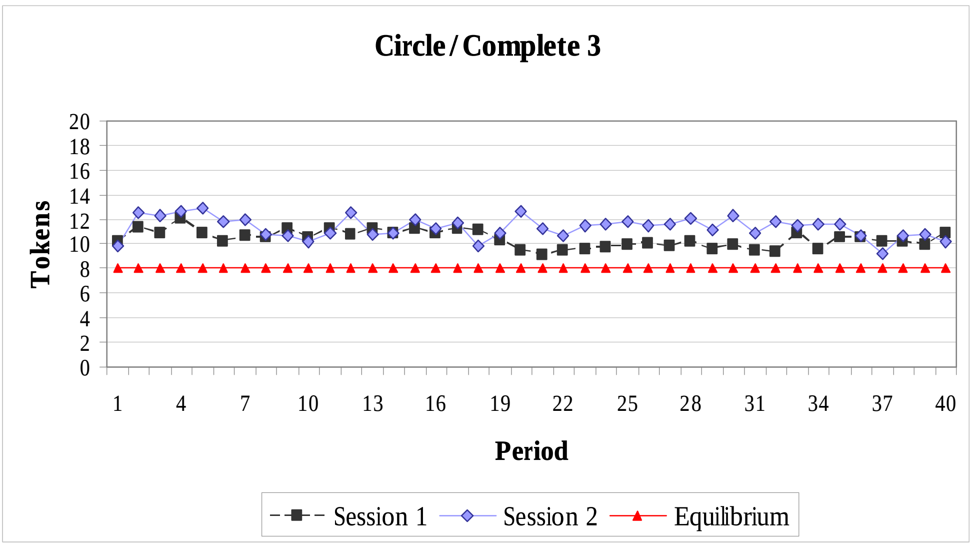

Figure 2.5. Investment Decisions in Circle / Complete-3 treatment

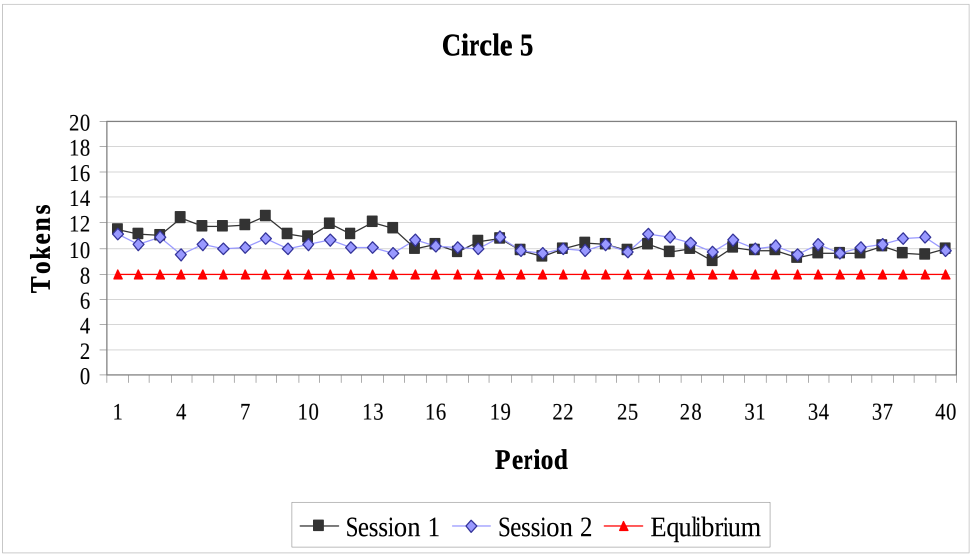

Figure 2.6. Investment Decisions in Circle-5 treatment

Figures 2.7 to 2.10 correspond to averages of subjects per period for irregular networks, i.e. star treatments. Figures 2.7 and 2.9 show the investment behavior of the centers; whereas, Figures 2.8 and 2.10 represent the behavior of the peripheries for star-3 and star-5 treatments respectively. As mentioned before, in star treatments, each subject takes the role of center for 8 consecutive periods; therefore, the graphs for star sessions show the corresponding partition of 8 periods. For the sessions of star-5, there are 4 center players for each 8 periods, whereas, for the sessions of star-3, there are 6 center players for each 8 periods. Therefore the graphs show averages of 4 centers or 6 centers respectively.

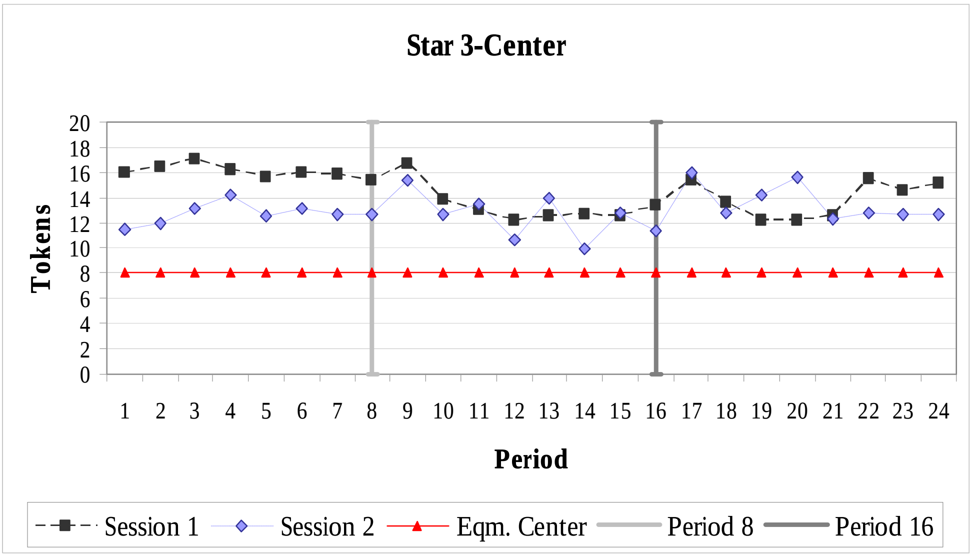

Figure 2.7. Investment Decisions of Center Players in Star-3 treatment

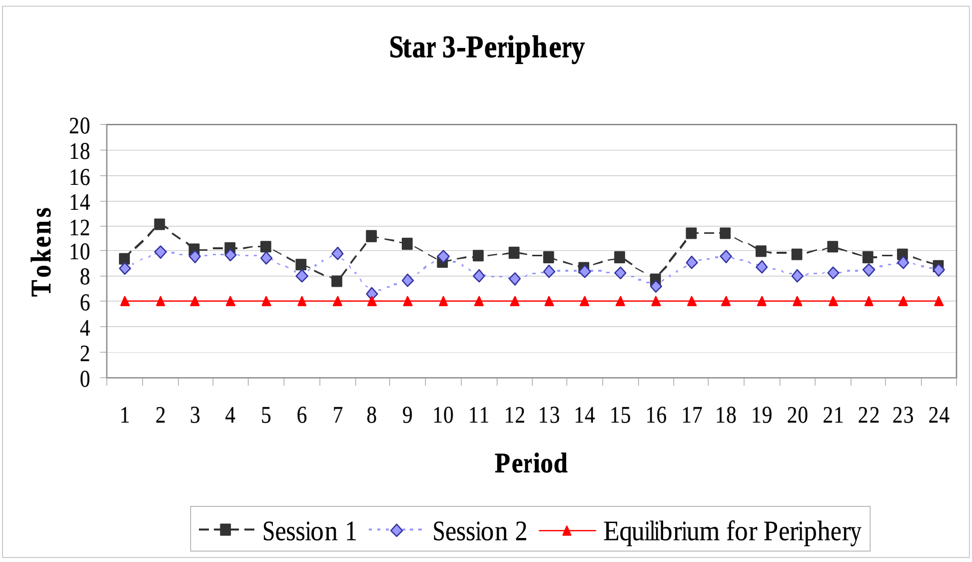

Figure 2.8. Investment Decisions of Periphery Players in Star-3 treatment

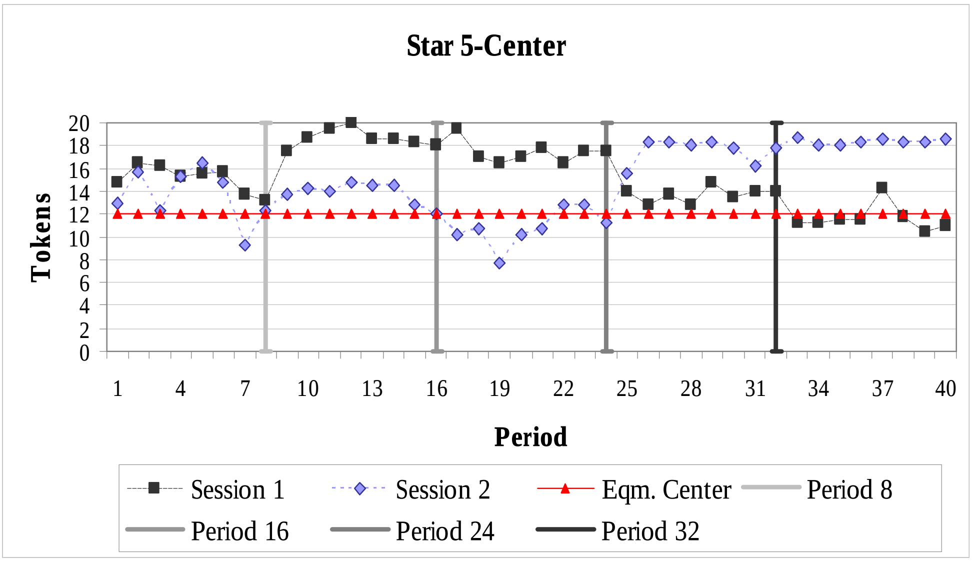

Figure 2.9. Investment Decisions of Center Players in Star-5 treatment

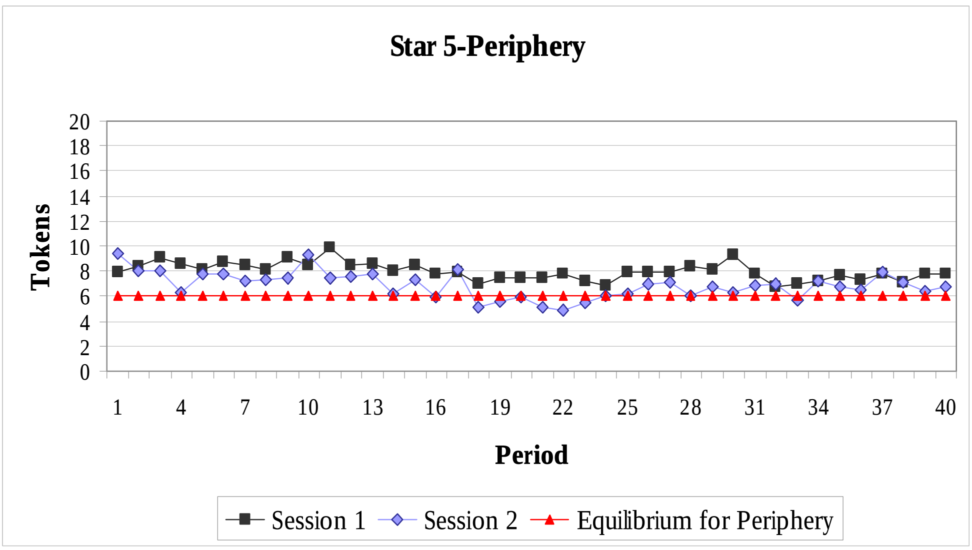

Figure 2.10. Investment Decisions of Periphery Players in Star-5 treatment

From the figures above, as subjects seem to over-invest on average except for the complete-5 treatment, average investments are tested to see if they are different than equilibrium predictions. Normality is checked for in the data and is rejected for some variables.[31] Therefore, in order to check if subjects differ from equilibrium predictions a Wilcoxon sign rank test is used. This one sample median test allows to test whether a sample median differs significantly from hypothesized values that are given in columns 3 and 4 of Table 2.10. These tests show that for all treatments and in all sessions total tokens bought per subject is significantly different than equilibrium predictions on total conflict investment per subject. In addition, almost in all networks this significant difference from equilibrium predictions persists even in investments per link. In the first session of complete-5 and in the second session of star-5 treatment, median investment on the fourth link is not significantly different than equilibrium levels. There is also no significant difference for investments on third and fourth links in the first session of star-5 treatment. Hence, as the figures on average investments suggested results confirm over investment behavior.

