EXPERIMENTS ON INTERACTIVE ECONOMIC BEHAVIOR

by

Giorgio Coricelli

A Dissertation to the Faculty of the

DEPARTMENT OF ECONOMICS

In Partial Fulfillment of the Requirements
For the Degree of

DOCTOR OF PHILOSOPHY

In the Graduate College

THE UNIVERSITY OF ARIZONA

2002

UMI Number: 3053861

ProQuest Information and Learning Company
300 North Zeeb Road
P.O. Box 1346
Ann Arbor, MI 48106-1346

THE UNIVERSITY OF ARIZONA ®
GRADUATE COLLEGE

As members of the Final Examination Committee, we certify that we have read the dissertation prepared by Giorgio Coricelli

entitled EXPERIMENTS ON INTERACTIVE ECONOMIC BEHAVIOR

and recommend that it be accepted as fulfilling the dissertation requirement for the Degree of Doctor of Philosophy

James C. Cox — 5/23/02
Date

Amnon Rapoport — 5/23/02
Date

Lee Ryan — 5/23/02
Date

Stanley S. Reynolds — 5/23/02
Date

Date

Final approval and acceptance of this dissertation is contingent upon the candidate's submission of the final copy of the dissertation to the Graduate College.

I hereby certify that I have read this dissertation prepared under my direction and recommend that it be accepted as fulfilling the dissertation requirement.

Dissertation Director James C. Cox — 5/30/02
Date

STATEMENT BY AUTHOR

SIGNED: ____________________

AKNOWLEDGEMENTS

To my parents.

First, I would like to thank Raffaella for having made these last two years different with her presence in my life. I know very well in my heart that I would never have been able to do what I have done without her.

I am immensely grateful for having been part of a wonderful family without whose help, energy and inspiration I would not have engaged in such a challenging experience. I particularly thank my brother Alessandro for having convinced me to come here and having been so close to me even from afar. And thanks to my eleven nieces and nephews for making life fun.

Thanks to my dearest friends in Tucson, and in Italy, Roumen, Athena, Carlos, Laura, Pierre, Massimiliano, Francesco, Massimo, and Carmelo for having made these years different with their presence, and for having given me a friendship that will always be part of me.

I thank my dissertation committee, James Cox, Stanley Reynolds, Amnon Rapoport, Massimo Piattelli Palmarini and Lee Ryan. Each of them has helped in different ways and in different times during these years. This dissertation has benefited so much from their comments and criticism. I am immensely grateful to James Cox for having made the difference when times were hard.

For *Chapter Two*, I acknowledge Luis Gonzáles Morales, Werner Güth, Amelie Mahlstedt, and John Hey. For financial support, I thank the European Network for the Development of Experimental Economics and its Application to Research on Institutions and Individual Decision Making.

For *Chapter Three*, I thank my co-author and friend Luigi Luini.

TABLE OF CONTENTS

TABLE OF CONTENTS-*Continued*

TABLE OF CONTENTS-*Continued*

LIST OF FIGURES

LIST OF TABLES

LIST OF TABLES-*Continued*

ABSTRACT

This dissertation investigates human economic behavior in contexts which are characterized by different types of human interaction. First, we analyze the effects of introducing asymmetric information in an investment game (Berg et al., 1995), in which the division of an economic surplus between a trustor and a trustee is not contractible. Backward induction suggests that rational self-interested players would not voluntarily engage in any transaction, unless they expect trust and reciprocity to play a role in determining the behavior of their counterparts. In our experiment, only the trustee is aware of the size of the surplus obtained, so the trustor cannot tell if a low back-payment corresponds to a low or a high level of reciprocity. The introduction of asymmetric information in the investment game does not reduce the amounts sent and returned, when compared with previous experimental studies. Moreover, average payback levels increase with the average amount sent. Expectations about other's behavior and risk attitude are also elicited in the experiment. Our results show that the first movers' choices are functions of their expectations about the second movers' payback, and the second movers' choices depend on the difference between the amount the first movers have sent to them and their expectations about this amount. In the second part of the dissertation, we carry out a theoretical and experimental analysis of the problem of double moral hazard arising in a context of asymmetric information. We design a two-stage experiment to analyze a market for durable goods with warranties. In such a market, double moral hazard may arise as the seller can reduce (or increase) the initial quality of the product, while the buyer can reduce (or increase) the maintenance effort. In the first stage of the

experiment, we analyze the impact of the warranty on the equilibrium levels of the product's initial quality and the effort of the buyer. In the second stage, we analyze the role of signaling and reputation in an intertemporal model. There, we show the suboptimality of the equilibria with warranty. We conclude that buyers will accept deviation from equilibrium price induced by sellers of durable goods with warranties. In the third and last part of the dissertation, we design an experiment to study the strategic dependency in two-person iterated zero-sum games, and propose an account of the evidence for large variance in players' win rates across pairs of opponents. Our experiment controls the structure of the interdependence between players. This is achieved by using a computer program as one of the two players. The experimental analysis allows us to distinguish strategic dependence from non-strategic dependence in subjects' play.