Furthermore, one needs to check if there are any significant differences among investments per link per subject, i.e. if subjects decide an average per link or whether they choose different values for different links they have. Theoretically, subjects should split their tokens equally among links. In this case, a k-wallis test is used when subjects have 4 available links, whereas a Wilcoxon rank-sum test is used when there are 2 available links. These results are summarized in the last column of Table 2.10. Within regular networks, results show that for complete-5 treatment investments for each four links are significantly different.

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[31] Normality is rejected for 23% of the variables for various sessions. Moreover, given that many observations are lacked, non-parametric testing methods are used.

Network	Descrip-tion	Experimental Predictions for each agent: Total	Experimental Predictions for each agent: per Conflict		Total Token	Token 1	Token 2	Token 3	Token 4	Differences
complete-3 (circle-3)	n = 3	8	4	session 1	5.513*** P=0.000	5.513*** P=0.000	5.512*** P=0.000	-	-	0.515 P=0.6063
	d = 2			session 2	5.512*** P=0.000	5.512*** P=0.000	5.512*** P=0.000	-	-	2.754*** P=0.0059
circle-5	n = 5	8	4	session 1	5.512*** P=0.000	5.512*** P=0.000	5.494*** P=0.000	-	-	2.886*** P=0.0039
	d = 2			session 2	5.513*** P=0.000	5.515*** P=0.000	5.514*** P=0.000	-	-	0.188 P=0.8508
complete-5	n = 5	12	3	session 1	5.506*** P=0.000	5.023*** P=0.000	4.184*** P=0.000	3.628*** P=0.0003	0.417 P=0.6764	21.164*** P=0.0001
	d = 4			session 2	5.512*** P=0.000	5.374*** P=0.000	3.698*** P=0.0002	5.427 *** P=0.000	5.494 *** P=0.000	20.717*** P=0.0001
star-3	n = 3	center = 8	center = 4	session 1	4.288*** P=0.000	4.287*** P=0.000	4.287*** P=0.000	-	-	0.477 P=0.4897
				session 2	4.291*** P=0.000	4.261*** P=0.000	4.175*** P=0.000	-	-	2.392 P=0.1220
	$n_c = 2$	periphery = 6	periphery = 6	session 1	4.286*** P=0.000	-	-	-	-	-
				session 2	4.287*** P=0.000	-	-	-	-	-
star-5	n = 5	center = 12	center = 3	session 1	5.535*** P=0.000	5.469*** P=0.000	4.766*** P=0.000	1.294 P=0.1955	1.456 P=0.1455	47.137*** P=0.0001
				session 2	4.271*** P=0.000	4.950*** P=0.000	2.31*** P=0.0257	2.74*** P=0.0061	-0.869 P=0.3849	26.077*** P=0.0001
	$n_c = 4$	periphery = 6	periphery = 6	session 1	5.513*** P=0.000	-	-	-	-	-
				session 2	4.208*** P=0.000	-	-	-	-	-

Table 2.10. Tests for equilibrium

This significant difference is also valid in the second session of circle-3 treatment and the first session of circle-5 treatment. As for irregular star networks, in the case of center players, who always have more than one link in contrast to periphery players, one fails to reject the hypothesis of equality of investments per link. This result is reversed in star-5 where one can observe a significant difference among investments for each link.

Network	Type	Total Token	Token 1	Token 2	Token 3	Token 4
complete-3	-	-4.631*** P=0.0000	-4.444*** P=0.0000	-2.032** P=0.0422	-	-
circle-5	-	0.563 P=0.5732	1.392 P=0.1640	-1.706* P=0.803	-	-
complete-5	-	-4.015*** P=0.0001	0.169 P=0.866	0.810 P=0.4179	2.462*** P=0.0138	6.015*** P=0.000
star-3	center	-2.468** P=0.0136	0.424 P=0.6719	-2.592*** P=0.0096	-	-
	periphery	3.456*** P=0.0005	-	-	-	-
star-5	center	0.496 P=0.6199	1.167 P=0.2432	1.78* P=0.0750	-1.847* P=0.0647	1.544 P=0.1226
	periphery	4.9*** P=0.0000	-	-	-	-

Table 2.11. Comparing sessions per treatment

Results of Table 2.11 outlines if there are any differences between sessions of each treatment using a Wilcoxon test (in terms of period averages). Mixed results are found while comparing period averages per session[32], therefore an additional check is done to see if there are any significant differences in subjects behavior in a particular treatment by using independent observations per treatment.

[32] There are significant differences between the two sessions per treatment for 13 out of 21 variables considered. Please refer to Table 2.10 for results.

First the session averages for total number of tokens are calculated as well as conflict investment in each link, i.e. tokens 1 to 4, per independent observation. The data for independent observations is summarized in Appendix B.1. Table 2.12 shows if investments are significantly different than each other (in average) using independent observations. The results show that, there is no systematic difference among the independent observations for each treatment and thus one could use these independent observations in order to withdraw conclusions in terms of comparing the treatments.

Network	Type	Total Token	Token 1	Token 2	Token 3	Token 4
complete-3 circle-3	-	5.000 P=0.4159	5.000 P=0.4159	5.000 P=0.4159	-	-
circle-5	-	3.000 P=0.3916	3.000 P=0.3916	2.70 P=0.4402	-	-
complete-5	-	3.000 P=0.3916	3.000 P=0.3916	3.000 P=0.3916	3.000 P=0.3916	3.000 P=0.3916
star-3	center	5.000 P=0.4159	5.000 P=0.4159	5.000 P=0.4159	-	-
	periphery	5.000 P=0.4159	-	-	-	-
star-5	center	3.000 P=0.3916	3.000 P=0.3916	3.000 P=0.3916	3.000 P=0.3916	3.000 P=0.3916
	periphery	3.000 P=0.3916	-	-	-	-

Table 2.12. Comparing the independent observations per treatment

Table 2.13 summarizes the comparisons among treatments by using independent observations. On the one hand, in order to check the differences in size, circle-3 and circle-5 treatments are compared. As mentioned before, one does not expect to find any significant difference between these treatments and results are in line with the aforementioned findings. On the other hand, in order to check the effect of degree, circle-5 and complete-5 treatments are compared where it is expected to find significant differences. Again, the results confirm the predictions.

Network Compared	**Type**	**Total Token**	**Token 1**	**Token 2**	**Token 3**	**Token 4**
circle-3 vs. circle-5	-	1.636 P=0.2008	0.727 P=0.3938	3.682* P=0.0550	-	-
circle-5 vs. complete-5	-	5.333** P=0.0209	5.333** P=0.0209	5.333** P=0.0209	5.398** P=0.0202	5.312** P=0.0211
star-3 vs. star-5	center	2.577 P=0.1098	6.545** P=0.0105	6.545** P=0.0105	-	-
	periphery	4.545** P=0.0330	-	-	-	-

Table 2.13. Comparing treatments (via independent observations)

Finally for irregular graphs, treatments star-3 and star-5 are examined. Comparing the two treatments (last two rows of Table 2.13), first for the center, significant differences in investments per link are found as expected. Second, center's total investment in star-5 treatment is predicted to be significantly different and higher than in star-3 treatment. However, this prediction[33] cannot be replicated due to the observation that over-investment in sessions for star-3 treatment is higher than the over-investment in star-5 sessions. Therefore, even though in star-5 higher investment levels are expected, investment levels in star-3 catches up. Due to this reason, one also fails to replicate the predictions for the peripheries' investments where one did not expect to find any differences between the two treatments. The reasons for this phenomenon are worth studying further.

[33] Similarity of treatments could only be rejected at an 11% level.

2.6. Conclusions and Further Research

Similar to the literature, results of this chapter show that subjects over-invest on average. This over-investment behavior is not only observed on total conflict investment per subject but also on the conflict investment per link. Additionally, subjects were expected to invest equally in each link. Yet, almost in all sessions for the regular networks, there is a significant difference in investments for different links. This observation persists for center players in the star network with 5 players. However, within star networks center players are more successful in allocating their investments equally when they interact with less periphery players. Another observation additionally come across in the results is that subjects invest closer to equilibrium levels as the network becomes regular. Therefore, these findings give way to the argument that the symmetric structure of the regular networks helps subjects during decision making.

The theory at hand is also found to predict the qualitative differences among different treatments. Findings show that conflict investment in circle-3 and circle-5 treatments are not significantly different from each other confirming the theoretical prediction that individual investment should be independent of number of agents in the circle. Moreover, within the class of regular networks, findings are in line with the theory predicting that investments should increase when the degree of the network decreases keeping the number of players fixed (circle-5 versus complete-5). Therefore, it can be construed that network structures influence the subject's behavior and thus for peaceful conflict resolution it is important to take the network structure of conflicts into account.

In this part of the experiment, as a further extension one could allow subjects to revise the submitted strategies in order to possibly induce them to play closer to equilibrium levels. However, as this procedure opens the possibility for cheap talk it could alter the unique equilibrium predicted by the theory.

Additionally, another observation one encounters in the results is that over-investment in star-3 treatment exceeds over-investment in star-5 treatments. The reason behind this might be that the subjects are willing to keep a certain fixed threshold of their budgets as a secure payoff and invest the rest in conflict technology. In the design presented in this chapter, the budget constraint is the same in all the treatments but equilibrium investment levels are different. This might affect subject's behavior and explain the reason why one encounters different levels of over-investment in different treatments. Furthermore, in the first stage of the experiment, various degrees and types of risk attitudes are observed for the subjects. Stemming from previous literature, it is reasonable to believe that a subject specific analysis incorporating their risk attitudes would provide useful insights in explaining the observed behavior in the experiment, especially the differences in sessions within treatments.

Finally, an interesting line of research is to investigate the specific effects of centrality in the presented conflict network experiment by running treatments with larger networks structures in size and degree. In these larger networks with very similar yet different structures to capture the differences between various measures of centrality, it is possible to check if subjects take into account a specific type of centrality, for example eigenvector versus betweenness centrality (Bonacich (2007)).

3. ENDOWMENT EFFECT: ANOTHER EXPLANATION FOR PREFERENCE REVERSALS?

3.1. Introduction

Preference reversal behavior is a well-known issue both in economics and psychology literature. It was the findings of Lichtenstein and Slovic (1971) that demonstrated one could construct a pair of lotteries among which subjects would prefer one lottery to the other while placing a higher selling price on the “undesirable” lottery in the pair. This, known as the preference reversal behavior (PR), was to the theorists’ surprise because it was contradictory with the expected utility (EU) theory predictions that preferences should be independent of the elicitation procedure.

This finding brought up a prolonging debate in explaining this particular behavioral decision-making. The debate shaped itself along the different disciplinary lines of arguments of psychology and economics. Psychologists pursued the explanatory strategy of context-dependent preferences while the economists explained it as evidence to intransitive preferences and procedure invariance or as an artifact of the methodology of these experiments.

Among all theoretical explanations provided so far, the existing evidence to the gap between buying and selling prices of individuals, explained by the endowment effect, is a recent attempt in trying to predict PR. In all PR experiments, within the task of elicitation of prices, individuals are given each lottery as an initial endowment. Keeping this as a motivation, Masatlioglu and Ok (2005), proposed that this method induces subjects to claim higher prices due to an endowment effect. Yet these high prices driven by the endowment effect can comply with individuals' preferences within their revealed preference framework that allows for status quo bias. Hence, to conclude whether endowment effect is actually the driving force behind their decisions or not, they suggested that one should further check their willingness to exchange their endowment with an alternative lottery.

Henceforth, this chapter aims to test the conjecture whether endowment effect stands as an alternative explanation for preference reversals. Towards this goal, Section 2 provides the existing explanations for preference reversal and Section 3 focuses on the theory of Masatlioglu and Ok (2005) to provide further insight for their conjecture. While Section 4 explains the experimental design of the study conducted towards testing this explanation, Section 5 elucidates the theoretical predictions under the design of the experiment. Finally, Section 6 discusses the results and Section 7 concludes.

3.2. Existing Explanations for Preference Reversal

Recognizing the burden preference reversals have placed on the modern theory of decision under risk, Grether and Plott (1979) ran experiments in an effort to discredit the results of researchers in psychology. Despite their attempts to eliminate this behavior, preference reversals persisted to be of evidence also in their experiments. Their study prompted several other studies in this area. However, as opposed to these attempts, like those of Pommerehne, Schneider and Zweifel (1982) or Reilly (1982), the persistence of preference reversals remained to be a puzzling behavior waiting to be explained.

Among the possible explanations proposed later for PR was the violation of procedure invariance, violation of transitivity of preferences and a consequence of the method used to elicit bet prices – Becker, DeGroot and Marshack (1964) (BDM) procedure. Among these explanations, principle of procedure invariance is a crucial assumption in the representation of preferences through maximization of utility. It requires that different elicitations of a choice problem should not change preferences. It entails a higher selling price for the "desirable" lottery if subjects have "consistent" preferences, as opposed to the observed behavior due to PR. Tversky, Slovic and Kahneman (1990) designed an experiment to separate violations of transitivity and procedure invariance. In case of a PR, an amount of money was predetermined between the selling prices of the two lotteries. Next, subjects were to choose between each lottery and this predetermined amount. In case of choosing the predetermined amount over the higher priced lottery, the higher priced lottery would be overpriced and a violation of procedure invariance would occur. Yet if one observed that subjects chose the predetermined amount over the preferred lottery and the higher priced lottery over the predetermined amount, this would correspond to a violation of transitivity of preferences. Through this analysis, Tversky et al. (1990) found that PR was due to a violation of procedure invariance 66% of the time. However, Loomes, Starmer and Sugden (1989) disputing these results showed with their experiments that previous results understate the degree of intransitivity and overstate importance of mispricing.

As for PR being an artifact of the BDM procedure, there were several studies trying to elicit prices through different methods. Cox and Epstein (1989) were able to reduce the commonly observed kind of PR through their elicitation method, yet this method increased the PR in the opposite direction. Bostic, Herrnstein and Luce (1990), Loomes (1991) elicited prices using an iterated choice procedure in which subjects made a choice between a bet and series of certain amounts that varied up and down until indifference was reached. This method decreased the PR rate. However, all of these theories were not strong enough to refute the conjecture that BDM procedure does *not* elicit truthful selling. Thus, it still remains to be of common use to extract minimum selling prices.

There were several other efforts in trying to explain PR with alternative theories, especially by relaxing axioms of EU theory. One subset retains transitivity and relaxes the independence and/or reduction axioms (Holt (1986); Karni and Safra (1987); Segal (1988)). Cubitt, Munro and Starmer (2004) came up with a generalized economic theory that postulated context-free preferences yet allowed for the violation of EU theory. They also considered several other explanations provided by psychologists towards explaining PR yet failed to show that any of these are actually relevant to predicting it.

As mentioned earlier, PR phenomenon is also very reminiscent of the overpricing phenomenon. Specifically, in a PR experiment at the stage where minimum selling prices are elicited, one could suspect an overstatement of these prices. Actually, economic theory predicts that prices an individual will pay to buy and sell an object should be about the same. However, starting with Kahneman, Knetsch and Thaler (1990), the disparity between buying prices (measures "willingness to pay" or WTP) and selling prices (measures "willingness to accept" or WTA), or the overpricing phenomenon, has been the finding of various studies.

In the experiments of Kahneman et al. (1990), BDM procedure was used to elicit buying prices and selling prices of mugs and chocolates. After these prices were educed for buyers and sellers, the number of trades for goods was determined through the intersection of the given supply and demand. "*The results showed a large and significant endowment effect*" (p.1338) since the observed volume of trade was significantly different than the predicted level. This difference was further clarified by Thaler (1980) due an "endowment effect", where the value of a good enhanced once the good became a part of individual's endowment. Concerning lotteries, this disparity has also been shown to be at a significant level in a variety of studies, starting with Knetsch and Sinden (1984). After this finding, several theories have linked the endowment effect and uncertainty.

One of these theories is due to Rankin (1990), who has used an approach combining Adaptive Utility and Regret Theory. According to Adaptive Utility, utility derived from goods is uncertain before purchase and is updated with a decrease in this uncertainty after consumption. Rankin used this uncertainty towards explaining endowment effect. In line with his theory, individuals compare consequences of each action to their initial state, and for any state that is worse (better) than their initial, they suffer (enjoy) regret (rejoice).

Sugden (2003)'s model of reference-dependent subjective EU theory provides an alternative elucidation in connecting endowment effect and uncertainty. In this theory, Sugden allowed for the reference points to be state-dependent, i.e. allowing for lotteries to be reference points. This model had the merit of explaining PR and endowment effect separately.

After these theories that had allowed lotteries to be status-quo points, Blondel and Lévy-Garboua (2008) also provided an explanation to PR with a psychologically founded "cognitive consistency theory":

> *"Let us consider that, prior to making a choice, the individual has a normative, i.e. procedure-invariant, preference under risk which can be represented by an EU function.* [*Whatever*] *this prior preference* [*is*]*, it raises doubt when the subsequent choice of one lottery against another raises a visible objection.* […] *The possibility of finding an objection to one's normative preference, which characterizes most decisions under risk or uncertainty, means that the decision-maker demands information. In seeking additional information, she must perceive the available objection to her normative preference. Thus she must sequentially perceive, first her normative preference, then the available objection to the latter. Since the objection is dissonant with the prior preference, the individual experiences cognitive dissonance and must feel uncertain of her true preference."* (p. 8)

Hence, they let individuals to evaluate a specific lottery differently, when stating WTP and WTA. Allowing for a difference between WTP and WTA in their theory, they also succeeded in explaining the endowment effect and predict only the standard PR.

Finally, “Rational Choice with Status-Quo Bias” by Masatlioglu and Ok (2005), which constitutes the actual interest of this study, is a recent attempt in theory trying to relate the endowment effect with uncertainty. They also conjecture PR to be a consistent behavior when allowing for status quo bias within the framework of their axiomatic revealed preference approach, which also encapsulates the EU theory. Thus, rather than providing a new theory, only by restricting the choice set when facing an initial reference point, they succeed in predicting all kinds of PR as a result of the endowment effect causing the WTP/WTA disparity.

Apart from the aforementioned attempts trying to explain PR, there were also studies trying to eliminate this anomaly. Knez and Smith (1987), Cox and Grether (1996) observed that experience in trading bets also reduce reversals. Later, Chu and Chu (1990) used money pumping with their subjects and was able to decrease PR rates.

Contrary to economists, psychologists were rather interested in explaining the behavioral rationale behind this “irregularity”. The compatibility hypothesis, initially proposed by Lichtenstein and Lichtenstein and Slovic (1973) then revised by Slovic, Griffin and Tversky (1990), asserted that preference reversal was caused by the compatibility of prices and payoffs within the task of determining a minimum selling price. On the other hand, the prominence hypothesis, generalized from the results of Slovic (1975) and Tversky, Sattath and Slovic (1988), claimed that this discrepancy in choice behavior was due to the fact that the probabilities of winning, “the prominent attribute” had more weight in decision made on the choice task. All of these studies concluded with a necessity of further adjustments in the theory rather than abandoning axioms.

3.3. Can it really be the endowment effect?

As mentioned earlier, paper by Masatlioglu and Ok (2005) founds the main purpose of this study in trying to explain standard and counter PRs through an endowment effect. They represent the endowment effect, causing the gap between WTP and WTA, as a utility pump that augments the utility of the object once the object is the source of a status-quo bias. With this further adjustment, they predict preference reversals to be part of a consistent decision making within their revealed preference approach.

The first characterization of the model resolves the problem coming up when there exists a status quo, in which case the agent's preferences become incomplete. The agent's evaluation of the problem in such a case depends upon several criteria. In the case that there are no other alternatives that are better than the status quo, in terms of all criteria, the agent adheres with his status quo. That is if the agent is “confused” or “indecisive” about switching from his initial alternative to another, then he is allowed to stick with his current position, leading to a status quo bias. However, if there are alternatives that are superior to the status quo without any doubt, then the agent is to base her decision upon maximization among these superior alternatives.

The second characterization theorem deals with the endowment effect problem. In this case, again in the absence of a status quo, the agent maximizes his utility function. However, when the agent is to make a choice with an initial endowment in hand, he considers only those alternatives that give him higher utility than the endowment's utility plus a strictly positive "utility boost" of the endowment. This boost, which can possibly be interpreted as a "psychological switching cost", allows one to assign different utility levels to owning an object and not owning it, and hence the "endowment effect". Furthermore, as an extension of their characterization, they state another result concerning the monotonicity of the endowment effect. That is, "the choice model warrants that an agent who finds an alternative *x* more valuable than another alternative *y* in the absence of status quo bias, must be compensated more generously to move away from her status quo, when her status quo is *x* as opposed to *y*. "

Extending the model to risky choice situations, particularly to the case of choice sets consisting of lotteries, they propose that the PR behavior can be viewed as a particular case of the endowment effect in light of their model. Indeed, taking this inconsistent behavior of the agent of stating a higher price on the "undesirable" lottery as given, they predict that "*a substantial fraction of the agents […] will in fact change their choices to (the desirable lottery), when (the desirable lottery) is the status quo of the problem.*" (p. 21)

To get a better understanding of this prediction, it is important to clarify the intuition behind the provided theory. On the one hand, if individual is faced with a choice problem that does not involve an initial status quo, then his/her choice follows what the EU theory would have chosen. That is, individual chooses the lottery with the highest expected utility in the available set of lotteries. Thus, if the expected utility of a lottery *q* for an individual is denoted by the utility function u as $E_q(u)$, problem of the individual will be to pick the lottery that maximizes his utility, i.e. $\max_q E_q(u)$.

On the other hand, in the case when individual already owns a lottery p and is offered with a new set of lotteries to choose from, before taking any decision, individual will take into consideration the "utility pump" of owning initial endowment p. Indeed, the utility pump, denoted by $j(p)$, will augment the utility level of this endowment as $E_p(u) + j(p)$. Consequently, individual will first compare the expected utility of a possible alternative, say lottery q**,** to the utility level of the endowment. From here on, there will be two possibilities. If the utility of the endowment surpasses the expected utility of all other possible lotteries, then individual sticks with his/her endowment, i.e.

$$E_p(u) + j(p) > E_q(u) \text{ for all } q$$
$$\Downarrow$$
$$\text{stick with endowment } p$$

Otherwise, individual decides to give up his/her endowment and chooses the lottery out of the alternative set with the highest expected utility, i.e.

$$\exists q \text{ s.t. } E_p(u) + j(p) \le E_q(u)$$
$$\Downarrow$$
$$\text{choose } q \text{ according to } \max_q E_q(u)$$

Finally, to be able to provide an explanation for PR, one needs to fit the concept of a minimum selling price into the model. Notice that this formulation has to recognize the fact that a seller, when naming the price for a lottery, is in possession of the lottery, as is assumed in the PR experiments. Accordingly, to begin with, assume that individuals will always prefer to win more money for sure to less money and denote the minimum selling price of lottery *p* by $S_c(p)$. Minimum-selling price is then defined as the minimum amount of sure money one would be willing to exchange the lottery *p*, when s/he is initially endowed with it. That is, at this selling price, the individual is indifferent between playing out her/his endowment and getting this price for sure. So, it follows that the expected utility of the selling price has to satisfy the following condition:

$$E_{S_c(p)}(u) = E_p(u) + j\,(p) \tag{3.1}$$

Henceforth, starting point of this explanation follows from the fact that, in these experiments, once people are asked to place a minimum-selling price on the lotteries, they are told to presume that they own the lottery they are stating a price upon. Since people are likely to attach a higher value to objects once they own them, this brings along the idea of endowment effect. In this theory, as long as the subject is <u>not</u> in the possession of the lottery, utility attached to choosing it will be determined by means of the possible gains and losses, as in the EU theory approach. On the other hand, tendency of the subjects to claim higher prices on relatively riskier lotteries, once they are the owners, is claimed to be due to looming the utility of keeping them greater than the utility of the money they would receive by selling.

With notation in hand, PR could be analyzed as follows. In these experiments, when subjects are asked to choose between two binary lotteries, they tend to choose the lottery with a high probability of winning a small amount (the P-bet) over the lottery with a small probability of winning a comparatively larger amount of money (the $-

bet).[34] In terms of the notation introduced, this choice would be summarized as:

$$E_{\mathrm{P}}(u) > E_{\$}(u) \qquad (3.2)$$

In contrast, while determining the minimum-selling price of a lottery for which one would not be willing to play it out, the common tendency is to place a higher selling price on the \$-bet, i.e. S_c (\$) > S_c (P). Rewriting this inequality making use of the relation given in equation(3.1), one obtains:

$$\begin{aligned} E_{S_c(\mathrm{P})}(u) &= E_P(u) + j(\mathrm{P}) \\ &< E_{\$}(u) + j(\$) = E_{S_c(\$)}(u) \end{aligned} \qquad (3.3)$$

Note that the introduction of the utility boost will enable inequality in (3.3) to hold in the presence of (3.2), as long as the utility pump of j(\$) is greater than the utility pump j(P).