CHAPTER 1

INTRODUCTION

The topics of this dissertation concern trust and reciprocal behaviors, incentive mechanism in the presence of asymmetric information, and strategic interactions in games of pure conflict. The common denominator of the three parts of this work is the use of experimental methods. We design and run experiments involving financially motivated subjects. In the experiments, subjects' earnings are contingent on their performance and the performance of the other participants. Citing Vernon Smith, "The laboratory becomes a place where real people earn real money for making real decisions about abstract claims that are just as 'real' as a share of General Motors" (cf. Smith, 1976, pp. 274).

The presence of salient monetary rewards is just one of the characteristics of experimental economics. Experimental economics has emerged as a distinct discipline since the late fifties following a pioneering experiment by Edward Chamberlin (1948). The first studies concern experiments on competitive market behavior (Smith, 1962), oligopoly (Sauermann, and Selten, 1960; Fouraker, Shubic, and Siegel, 1961; Suppes and Carlsmith, 1962), and bargaining behavior (Fouraker and Siegel, 1963). More recently we have an increasing body of experimental literature on public goods (Bohm, 1972; Isaac and Walker, 1988; for a review see Ledyard, 1995), coordination problems (Cooper, DeJong, Forsythe and Ross, 1990) and social dilemmas games. The distinctive characteristics of experimental economics as compared to experimental psychology have been pointed (Hertwig and Ortmann, 2001) to be: the presence of scripts vs. open ended; repeated trials vs. one-shot; truth-telling vs. deception; salient rewards (corresponds to outcome function you try to induce) vs. fix rewards (for participating). Control in economics experiments is achieved by implementing a salient reward structure that induces individual preferences. The purpose of economics experiments is the comparison of alternative theories (at least two theories), testing predictive power and robustness (one theory), looking for regularities (pre-theory, no theory), and calibrating models' parameters. This is stated by Vernon Smith "The fact that one can always run a new experiment means that it is never taoutological to modify the model in ways suggested by the results of the last experiment. Since economic theories always deal with certain alleged behavioral tendencies in isolation, the experimental laboratory is uniquely well suited for testing the validity of such theories." (Citation from Smith's seminal paper: "Experimental Economics: Induced Value Theory", pp. 275). This unique relationship between experimental method and theoretical model represents the strength of this methodology.

In this work, we implement different types of experiments. Our first experiment implements the strategy method (Selten, 1967). We ask the subjects to specify their choices for every possible choice of their counterpart. In this way we elicit subjects' preferences over all the space of possible outcomes of the interaction. In the other experiments we use the decision method that corresponds to asking the subject for one choice at a time. The subjects of our studies are undergraduate students with no previous experience in other experiments. Subjects read instructions that describe the procedures of the experiment and then participate in computerized or "paper" experiments (written decision forms).

The first part of the dissertation studies human behavior in games with underlying reciprocity responses. We use the explication of reciprocity given by Fehr and Gächter: "Reciprocity means that in response to friendly actions, people are frequently much nicer and much more cooperative than predicted by the self-interest model; conversely, in response to hostile actions they are frequently much more nasty and even brutal" (cf. Fehr and Gächter, 2000, pp159). In this definition there are two implicit concepts: positive reciprocity and negative reciprocity. People respond to friendly or hostile actions disregarding material incentives.

Altruism (unconditional kindness) differs from reciprocity because it is not a response-based behavior. Experimental results from ultimatum bargaining games, trust games, gift exchange games, public goods experiments, and social dilemma games show evidence for reciprocal behaviors (negative and positive reciprocity). In the experimental literature we can find several explanations for the evidence of reciprocal behavior: (i) inequality aversion (Bolton and Ockenfels, 2000; Fehr and Schmidt, 1999); (ii) person-based response: people respond to the type of person they face (Levine, 1998); (iii) intention-based response: a desire to reward good intentions or punish bad intentions (Rabin, 1993; Falk, Fehr, and Fischbacher, 2000); boundedly rational behavior (Roth and Erev, 1995; Gale, Binmore and Samuelson, 1995).