The aim of this chapter comes into vision at this very point. If endowment effect is the driving force of PR, then one should observe the same effect when subjects, who are already endowed with a lottery, are to decide whether they would like to switch to another lottery or to a sure amount of money. Responses of the subjects to these further questions will then help to analyze whether there really are these proposed utility boosts in accordance with the decisions undertaken.

3.4. The Experimental Design and Procedures

There were a total of 36 economics and business administration undergraduate students from Universitat Pompeu Fabra. Like in many other economics experiments conducted, preference for the selected

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34 Counter preference reversals are observed when subjects prefer the \$-bet over the P-bet, yet price the P-bet higher when asked to give a minimum selling price.

students has stood out for their relative familiarization with concepts in hand more than any possible subject. Thus, if there is any inconsistency observed in their behavior, it will be easier to make a more general claim upon others.

a) Design

Pair	TYPE	Pb	Win with Pb	Expected Value
1	P	0.97	3.0 €	2.91 €
	$	0.31	9.5 €	2.95 €
2	P	0.81	2.0 €	1.62 €
	$	0.19	9.0 €	1.71 €
3	P	0.94	3.0 €	2.82 €
	$	0.5	6.5 €	3.25 €
4	P	0.94	2.5 €	2.35 €
	$	0.39	8.0 €	3.12 €

Table 3.1. Lotteries used in the Experiment [35]

Some of the earlier controls that were suggested by Grether and Plott (1979) have been undertaken for conducting the actual experiment. There were four different tasks. Each task was repeated for 8 different lotteries (please refer to Table 3.1 for a summary of these lotteries). Lotteries used in this experiment, given in the table above, were inspired by those used by Tversky et al. (1990).[36] To avoid any distortions in behavior due to prospect theory, only gains were considered in this experiment.

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[35] In the table Pb stands for probability and in all these lotteries, one wins 0 with probability (1-Pb).

[36] Pairs 2 and 3 correspond respectively to pairs 2 and 4 used in set I of their paper. Pairs 1 and 4 use the same probabilities of pair 1 and 5 of set I, with different payoffs. Tversky et al. (1990) used (0.97, 4€) and (0.31, 9.5€) instead of pair 1; and (0.94, 2.5€) and (0.39, 8.5€) instead of pair 4.

Task 1 – CHOICE

This part of the experiment was similarly designed as in the earlier studies. The subjects at this stage were given four pairs of lotteries, with each lottery having two different outcomes.

As described earlier, pair of lotteries consisted of one P-bet and one $-bet that were close in expected returns. The response mode expected out of this first task was to choose one of the lotteries introduced. If this task was picked at random at the end of the experiment, subjects received the payoff from the preferred lottery that had been played out after their decision.

Task 2 – VALUATION

This task also followed the earlier designs. Subjects were given different lotteries, for which they had to determine a minimum selling price. In accordance with the BDM procedure, after they stated their own selling prices, a random offer price was picked from a uniform distribution of [0, 9]. After each decision, if the random offer price was less than the subject's report, subject kept the lottery and played it out.[37] Otherwise, he had to sell his lottery at the randomly drawn offer price, and received the offer.

BDM procedure at this point ensures that the individual's best strategy is to reveal his true willingness to sell. Telling the truth does not necessarily need to be the best report as when asked to state a "selling price", one's natural response may be to state a higher price. In this mechanism, it is not in the individual's interest neither to understate nor to overstate the minimum-selling price. In the case of an

[37] Notice that this is the crucial point that is expected to induce the endowment effect.

understatement, if the random offer price is greater than his report, the subject will have to give up the lottery. In that case, the individual will end up receiving less than his valuation. On the other hand, in case of an overstatement, if the random price is below his report, the subject will not be able to sell the lottery and hence, will not receive the offer price, which actually was greater than his evaluation. In the instructions, all participants were informed about their incentives to reveal their true valuations with examples provided to the two cases explained above.

Task 3 – SWITCH LOTTERY

choice 1	P1 vs. P2 vs. P3	**choice 5**	\$1 vs. \$2 vs. \$4
choice 2	P1 vs. \$1 vs. \$3	**choice 6**	P2 vs. \$2 vs. P4
choice 3	\$1 vs. \$3 vs. \$4	**choice 7**	P2 vs. \$2 vs. \$3
choice 4	P1 vs. P3 vs. P4	**choice 8**	P3 vs. P4 vs. \$4

Table 3.2. Combinations of Lotteries offered in Task 3[38]

In the second sub-stage, they were presented with a single alternative lottery, close in expected returns yet different in risks, to the one they have chosen in the first sub-stage. That is, if subjects initially chose a \$-bet in the first sub-stage, then as the single alternative, they were introduced with a P-bet belonging to the same pair that was close in returns, and vice versa.[39] Thus, as the final response mode of the task, they had to decide whether they would like to switch from the lottery in hand to the available alternative. In the case of an affirmative response, they played out the alternative lottery. Otherwise, they kept their own endowment, and had to play out that one. If this task was picked at random at the end of the experiment, subjects received the

[38] Here P1 and \$1 correspond to the P-bet and the \$-bet from Pair 1, respectively.
[39] These alternatives were determined according to the possible lotteries provided in Table 3.1.

payoff from the preferred lottery that had been played out after each decision.

Task 4 – SWITCH MONEY

The additional final task subjects had to undertake, again aimed to determine the endowment effect in the decisions of the subjects. At this stage, they had an initial endowment given by the experimenter, either a P-bet or a $-bet. Then subjects were asked to decide whether they would like to exchange this lottery for a sure amount of money or not. The amount of money they were presented with was determined according to the selling prices they have earlier set in task 2.[40] Subjects were offered 0.5 € less than the minimum of the selling prices of the bet they initially have and the bet close in expected returns to this endowment within the same pair.[41] In case of a decision in favor of swapping to this monetary value, they received the sure amount of money, whereas in the decision of adhering to what they had in hand they had to play out the lottery.

b) Procedure

The experiment was programmed and conducted at Laboratori d'Economia Experimental (LeeX) in two separate sessions with the software z-Tree, Fischbacher (2007). To eliminate any possible prominence effects, tasks were introduced in alternating order in the different sessions. For the first session, sequence of tasks was Choice, Valuation, Switch Lottery and Switch Money whereas for the second session this sequence was Valuation, Choice, Switch Money and Switch Lottery. Yet the order in which the lotteries were introduced

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[40] Notice that in the actual experiment, this method will restrict the order in which the tasks have to be presented to the subjects. That is, Task 2 has to be presented to participants always prior to Task 4.

[41] Participants were only offered 0€, if this amount was calculated to be negative.

within each task was the same for both sessions. The instructions were distributed out separately for each task.[42]

Subjects were initially given 5€ for their participation. Yet to further increase incentives, subjects' final payoffs at the end of the experiment were determined by selecting randomly only one of their decisions in one of the tasks. In the first session, random period picked was the same for every participant whereas in the second, it was different for all. Any gains were added to the initial amount of money given.

3.5. What Kind of Decision-Making Behavior Can Be Observed? (Theoretical Predictions)

Before analyzing the data, one has to first realize that there could be several combinations of responses given to these tasks. Moreover, only some of these combinations will be consistent with the hypothesis underlying the experiment.

For the sake of a tractable analysis, results will be studied with the following notation. The response to the CHOICE task will be denoted either by P (for choosing the P-bet over the $-bet) or $ (for choosing the $-bet over the P-bet). As mentioned earlier, $S_c(l)$ will denote the minimum selling price of a lottery *l* when analyzing the VALUATION task. And finally, the third and the fourth tasks' responses will be similarly denoted as in the CHOICE task with the difference of choice being made under a given endowment. Although initial endowment is always a lottery $l \in \{P,\$\}$ in both tasks, alternative sets will be different for each. In the third task, SWITCH LOTTERY, the alternative set

[42] The experiment was conducted in Spanish. The translated version of these instructions for each task is available in the Appendix C.

will be a single lottery. Whereas in the fourth task, SWITCH MONEY, the alternative set will only be the sure amount of money, denoted by M, satisfying

$$\mathrm{M} < \min\left\{S_c(P), S_c(\$)\right\} \tag{3.4}$$

To further clarify this notation, consider the following examples: If a subject decides to keep the endowment of a P-bet when a \$-bet is offered as an alternative, according to the notation introduced, this decision will be summarized as P. Alternatively, if a subject decides to switch from his endowment of the \$-bet to the sure amount of money offered, this will be denoted by M.

The analysis will first involve interpreting the relevant consistent responses to the task of SWITCH LOTTERY within the standard PR behavior observed in the first two tasks. Note that in this third task, each subject faces two questions for each pair of lotteries:

- In a given pair, when they are initially endowed with a P-bet, would they be willing to switch to the \$-bet in the same pair?
- In a given pair, when they are initially endowed with a \$-bet, would they be willing to switch to the P-bet in the same pair?

Before commenting on the predicted responses to abovementioned questions, one should note that the exchange of a good for another one in trying to determine an endowment effect has also been the concern of earlier studies (e.g. Knetsch (1989)). However, this question has only been analyzed with riskless goods and has not been posed for risky alternatives, as in this case with lotteries. The endowment effect for risky alternatives has only been proved to be in force through the WTP/WTA disparity. Hence, the proposed questions aspire to observe an endowment effect both through a disparity in prices and switching decisions, as has earlier been done with riskless goods.

Now, given the above notation and given PR, following elaboration could be made for the possible subjects' responses to be observed in the SWITCH LOTTERY task.

	PREFERENCE REVERSAL		***TASK 3***	
	TASK 1 Choice	**TASK 2 Higher selling price**	**Switch Decision when endowed with P-lottery**	**Switch Decision when endowed with $-lottery**
case 1	P	$	P	P
case 2	***P***	***$***	***P***	***$***
case 3	P	$	$	P
case 4	P	$	$	$

Table 3.3. Possible Responses to Task 3 given PR behavior

The above table considers the case when an individual exhibits PR behavior. Thus, in the first task individual prefers P-bet over the $-bet; yet, in the second task states a higher selling price for the $-bet. Now there are four possible answers to the above two questions in the third task. For each question, the response could be either to keep one's endowment or take the alternative offered instead. If, when endowed with P-bet ($-bet), you decide to keep your endowment, this decision is summarized as P ($) in the table whereas in the case of taking the alternative, this is summarized as $ (P). However, only one[43] will be consistent with the earlier suggested theory. Remember that implications of the preference reversal behavior under this setup have

43 Note that the answers to the two questions have to be consistent with each other. Thus, one has to consider these two answers simultaneously.

been previously deduced according to equations (3.2) and (3.3). Indeed, combination of the two implies that following must be true:

$$E_{\$}(u)+j(\$)>E_{P}(u)+j(P)>E_{P}(u)>E_{\$}(u) \tag{3.5}$$

In turn, equation (3.5) helps to realize that only adhering to your endowment, whether it be the P-bet or the $-bet, is the consistent decision making behavior. This follows from the fact that equation (3.5) gives us the following two inequalities that can be reinterpreted as:

$$\left.\begin{array}{l} E_{P}(u)+j(P)>E_{\$}(u) \Leftrightarrow \text{ keep endowment } P \\ E_{\$}(u)+j(\$)>E_{P}(u) \Leftrightarrow \text{ keep endowment } \$ \end{array}\right. \qquad \textbf{Condition 1}$$

Therefore, **Condition 1** restricts the focus to case 2 in Table 3.3. If one considers all other possible combinations of responses for the first three tasks, the following table summarizes the consistent decisions with the underlying theory.

	TASK 1	***TASK 2***	***TASK 3***	
	Choice	**Higher selling price**	**Switch Decision when endowed with P-lottery**	**Switch Decision when endowed with $-lottery**
Preference Reversal	P	$	P	$
	P	P = $	P	$
	P	P	P / $	$
Counter PR	$	P	P	$
	$	P = $	P	$
	$	$	P	P / $

Table 3.4. Possible Consistent Behavior for first three tasks

Hence, as the above table suggests, when endowed with the P-bet ($-bet), if you state a higher or equal price for the $-bet (P-bet), then provided theory predicts that the best answers to the two questions in the third task is to keep your endowment in both cases. Nonetheless, when endowed with the P-bet ($-bet), if you state a higher price for the P-bet ($-bet), then the best answers to the two questions in the third task is to keep your endowment when endowed with $-bet (P-bet) and to choose either of the two lotteries when endowed with P-bet ($-bet).

Yet overall consistent behavior will be determined by means of the response to the last task, SWITCH MONEY. Again the question of exchanging a sure amount of money for a given risky/riskless good has been posited in the earlier literature (Knetsch and Sinden (1984), Knetsch (1989), Tversky et al. (1990), Blondel and Lévy-Garboua (2008)). However, in all of these studies, these sure amounts offered as an exchange were predetermined amounts whereas in this study, this sure amount purely depends on the individual selling prices determined earlier.

Back to the analysis, at this stage, the introduction of M satisfying equation (3.4)**,** in terms of the utilities, can be rewritten as:

$$E_{\mathrm{M}}(u) < \min\left\{E_{\mathrm{P}}(u) + j\ (\mathrm{P}), E_{\$}(u) + j\ (\$)\right\} \qquad (3.6)$$

Now, equation (3.6) will help to conclude that endowment effect should induce subjects always to stick with their endowed lottery when they are introduced with such a sure option. This can be verified as follows:

$$\begin{aligned} &E_P(u) + j\ (u) > E_M(u) \Leftrightarrow \text{ keep endowment } P \\ &E_\$(u) + j\ (u) > E_M(u) \Leftrightarrow \text{ keep endowment } \$ \end{aligned} \qquad \textbf{Condition 2}$$

Condition 2 requires that subjects should always stick to their initial endowment in a decision of switching to an amount of money that is less than their selling price. This analysis is totally independent of task 1 and task 3. It is only the selling prices determined in task 2 that matters. With the restrictions of **Condition 2** imposed, Table 3.4 could be updated to define the possible combinations of overall consistent behavior as follows:

	TASK 1	***TASK 2***	***TASK 3***		***TASK 4***	
	Choice	**Higher selling price**	**Lottery Switch when endowed with P-lottery**	**Lottery Switch when endowed with $-lottery**	**Money Switch when endowed with P-lottery**	**Money Switch when endowed with $-lottery**
Preference Reversal	P	$	P	$	P	$
	P	P = $	P	$	P	$
	P	P	P / $	$	P	$
Counter PR	$	P	P	$	P	$
	$	P = $	P	$	P	$
	$	$	P	P / $	P	$

Table 3.5. Overall Possible Consistent Behavior

Indeed, if it is an endowment effect that counts for the higher prices of $-bets, it is easy to expect that subjects will prefer to keep the $-bet when offered an amount of money that is less than its expected return. It is very likely to observe that decisions of the subjects will behaviorally not favor switching from a P-bet to an offer that is close in expected returns. Hence, the expected frequency of these tendencies along with the tendency of a preference reversal will be the point where behavioral explanations finally agree with theoretical conjectures under the light of the endowment effect.

3.6. Results

Prior to analyzing the results of the experiment according to the aforementioned theory, one should first check that preference reversal rates replicate those that have been suggested earlier by the literature. In the experiment, overall observed frequencies and rates of preference reversals are given in Table 3.6. In the table, reversal rates corresponding to the P-bet stand for the standard preference reversal whereas those standing for the $-bet stand for the counter-preference reversal rates. The choices column stands for the number of times a bet has been chosen in Task 1. As for the prices column, inconsistent prices are the minimum selling prices stated in Task 2 that do not satisfy procedure invariance and consistent prices are the ones that do satisfy procedure invariance. Finally, the equal column gives the number of times P-bet and $-bet had equal selling prices.

	Task 1		Task 2 PRICES			
	Preferred Bet	**no. of obs**	**Consistent**	**Inconsistent**	**Equal**	**Reversal Rate**
Total	P	76	25	40	11	**0.53**
	$	68	50	15	3	**0.22**
Session1	P	31	9	20	2	**0.65**
	$	41	34	5	2	**0.12**
Session2	P	45	16	20	9	**0.44**
	$	27	16	10	1	**0.37**

Table 3.6. Observations on Task 1 and 2 classified by consistent, inconsistent, equal price behavior and total Preference Reversal Rates

Standard preference reversals were originally shown to exist at a rate of 69% by Grether and Plott (1979) or 45% of Pommerehne et al. (1982). The above results validate these numbers. Moreover, since the pairs of lotteries used in this experiment are taken from Tversky et al. (1990), comparing the above to those they have obtained in their study, it follow that their overall observation of 45% of standard preference reversals and 4% counter preference reversals are replicated within this study as well. Yet, it is also necessary to further restrict attention to the specific pairs in hand. The following data for different pairs of lotteries follows for the overall decisions observed in the experiment:

		TASK 1	**TASK 2 PRICES**			**PR RATES**	
	Bet	**Choice**	**Consistent**	**Inconsistent**	**Equal**	**This study**	**Tversky et al. (1990)**
Pair 1	P $	24 12	5 8	14 4	5 0	**58%** **33%**	**59%**
Pair 2	P $	24 12	10 9	11 2	3 1	**46%** **17%**	**53%**
Pair 3	P $	15 21	5 16	9 5	1 0	**60%** **24%**	**41%**
Pair 4	P $	13 23	5 17	6 4	2 2	**46%** **17%**	**59%**
Mean %	**P** **$**	**53%** **47%**	**17%** **35%**	**28%** **10%**	**8%** **%2**	**53%** **22%**	**45%** **4%**

Table 3.7. Lottery Specific Preference Reversal Rates

In the earlier study of Tversky et al. (1990), the standard rates for the standard preference reversals for the above four pairs were 0.59, 0.53, 0.41 and 0.59 respectively. Hence within the specific pairs, their result of the preference reversal rates is again replicated.

As the second step, an analysis for the extensions that have been suggested is necessary as a proof to the endowment effect. As a result of the earlier predictions, it is easier to first analyze the decisions of individuals concerning the switch to the sure amount of money. The theory predicted that independent of your choice decisions in task 1 and 3, in case of an offer of an amount less than your selling price, one should always hold on to the initial lottery in hand. Table 3.8 summarizes the observed percentage of decisions of switching to the offered sure amount in the experiment:

TASK 4		**SWITCH TO MONEY RATES**		
	Endowment	**Overall**	**Session 1**	**Session 2**
All Pairs	P	38%	40%	36%
	$	33%	31%	35%
Pair 1	P	39%	39%	39%
	$	3%	6%	0%
Pair 2	P	31%	22%	39%
	$	44%	39%	40%
Pair 3	P	36%	44%	28%
	$	42%	39%	44%
Pair 4	P	47%	56%	39%
	$	42%	39%	44%

Table 3.8. Percentage of switch decisions in favor of M in Task 4

Note that only the $-bet in the first pair has a very small reversal rate. The most important reason behind this observation is due to the biggest discrepancy between the selling prices given for P-bet and $-bet in pair 1. Hence, $-bet, on average having a much higher selling price, was less often disclaimed in favor of the sure amount money, that being the same amount also offered for the P-bet in this pair. Nonetheless, results in Table 3.8 show that, contrary to the predictions of the theory; a substantial amount (most of the time above 30%) of the participants chose to switch to the sure amount of money. This is a surprising outcome given that the predictions of the responses to this task were to keep one's endowment, independent of the responses to the other tasks. An interpretation of this result can be due to the "certainty effect". This phenomenon characterized by Kahneman and

Tversky (1979) is due to "*[…] people underweight(ing) outcomes that are considered certain, relative to outcomes that are merely possible*". (p. 265) Hence, concerning the observed behavior of the subjects, it seems plausible to think that the certainty effect is dominating the endowment effect in the decision process of individuals.

Up till this point, the analysis concerns only this decision alone. However, to be able to conclude whether theoretical predictions are valid or not, one needs to further analyze decisions in Task 3. There are two main restrictions that need to be taken into consideration when analyzing consistent behavior related to Task 3. The actual idea behind this task was to observe decisions when offered an alternative lottery to the endowment, where this endowment had to be one of ***every possible of lottery*** determined at the beginning of the experiment. However, as the first restriction, not all subjects chose all lotteries in this task. Actually, it was only the P-bet in pair 1 that was chosen at least once by all subjects as an initial endowment. As for all the other lotteries given in Table 3.1, the following table, Table 3.9, summarizes the number of subjects who have chosen each lottery as an initial endowment as a result of the first sub-stage of Task 3:

	P	**$**
Pair 1	36	25
Pair 2	1	10
Pair 3	19	33
Pair 4	27	29
Total	**83**	**97**

Table 3.9. Observation number on choice of endowment in Task 3

Note that especially lotteries in Pair 2 were least chosen relative to the other available lotteries. This, most possibly, is due to the fact that lotteries in Pair 2 were smaller in expected returns compared to the others. Therefore, in the first sub-stage of the experiment, lotteries of pair 2 were dominated by the other alternatives almost all the time. Overall, the above table indicates that the data needs to be handled with care since there is a different sample size for each pair of lotteries and for the overall comparison of the P and $ lotteries.

The second restriction in the data comes about as a result of the first. Although there were eight periods to decide, not all eight lotteries were chosen in these eight periods; and moreover, some participants chose the same lottery as an endowment more than once. The second restriction kicks in at this very point. Some of these participants, who chose a lottery as an endowment more than once, did not make consistent decisions in the second sub-stage of Task 3. That is to say, the first time they picked this lottery as their endowment, they chose to keep it; whereas the next time they chose it as their endowment again, they decided to switch for the alternative lottery offered, or the other way around. This obviously is an inconsistent behavior that needs special attention when analyzing the data. That is to say, when reporting the frequencies of behavior in Task 3, one has to keep in mind the non-available data points along with the inconsistent ones.

Table 3.10 summarizes the number of inconsistencies within the subjects and within the observed frequencies of a lottery being selected as an endowment.

	Bet	Subjects' Selections	Inconsistent Subjects	Number of Selections	Inconsistent Selections
Pair 1	P	18+18 = 36	**2 + 3 = 5**	40 + 42 = 82	**4 + 6 = 10**
	$	12 + 13 = 25	**0 + 3 = 3**	23 + 27 = 50	**0 + 6 = 6**
Pair 2	P	1 + 0 = 1	**0 + 0 = 0**	1 + 0 = 1	**0 + 0 = 0**
	$	5 + 5 = 10	**0 + 0 = 0**	5 + 7 = 12	**0 + 0 = 0**
Pair 3	P	9 + 10 = 19	**1 + 0 = 1**	11 + 10 = 21	**2 + 0 = 2**
	$	17 + 16 = 33	**8 + 5 = 13**	25 + 24 = 49	**16 + 10 = 26**
Pair 4	P	14 + 13 = 27	**0 + 0 = 0**	14 + 13 = 27	**0 + 0 = 0**
	$	15 + 14 = 29	**1 + 1 = 2**	25 + 21 = 46	**2 + 2 = 4**
Total	P	83	**6**	131	**12**
	$	97	**18**	157	**36**

Table 3.10. Number of inconsistencies observed in Task 3[44]

Note that in Table 3.10, the largest number of inconsistencies occur with the $-bet in the third pair. This lottery was the one where you obtained 6.5€ with a probability ½ and win nothing with a probability ½. Among all the possible $-bets used in the experiment, this lottery has the highest probability of winning a positive amount (0.5 vs. 0.19, 0.31 and 0.39). Consequently, there is a high possibility that participants do not perceive this lottery as risky as the other ones, and hence they are prone to be more indecisive as to keep it or not; hence displaying an inconsistent behavior.[45] With these restrictions in mind, Table 3.11 summarizes the findings in the data concerning Task 3.

[44] In each cell, the numbers of observations from different sessions are specifically indicated to find the overall sum of selections and inconsistencies.

[45] Note that, there are also cases where, within one pair, individuals display consistent behavior with one lottery and inconsistent choices with the other lottery in the pair.

		Size of data		Observed Predicted choices	% of predicted choices in data	
		with	without		with	without
		inconsistencies			inconsistencies	
TASK 3	only for P endowment	83	77	43	52%	56%
	only for $ endowment	97	79	60	62%	76%
	P and $ endowment	65	52	15	23%	29%
TASKS 3 & 4 together		65	52	5	8%	10%

Table 3.11. Predicted choices for Task 3 alone and together with Task 4

The first row of Table 3.11 restricts attention to decisions that comply with the predictions given in Table 3.4 when individuals are endowed with a P lottery. Excluding the inconsistent responses, 56% of these decisions agree with the third column of Table 3.4. On the other hand, if cases where individuals chose to be endowed with a $ lottery are considered, then 76% of the individuals comply with the predicted behavior given in the fourth column of Table 3.4, when inconsistent choices are excluded. However, actual predictions of Task 3 come about when these two decisions are considered at the same time, given the decisions of the participants in the choice and valuation tasks. In this manner, one can observe the overall compliant decisions with those predicted in Table 3.4. This rate is found to be only 29% as given in third row of Table 3.11. Furthermore, within these observations, 21 observations (excluding the two inconsistent ones) displayed preference reversals, yet only 4 of these conformed with the predicted behavior of sticking to your initial endowments.

As the last step, to be able to determine the overall predictive power of the earlier suggested theory, response modes to the tasks of switch lottery and switch money have to be considered together. This final analysis is summarized in the last row of Table 3.11. The highlighted cells show that, again excluding the inconsistent observations, only 10% of these observed decisions agree with the predicted ones. Additionally, 15 of these 52 available data points correspond to preference reversals; yet only 2 of them (13%) satisfy the requirements given in the first row of Table 3.5.

3.7. Conclusions and Further Research

Towards interpreting the results given earlier, it is quite surprising that most of the time above 30% of the subjects were willing to give up the lottery they had in hand for a sure amount of money that was even less than their selling price. This result can be due to the earlier criticisms of the BDM procedure. Throughout the whole analysis, it is presumed that the BDM procedure extracts the selling prices truthfully. Yet, if this method does not work as intended, then subjects could as well exhibit the observed behavior in the experiment. However, since there is not strong enough evidence against this mechanism, this result is remarkable. According to the predictions, independent of earlier choice among lotteries, decision of holding onto your endowment should be optimal when offered an amount that is less than your valuation. However, these findings show that a substantial amount of the observed decisions counteract to this argument.

Still, the most striking result appears in analyzing the decisions of the task of switching lotteries. It is observed that participants have a very high tendency to give up their endowments as opposed to holding onto them as the theory predicts. If these decisions are considered separately for P lotteries and $ lotteries, then it follows that respectively 56% and 76% percent of the time people hold on to their own endowments. However, once attention is restricted to the specific pairs, then 81% of the time individuals favor to switch to an alternative lottery when endowed with a P and/or $ lottery within the same pair. Hence, it seems that a decision of adhering to your lottery is most often irrelevant of which lottery you preferred or which lottery you have priced higher. Thus, endowment effect does not seem to be a driving force of the preference reversals based on the discussed results. Yet, one needs to keep in mind that the plausibility of these findings would have been stronger if one had a bigger sample size.

The only limitation of this chapter was due to some unobservable data points in the task of switching lotteries. This specifically restricted the decisions to be analyzed. Specifically, missing data for the second pair ruled out almost 36 observations. This is the main reason why the within pair comparison was not provided for this particular task.

As a critique of the aforesaid results, one could argue that all of the above could as well include a randomness component in the decision making process of individuals. Hence, to come to a stronger conclusion that reported results actually refute the suggested theory, a further extension to this work would be to take this randomness into consideration and compare predicted and observed behavior accordingly.

Finally, another study could consider the stock markets under the same predictions. As a big part of our daily lives, people are observed to be likely to prefer safer portfolios to riskier ones. However, once they own these portfolios, their unwillingness to switch from stocks to bonds or from bonds to stocks, along with a tendency of over-pricing a stock, leads one to think of endowment effect in a similar fashion. Hence, a similar study could be constructed with stock portfolios instead of using lotteries. Moreover, such data would be more realistic than the lotteries employed within the limitations of this study. This, in turn, would help to conclude further about the validity of the analyzed theory.

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A. APPENDIX TO CHAPTER 1

A.1. Calculating Payoffs

a) The Star Network

Consider the star network in Figure 1.1. Suppose that the center, individual **1**, makes a contribution of **1**, one of the periphery individuals, say individual **3**, makes a contribution of **2** while others choose to contribute **0**. As individual **1** is connected to all peripheries, he benefits from all of their contributions. Thus, as contributions of the peripheries add up to **2** plus his contribution of **1**, according to Table 1.1, he enjoys benefits of **82** from a total of **3** tokens. On the other hand, peripheries only benefit from their own contributions along with the contribution of the center, which is their only direct link. Hence, this gives a benefit of **82** to individual **3** out of the total of **3** tokens, and a benefit of **33** to individuals **2** and **4** out of the total of **1** token they get to enjoy. Clearly, final payoffs are determined by adding to these benefits the returns they earn from the tokens they kept to themselves. Thus, for the given example, individual **1** has a total payoff of **82 + 21 * (3-1) = 124**, individual **3** has a total payoff of **82 + 21 * (3-2) = 103**, and finally individuals **2** and **4** have a total payoff of **33 + 21 * (3-0) = 96**.

b) Circle Network

As in the star network, subjects only benefit from the contributions of those subjects to whom they are directly connected to. Let us elaborate on the final payoffs of the subjects with the following example. Consider the circle network given in Figure 1.1. Suppose that subjects **1** and **4** make a contribution of **1** token, while subject **2** contributes nothing and subject **3** contributes **2** tokens. Subject **1** being connected to subjects **2** and **4**, he earns benefits from a total of **2** tokens, gaining a benefit of **60**. As for her final payoff, one again needs to take into consideration the number of tokens he kept for the private account. Hence, subject **1**'s final payoff is **60 + 21 * (3-1) = 102.** Next, consider subject **4** whose direct connections are subjects **1** and **3**. Her neighbours' total contributions of **3** tokens plus her own contribution of **1** token give him a benefit of **100** from the total of these **4** tokens he enjoys. Consequently, her final payoff is **100 + 21 * (3-1) = 142**. Calculating in a similar fashion, one will find the final payoffs of **145** and **103** for subjects **2** and **3** respectively.

A.2. Instructions

Thank you for participating in this experiment about decision making. You will be paid for participating, and if you read the following instructions carefully, you can, depending on your decisions and the decisions of others, earn a considerable amount of money. It is therefore very important that you read these instructions with care. The money you earn will be paid to you in cash at the end of the experiment.

From now on, you are not allowed to talk or communicate in any way with the other players. If you have any questions, please raise your hand and one of the experimenters will answer them in private. Please do not ask your questions aloud.

In this experiment, you will play 20 rounds in total.

- In the **first round**, each player will be assigned with a label (***A* or *B***) that will stay the same until the end of the experiment.
- At the **beginning of each round** you will be randomly paired with three other players to form a group of four.
- Each group in each round will have one player with a label *A* and three players with label *B*. The members of a group are not necessarily sitting side by side.

Once you are assigned to a group for that round, you will have to take a decision. The decisions of the players in your group will determine your points in each period. These points will be converted to Euros at the end of the experiment.

Structure of Your Neighbors In Each Round

In your group of four, you will be neighbors only with ***only one*** or ***all*** other 3 players. (Please see Figure A. 1) If you have label *A*, then your neighbors will be the other three players with labels *B*. On the other hand, if you have label *B*, then your single neighbor will be the player with label *A*.

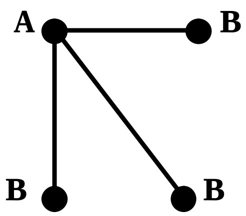


Figure A. 1. Structure of your neighbors

Your Decision

At the beginning of each round, each player will receive a total of 3 tokens. In each round, every participant in a group will need to determine how many of these tokens (0, 1, 2 or 3) he/she wants to contribute to a project.

[In the treatment with communication, the decision part of these instructions was further explained as follows:

Before making the contributions, one person from your group of four will be chosen randomly to make an announcement of a contribution of 0, 1, 2 or 3. This announcement may indicate what that person plans to contribute in that round.

If you are chosen to make an announcement:

You will not be required to contribute what you have announced. However, your announcement will be communicated to **your neighbors** before they decide on their contributions. So if you have label *A*, then all your neighbors with label *B* will learn your announcement. On the other hand, if you have label *B*, your single neighbor with label *A* will learn your announcement, while other people with label *B* in your group will NOT learn your announcement.

<u>If you have label *A* and you are NOT chosen to make an announcement:</u>

One of your neighbors with label *B* will make an announcement. You will be told about his announcement before deciding on your contribution (0, 1, 2 or 3).

<u>If you have label *B* and you are NOT chosen to make an announcement:</u>

- If your single neighbor with label *A* is chosen to make an announcement, then **you will be told** about his announcement before deciding on your contribution (0, 1, 2 or 3).
- If your single neighbor with label *A* is NOT chosen to make an announcement so that another person in your group also with label *B* is chosen to make an announcement, then you will decide on NOT BE TOLD your contribution (0, 1, 2 or 3) WITHOUT knowing his announcement. **]**

<u>Your Payoff</u>

Your income will be determined by the points you earn from **your contributions and your neighbors' contributions.**

<u>Payoff for Player with Label A:</u>

A player with label *A* will benefit from the contributions of all the other three neighbors, i.e. all three neighbors with label *B* (Please see Figure A. 1) In this case, player *A* can contribute from a number between **0** and **3** tokens, while his three neighbors with label *B* can contribute in total from a number between **0** and **9** tokens in total to the project. Number of points that a player with label *A* can obtain in each round is given in Table A. 1:

CONTRIBUTION AS PLAYER A	TOTAL CONTRIBUTIONS OF HIS NEIGHBORS WITH LABEL *B*									
	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
0	63	96	123	145	163	178	192	205	217	228
1	75	102	124	142	157	171	184	196	207	217
2	81	103	121	136	150	163	175	186	196	205
3	82	100	115	129	142	154	165	175	184	192

Table A. 1. Points for players with label A

For example, if a player with label *A*, contributes **2** tokens and his neighbors (with label *B*) contribute a total of **5** tokens, then total points of player *A* at the end of the round will be 163 (see row with contribution **2** as player *A* and column with his neighbors' contributions **5**). As you can see, for any level of contribution of player *A*, he will earn more as his neighbors contribute more (go along the points in a row). However, given the total of his three neighbors' contributions, the same relationship is not always true. Given his neighbors' contributions, player *A* does not necessarily earn more, the more he contributes (go along the payoffs in a column). Note that if his neighbors with label *B* contribute 4 or more in total, player *A* actually earns less, the more he contributes. In the next table, we show how much a player with label *B* will earn, depending on what a player with label *A* contributes and what the player with label *B* contributes.

Payoff for a player with Label B

A player with label *B* will **only** benefit from the contributions of his single neighbor, i.e. the neighbor with label *A* (Please see Figure A. 1). In this case, player *B* can contribute from a number between **0** and **3** tokens, while his neighbor with label *A* can as well contribute from a number between **0** and **3** tokens to the project. The number of points a player with label *B* can obtain in each round is given in Table A. 2:

CONTRIBUTION AS PLAYER *B*	CONTRIBUTION OF NEIGHBOR *A*: **0**	**1**	**2**	**3**
0	63	96	123	145
1	75	102	124	142
2	81	103	121	136
3	82	100	115	129

Table A. 2. Points for players with label B

For example, if player with label *B* contributes **1** token and his neighbor (with label *A*) contributes **2** tokens, then total points of player *B* at the end of the round will be 124 (see row with contribution **1** as player *B* and column with neighbor's contribution **2**). As you can see, for any level of contribution of player *B*, he will earn more as his neighbor *A* contributes more (go along the payoffs in a row). However, given the contributions of his neighbor *A*, the same relationship is not always true. Given his neighbor's contributions, player *B* does not necessarily earn more, the more he contributes (go along the payoffs in a column).

Information at Each Round

In each round, you will learn about your previous decisions. While you decide how much to contribute, you will be able to refer to your previous contributions and the previous contributions of each of your neighbors.

Each row will give information about each round. Your previous contributions will be in the second column and your previous points from previous rounds will be in the last column. Column(s) in between the second and the last will display the previous contributions of your neighbor(s). Depending on your label, the screen you will see in each round will be similar to one of the following:

<u>IF YOUR LABEL IS A:</u>

ROUND	Your Contribution	Contribution of 1st neighbor with label *B*	Contribution of 2nd neighbor with label *B*	Contribution of 3rd neighbor with label *B*	Your points In Round
….	**….**	**….**	**….**	**….**	**….**

<u>IF YOUR LABEL IS *B*:</u>

ROUND	Your Contribution	Contribution of neighbor with label *A*	Your points In Round
….	**….**	**….**	**….**

After you make your decision, you will also be informed about your current contribution, the current contribution(s) of your neighbor(s) and your points from that round. Note that a player with label *B* will not know what his neighbor with label *A* earns, since he will not know what other players with label *B* contributed.

Payment

The total amount of points you collect after each round will be summed up to determine your total points at the end of the experiment. This final sum will be converted into Euros and will be paid out in cash immediately after the experiment is finished. The payment will be made individually and anonymous.

B. APPENDIX TO CHAPTER 2

B.1. Data for Independent Observations

Session1	Indep Group	Type[46]	Total Token	Token1	Token2	Token3	Token4
Complete-5_1	1	1	14.44	3.7925	3.4575	3.6625	3.5275
Complete-5_1	2	1	11.4925	3.0275	3.1425	2.82	2.5025
Complete-5_2	3	1	13.61	3.515	3.225	3.375	3.495
Complete-5_2	4	1	13.7125	3.38	3.225	3.49	3.6175
Circle-5_1	5	1	10.9325	6.0625	4.8175	-	-
Circle-5_1	6	1	10.0225	4.88	5.0075	-	-
Circle-5_2	7	1	10.075	5.1725	4.9025	-	-
Circle-5_2	8	1	10.365	5.055	5.31	-	-
Star-5_1	9	2	7.49062	7.49062	-	-	-
Star-5_1	9	1	16.05	5.2875	4.3	3.4	3.2625
Star-5_1	10	2	8.45938	8.45938	-	-	-
Star-5_1	10	1	14.5375	4.4625	3.775	2.95	3.35
Star-5_2	11	2	6.40312	6.40312	-	-	-
Star-5_2	11	1	14.125	4.6	3.5125	3.7625	2.25
Star-5_2	12	1	15.5	4.775	3.6	3.7375	3.3875
Star-5_2	12	2	7.32813	7.32813	-	-	-
Circle-3_1	13	1	9.6375	4.53333	5.10417	-	-
Circle-3_1	14	1	11.1333	5.7125	5.42083	-	-
Circle-3_1	15	1	10.4083	5.39167	5.01667	-	-
Circle-3_2	16	1	10.4667	5.05833	5.40833	-	-
Circle-3_2	17	1	11.9375	6.2625	5.675	-	-
Circle-3_2	18	1	11.5833	6.33333	5.25	-	-
Star-3_1	19	2	10.0417	10.0417	-	-	-
Star-3_1	19	1	15.5	7.8125	7.6875	-	-
Star-3_1	20	1	13.2917	6.72917	6.5625	-	-
Star-3_1	20	2	10.0521	10.0521	-	-	-
Star-3_1	21	1	14.4792	6.75	7.72917	-	-
Star-3_1	21	2	9.20833	9.20833	-	-	-
Star-3_2	22	1	12.2917	6.29167	6	-	-
Star-3_2	22	2	9.15625	9.15625	-	-	-
Star-3_2	23	2	8.35417	8.35417	-	-	-
Star-3_2	23	1	12.375	6.47917	5.89583	-	-
Star-3_2	24	2	8.41667	8.41667	-	-	-
Star-3_2	24	1	14.25	7.66667	6.58333	-	-

[46] There is only one type for regular networks, hence type is equal to 1 for all sessions, whereas for star networks, type=1 if the subject is a center, and type=2 if a periphery player

B.2. Instructions

Thank you for participating in this experiment about decision making. This experiment consists of two parts. If you read and apply the following instructions carefully, depending on your decisions and the decisions of others, you can earn a considerable amount of money. Moreover, you will be paid 3 Euros only for participating. The money you earn will be paid to you in cash at the end of the experiment. The details about the payments in each part will be explained separately in the instructions of each part. The points you receive will be converted into Euros with an exchange rate of 1 Euro per 200 points (for every 200 points you have you will receive 1 Euro).

From now on, you are not allowed to talk or communicate in any way with the other players. If you have any questions, please raise your hand and one of the experimenters will answer them in private. Please do not ask your questions aloud.

In the first part of the experiment, you have to decide between different risky or riskless options in 45 cases. The instructions for part 2 will be distributed once we complete part 1. The second part of the experiment will consist of 40 rounds.[47]

---

a) Instructions for Part I

This stage consists of 3x15 decisions, which will be explained in continuation. In all these cases, you have to decide between X and Y. Therefore, during part 1, you will see three different screens with 15 decisions each. At the end of the first part, 1 out of 45 decision

[47] For Star-3 treatment, the second part consists of 24 rounds.

situations will be chosen randomly. Your payment from part 1 will be according to the situation picked.

In each screen, each row will give information about each situation. The tables for each situation group can be found in the following pages. In these tables, the number of decision will be in the first column. The sure payment (in points) that you will receive if you choose X will be shown in the second column. The third column is where you will choose between X and Y. Finally, the risky payment (in points) that you will receive if you choose Y will be shown in the last column.

Decisions 1-15:

If one of the decision situations 1-15 is picked at the end, you will be paid in the following way:

1) If you choose X, you will receive the sure payment (in points) given in the second column. Please do not forget that actual payments depend on which situation is chosen randomly at the end of the first part.
2) If you chose Y, your payment will depend on the result of a die roll (rolled by the computer). The information below will also appear in the last column.
    - If the result of the die is **1, 2, 3, 4, or 5** you receive **0 points**.
    - If the result of the die is **6** you receive **300 points**.

Periodo

1 de 1

Decide entre X o Y para cada una de las 15 situaciones.

Numero de decisión	Pago para X:	Tu decisión: X o Y	
1	0 puntos	X ○ ○ Y	Pago para Y:
2	10 puntos	X ○ ○ Y	
3	20 puntos	X ○ ○ Y	0 puntos si el resultado del dado es 1, 2, 3, 4 o 5
4	30 puntos	X ○ ○ Y	
5	40 puntos	X ○ ○ Y	300 puntos si el resultado del dado es 6
6	50 puntos	X ○ ○ Y	
7	60 puntos	X ○ ○ Y	
8	70 puntos	X ○ ○ Y	
9	80 puntos	X ○ ○ Y	
10	90 puntos	X ○ ○ Y	
11	100 puntos	X ○ ○ Y	
12	150 puntos	X ○ ○ Y	
13	200 puntos	X ○ ○ Y	
14	250 puntos	X ○ ○ Y	
15	300 puntos	X ○ ○ Y	OK

Ayuda

Cuando hayas decidido tienes que hacer un click en el butón OK.

You have to choose X or Y for each situation and you can make your choices in any order. When you have made all your decisions click the "OK" button. Until you press the button you can change your decisions.

Decisions 15-30:

If one of the decision situations 15-30 is picked at the end, you will be paid in the following way:

1) If you choose X, you will receive the sure payment (in points) given in the second column. Please do not forget that actual payments depend on which situation is chosen randomly at the end of the first part.
2) If you chose Y, your payment will depend on the result of a die roll (rolled by the computer). The information below will also appear in the last column.
    - If the result of the die is **1, 2 or 3** you receive **0 points**.
    - If the result of the die is **4, 5 or 6** you receive **300 points**.

Please note that the probabilities in situations from 15 to 30 are different than those of 1 to 15.

Periodo

1 de 1

Decide entre X o Y para cada una de las 15 situaciones.

Numero de decisión	Pago para X:	Tu decisión: X o Y
16	0 puntos	X ○ ○ Y
17	50 puntos	X ○ ○ Y
18	100 puntos	X ○ ○ Y
19	110 puntos	X ○ ○ Y
20	120 puntos	X ○ ○ Y
21	130 puntos	X ○ ○ Y
22	140 puntos	X ○ ○ Y
23	150 puntos	X ○ ○ Y
24	160 puntos	X ○ ○ Y
25	170 puntos	X ○ ○ Y
26	180 puntos	X ○ ○ Y
27	190 puntos	X ○ ○ Y
28	200 puntos	X ○ ○ Y
29	250 puntos	X ○ ○ Y
30	300 puntos	X ○ ○ Y

Pago para Y:

0 puntos si el resultado del dado es 1, 2 o 3

300 puntos si el resultado del dado es 4, 5 o 6

OK

Ayuda

Cuando hayas decidido tienes que hacer un click en el butón OK.

You have to choose X or Y for each situation and you can make your choices in any order. When you have made all your decisions click the "OK" button. Until you press the button you can change your decisions.

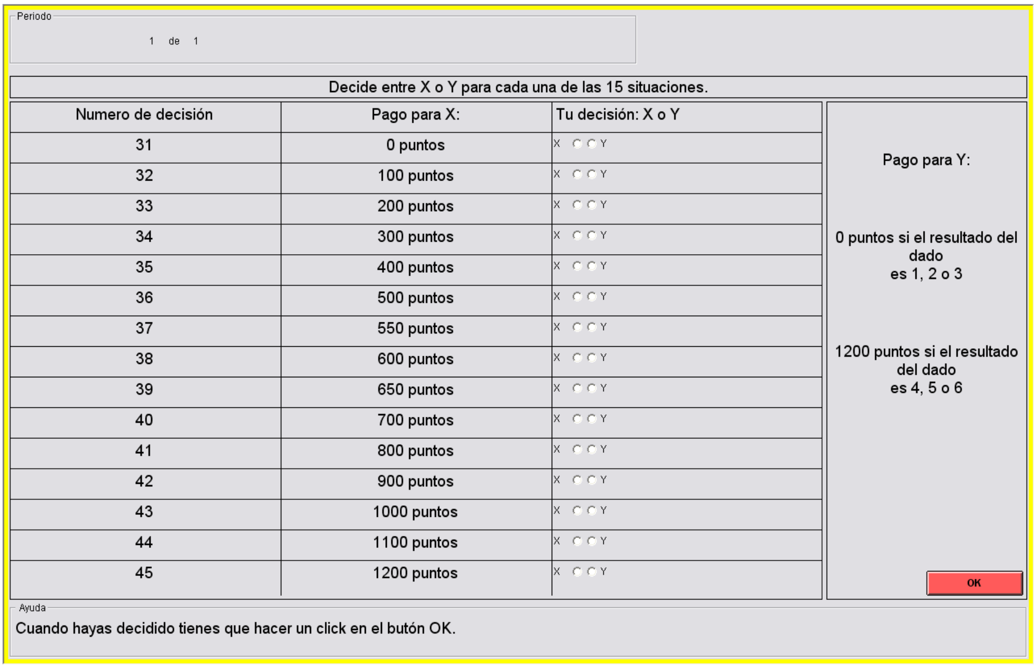
<u>Decisions 31-45:</u>

If one of the decision situations 31-45 is picked at the end, you will be paid in the following way:

1) If you choose X, you will receive the sure payment (in points) given in the second column. Please do not forget that actual payments depend on which situation is chosen randomly at the end of the first part.
2) If you chose Y, your payment will depend on the result of a die roll (rolled by the computer). The information below will also appear in the last column.

- If the result of the die is **1, 2 or 3** you receive **0 points**.
- If the result of the die is **4, 5 or 6** you receive **1200 points**.[48]

Please note that the probabilities in situations from 31 to 45 are the same as the situations 15 to 30, however the payoffs you might receive are different.


Periodo

1 de 1

Decide entre X o Y para cada una de las 15 situaciones.

Numero de decisión	Pago para X:	Tu decisión: X o Y
31	0 puntos	X ○ ○ Y
32	100 puntos	X ○ ○ Y
33	200 puntos	X ○ ○ Y
34	300 puntos	X ○ ○ Y
35	400 puntos	X ○ ○ Y
36	500 puntos	X ○ ○ Y
37	550 puntos	X ○ ○ Y
38	600 puntos	X ○ ○ Y
39	650 puntos	X ○ ○ Y
40	700 puntos	X ○ ○ Y
41	800 puntos	X ○ ○ Y
42	900 puntos	X ○ ○ Y
43	1000 puntos	X ○ ○ Y
44	1100 puntos	X ○ ○ Y
45	1200 puntos	X ○ ○ Y

Pago para Y:

0 puntos si el resultado del dado es 1, 2 o 3

1200 puntos si el resultado del dado es 4, 5 o 6

OK

Ayuda

Cuando hayas decidido tienes que hacer un click en el butón OK.

You have to choose X or Y for each situation and you can make your choices in any order. When you have made all your decisions click the "OK" button. Until you press the button you can change your decisions.

48 For Circle-3/5 and Star-3 treatments the payoff in option 2 is equal to 600 points instead of 1200.

b) Instructions for Part II

This part of the experiment consists of 40 rounds. At the **beginning of each round** you will be **randomly paired** with four other players to form a group of five. **Therefore, the members of your group will be different at each round.** The members of a group will not necessarily sit side by side. Once you are assigned to a group for that round, you will have to take a decision. Your decision and the decisions of the other players in your group will determine your points in each period.

Structure of your group in each round

- In **each round**, you will be assigned with a label (***A or B***).
- We will assign you the label A at a random period, and once you are assigned with a label A, you will continue to be **label A for 8 consecutive periods. The remaining 32 periods** of the experiment **you will have label B.**
- Each group in each round will have **one player with a label *A* and four players with label *B*.**
- Depending on your label, you will be directly linked with ***only one*** or ***all*** other 4 players. (Please see Figure B. 1) If you have label A, then you will directly linked with all other four players with labels *B*, whom will be your opponents. On the other hand, if you have label *B*, then your single direct link will be with the player with label A, whom will be your opponent.

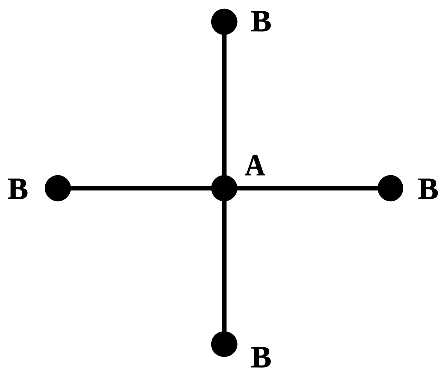


Figure B. 1. Structure of your group

Your Decision

In each round, for each link you have with another participant, you can earn a **prize of 300 points. So if you have label A, then you can win up to 4 prizes from 4 different links with participants of label B. On the other hand if you have label B, you only have the chance to win a single prize from the single link you have with a participant A.** Below, you can find out how you can win a prize for each link.

- At the beginning of each round you will receive 400 points from us.
- You can use these points to purchase “contest tokens”. If you buy X tokens in total, the total cost of these tokens will be equal to X^2. For example, if you buy a total of 2 tokens you pay cost of 4 points, whereas if you buy a total of 5 tokens you pay a cost of 25 points. Hence, you can purchase up to 20 of these tokens at a cost of all your points, since $20^2 = 400$. Any points you do not invest into contest tokens will simply be added to your point balance and are yours to keep. Likewise, your opponents will have the chance

to buy contest tokens. Please refer to table distributed separately for the calculations of the cost and point balance. Number of tokens you can acquire are in the first column. The total cost of the tokens bought is in the second column. Finally, your remaining points after buying tokens are in the third column (initial endowment-cost of tokens).

When you have Label A:

- As we have explained before, you can win up to 4 prizes from 4 links. Hence, the total number of tokens you purchase can be used for all links, some links or only one. For example, if you purchase 8 tokens, you can use 2 tokens for each link, or you can use all 8 tokens in one link and zero for the others. To ease the calculations you can use the calculator available in your screen.

When you have Label B:

- As we have explained before, you can use these tokens to win only one prize from the single link you have.

Prize:

As soon as everybody has chosen how many contest tokens to buy, a lottery wheel will determine whether you or your opponent wins the prize. When you have label A, you will see four lottery wheels on your screen corresponding to four available prizes from four links. When you have label B, you will see only one lottery wheel since you have only one link. Each prize is worth 300 points and your chances of winning a prize depend on how many contest tokens you have bought and how many contest tokens your opponent has bought in order to win that prize. This works as follows:

- The lottery wheel is divided into two shares with different colors. One share belongs to you (red) and the other share belongs to your opponent (blue). The size of your share and the size of your opponent's share on the lottery wheel are exact representations of the number of contest tokens bought by you and bought by your opponent. For instance; if you and you opponent have each bought the same number of contest tokens, each of you gets a 50 percent share of the lottery wheel. If you have bought twice as many contest tokens as your opponent has, you get two thirds of the wheel and your opponent get one third of the wheel.

- Once the shares of the lottery wheel have been determined, the wheel will start to rotate and after a short while it will stop at random. Just above the lottery wheel there is an indicator at the 12 o'clock position. If the wheel comes to a halt such that the indicator points at your share you win. If the wheel comes to a halt such that the indicator points at your opponent's share, your opponent takes the prize and you will have lost.

Thus, your chances of winning the prize increase with the number of contest tokens you buy. However, the cost of your tokens increases more than proportionally. Conversely, the more contest tokens your opponent buy, the higher the probability that you lose. If one of you doesn't buy any contest tokens, the other wins the prize with certainty. If nobody buys any contest tokens, the prize will be awarded randomly, with each participant having an equal chance of winning the prize.

Information at each Round

At the end of each round, you will learn you past and present decisions, the prizes won and therefore the points you obtained. The information for the current period will be in the upper half of the screen. The information about past periods will be in a table in the lower half of the screen. In this table, each row will give you information about each round. The table you will see will be similar to the following:

<table>
<tr><th rowspan="3">Round</th><th rowspan="3">Label</th><th colspan="4">Tokens bought against opponent</th><th rowspan="3">Total Cost of Tokens</th><th rowspan="3">Available Prizes (depending on your label)</th><th rowspan="3">Number of Prizes won</th><th rowspan="3">Points won from prizes</th><th rowspan="3">Points in Period</th></tr>
<tr><th rowspan="2">1</th><th colspan="3">if you have label A</th></tr>
<tr><th>2</th><th>3</th><th>4</th></tr>
<tr><td>….</td><td>….</td><td>….</td><td>….</td><td>….</td><td>….</td><td>….</td><td></td><td>….</td><td>….</td><td>….</td></tr>
</table>

Payment

At the end of this part, 2 out of 40 rounds will be chosen randomly. One of these rounds will be chosen from when you had label A and the other will be chosen from when you had label B. The payment of the second part will be according to your total points of the rounds chosen. The points from part 1 and 2 will be added and converted into Euros (for each 200 points you gain you will receive 1 Euro). Moreover, as we have mentioned at the beginning of the experiment, you will receive a 3 Euro participation fee. This final sum will be paid to you in cash at the end of the experiment. The payment will be made individually and anonymous.

C. APPENDIX TO CHAPTER 3

C.1. Instructions

This is an experiment in the economics of decision-making. Please read the instructions carefully. If you follow and apply them carefully, you can make some money. Your earnings of the experiment will depend **only** on your decisions. You are not allowed to communicate with anybody else during the experiment.

Each decision you shall make will involve one or more options (lotteries). Your earnings **at the end of the experiment** will depend on only **one of your decisions** that will be determined **randomly**. As for your earnings, you initially have **5 fixed Euros** for participating in this experiment. Every Euro gained, for each randomly chosen decision, is equivalent 2 Euros paid at the end of the experiment. So 5 Euros of the experiment are 10 Euros real.

Task 1:

In the first part you will have to make 4 decisions. Each decision involves two options of which you have to choose one. After each decision your choice will be carried out. This means your preferred option will be played out. Look at the following table for an example of an option.

OPTION
You win 16.00€ with a probability of 0.31
You win 1.50€ with a probability of 0.69

Options will be indicated as in the figure. For example, if you play the option in the figure, then you will win 16€ with a probability of 0.31 and win 1.50€ with a probability of 0.69. You can think of probabilities as drawing a ball out of an urn containing a total of 100 red and black balls. For the given option above, the urn has 31 red balls and 69 black balls. And if you choose this option in the example, in case of drawing a red ball you will win 16.00€ and win 1.50€ in case of drawing a black ball.

Practice Item:

Consider carefully the following two options shown in the figure:

OPTION 1	OPTION 2
win 16.00€ with a probability of 0.31 win 0.00€ with a probability of 0.69	win 4.00€ with a probability of 0.97 win 0.00€ with a probability of 0.03

Suppose you have the opportunity to have one of these options. Make one check below to indicate which you would prefer to play:

Option 1: ____________

Option 2: ____________

Task 2:

In the second part you will have to make 8 decisions. Each decision will include whether or not you want to sell a given option as shown in the figure.

OPTION
You win 7.00€ with a probability of 0.42
You win 0.00€ with a probability of 0.58

You will be asked for the **smallest** price at which you would sell option to the experimenter who will act as the buyer. Your selling price can be anything between **0.00€** and **9.00€**, both included.

After each decision of stating a selling price for a given option, the following will be done: First we will use a random process to determine a random price at which the experimenter will accept to buy the given option. The price will again be between **0.00€** and **9.00€**. If this buying price is greater than or equal to the price you state (which is your minimum selling price for your option in hand), you will sell your ticket to the experimenter and receive the buying price. If the buying price is less than your selling price, you will keep your option and it will be played out.

It is in your best interest to be accurate; that is, the best thing you can do is to be honest. If the price you state is too high, then you might not able to sell it even though you wanted to sell it. If your price is too low, then you will have to sell the option even though you wanted to play it out.

For example, suppose you would be willing to sell the option for 4€ but instead you say that the lowest price you will sell it for is 6€. If the offer price drawn at random were between the 4€ and 6€ (for example 5€) you would be forced to play the option even though you rather have sold it for 5€.

Suppose that you would sell it for 4€ but not for less and that you state you would sell it for 2€. If the offer price drawn at random were between 2€ and 4€ (for example 3€) you would be forced to sell the option even though at that price you would prefer to play it.

Practice Item:

What is the smallest price for which you would sell a ticket to the following option?

OPTION
You win 7.00€ with a probability of 0.42
You win 0.00€ with a probability of 0.58

My price is __. __ __€.

TURN THE PAGE OVER TO SEE THE RANDOM PRICE.

OPTION
You win 7.00€ with a probability of 0.42
You win 0.00€ with a probability of 0.58

My price is __. __ __€.

The buying price is **2.50€**.

Given my price: I am a SELLER / KEEPER (mark the correct one)

CHOOSE THE CORRECT CASE

<u>**Case 1:**</u> **If my price is greater than the offered price.**

I will be able to sell my ticket: Yes/No (circle correct word)

Choose the correct alternative (A or B) & fill in the relevant space:

A. I will play out the option. And I will either win _________€ with a probability of _________ or win _________ with a probability of _________.

B. I will receive the offer price and I will earn _________€.

<u>**Case 2:**</u> **If my price is less than the offered price.**

I will be able to sell my ticket: Yes/No (circle correct word)

Choose the correct alternative (A or B) & fill in the relevant space:

A. I will play out the option. And I will either win _________€ with a probability of _________ or win _________ with a probability of _________.

B. I will receive the offer price and I will earn _________€.

<u>Note:</u> Remember that what you gain at the end will be determined by **one** of the decisions you will take during the whole experiment. This decision will be chosen randomly.

<u>Task 3:</u>

In this third part you will again have to make 8 decisions. The options you will have to consider will be similar to the ones provided in the earlier parts.

In this part of the experiment, you first will have to choose one of the possible three options presented. Afterwards, as a part of your decision task, you will be asked whether you would like to give up this option and switch to another available one. After each decision, your choice will be carried out. This means your preferred option will be played out.

<u>Practice Item:</u>

Consider carefully the following option.

OPTION 1	OPTION 2	OPTION 3
win 7.00€ with a probability of 0.42	win 40.00€ with a probability of 0.11	win 150.00€ with a probability of 0.03
win 0.00€ with a probability of 0.58	win 0.00€ with a probability of 0.89	win 0.00€ with a probability of 0.97

You have the opportunity to take one of these options. Make one check below to indicate which you would prefer to play:

Option 1: _____________

Option 2: _____________

Option 3: _____________

Now you own this option. Suppose you have the opportunity of exchanging this option with another one. The only available option is as given in the following figure.

ALTERNATIVE OPTION
win 5.00€ with a probability of 0.17
win 0.00€ with a probability of 0.83

You have to make a decision whether you would like to keep your initial option or switch to the alternative. Make one check below to indicate your decision:

Choice 1 - I would like to keep my initial option. ______

Choice 2 - I would like to give up my initial option and switch to the alternative option. ______

Given my decision, (choice 1 / choice 2 - circle the correct option), I will either win _________€ with a probability of _________ or win nothing with a probability of _________.

<u>Note:</u> Remember that what you gain at the end will be determined by **one** of the decisions you will take during the whole experiment. This decision will be chosen randomly.

<u>Task 4:</u>

In this last part of the experiment you will again have to make 8 decisions. For each decision, the options you will have to consider will be similar to the ones provided in the earlier parts.

You will again have a particular option in hand initially. In each decision, you will be asked whether you would like to give up this option and switch to a certain amount of money that is going to be determined by the experimenter. Given your decision, if you choose to keep your initial option, it will be carried out, and the outcome of the option will determine your earnings. If, on the other hand, you decide to switch to the money offered, then you will be paid this certain amount as your earning.

<u>Practice Item:</u>

Consider carefully the following option. You are currently own following option.

INITIAL OPTION
You win 2.00€ with a probability of 0.91
You win 0.50€ with a probability of 0.03

Suppose you have the opportunity of exchanging this option with a sure amount of money. If you decide to give up your option, you will be paid **1.00€** by the experimenter.

Make one check below to indicate your decision:

Choice 1 - I would like to keep my initial option. ______

Choice 2 - I would like to give up my initial option and switch to the offered amount. ______

If this decision is chosen at the end of the experiment,

<u>Case 1:</u> I have chosen to keep my option.

I will either win _________€ with a probability of _________ or win _________ with a probability of _________.

<u>Case 2:</u> I have decided to take the offered amount.

I will earn _________€.

Note: Remember that what you gain at the end will be determined by **one** of the decisions you will take during the whole experiment. This decision will be chosen randomly.