Reciprocity has been modeled as evolutionarily stable behavior (Güth and Yaari, 1992; Bowles and Gintis, 1999). In this sense, reciprocity represents the best strategy in terms of fitness, i.e., no other strategy can enter the population and perform better. Bolton (1997) shows how a 50-50 split in a bargaining problem is a rational strategy in an evolutionary framework, i.e., it is an evolutionarily stable strategy (ESS). The proof of this statement is reached by solving the "deadline game" (Bolton uses Selten's trembling hand theory in the evolutionary setting). In this game two players (that have been randomly matched) decide how to split a pie. If they do not reach an agreement on this task, they will end up with zero earnings. The game is called the deadline game because of its sequential nature and the fact that the response time is shorter than the transmission time of a decision. This means that there is no time to state a counteroffer after a player has received the other player's offer. Once a player has received an offer he or she has the time just to accept or reject this offer, and there is no time for counteroffers. Bolton proves that "when bargainers can use a signal to discriminate among partners, 50-50 is the unique limit evolutionarily stable outcome." The evolutionary stability explains why equal split survives as a social norm (or convention).

Reciprocity is based on an inter-temporal (sequential) interaction: one person who moves first must trust the other person to reciprocate. Thus, to derive the benefit from the achievement of the cooperative outcome people must overcome their propensity for immediate self-gratification. Therefore, trust and reciprocity can be seen as self-interested behavior generated by a system of delayed gratification that enables individuals to capture the temporal gains from exchange. Psychologists have long observed that adult humans develop strategies to solve the problem of delayed gratification in making inter-temporal choices. This ability increases desirable outcomes by overcoming the brain's "hot system" propensity for immediate gratification (see Metcalfe and Mischel, 1999). The "hot system" is generally thought to be governed by the emotions, and is balanced by an interconnected cognitively 'cool system' (in analogy with the two-selves theory by Schelling, 1984).

The theory of Reciprocal Altruism (Trivers, 1971; Axelrod and Hamilton, 1981; Axelrod, 1984) is consistent with both the evolutionary approach and the delayed gratification theory introduced above. This was noticed by Dawes and Thaler (1998): "An implication of reciprocal altruism is that individuals will be uncooperative in dilemma situations when there is no possibility of future reciprocity from others, as in situations of anonymity or interacting with people on a 'one shot' basis." But the experimental evidence is in favor of a more "radical" definition of reciprocity: people engage in reciprocal behaviors even in single interactions (evidence of 40-60 percent of socially optimal contribution in "one shot" public good experiments; evidence of 50% trust and 75% reciprocal behaviors in the single play Trust Game by McCabe and Smith, 2000). Therefore, reciprocal altruism gives a limited explanation of the observed cooperation (and reciprocal behaviors). Another drawback of this approach is due to the excessive complexity of playing reciprocally altruistic strategies (like TIT-for-TAT, start cooperating and then mimic the other player's last move) with more than two players, i.e., it does not explain reciprocity in n>2 player games (e.g. public good experiments with n>2). Other evidence (Andreoni, 1987) of more cooperation in the "stranger" condition than in the "familiar" condition (reputation based) shows the explanatory limit of the concept of reciprocal altruism based on the assumption of strategic cooperation.

Our hypothesis is that human minds have a propensity to establish long-term reputations as cooperators and non-defectors, and consequently people are willing to incur the risk that their anonymous counterparts are like-minded persons (see Coricelli, McCabe, Smith, 2000); this assumption could explain the empirical and experimental evidence. This hypothesis implies that some subjects in single-play extensive form games will opt, or respond to, moves whose intentions are to signal a desire for positive reciprocity, and the achievement of greater individual as well as social surplus than if each agent played noncooperatively.

The first part of the dissertation (Chapter 2) studies experimentally the effects of introducing asymmetric information in the Investment Game (Berg et al., 1995). The Investment Game is a two-person sequential game; the first mover (player 1) must choose how much of $10 to send to the second mover (player 2). Both players know that the amount sent will be tripled when it reaches player 2. Player 2 must then decide how much of the tripled money to send back to player 1 (and how much to keep). The money sent back to player 1 does not triple again. Game theory predicts that rational agents playing once will act as follows: player 2 has a dominant strategy to keep all of the tripled money sent by player 1; player 1 should infer this behavior by player 2, and therefore send nothing. In fact, this does not happen. Over 90% of the player 1s exhibit some degree of trust by sending some amount of money, and over a third of the player 2s show themselves to be trustworthy by sending back more than player 1 initially sent. We introduce asymmetric information in this game, i.e., only the trustee (second mover) is aware of the size of the surplus obtained (amount sent multiplied by a stochastic multiplier), and the trustor (first mover) cannot tell if a low back-payment corresponds to a low or high level of reciprocity. We want to test if trust and reciprocity survive as behavioral primitives even in the presence of asymmetric information, where individual decisions have very low informational content about any predisposition to be cooperative. Our analysis contributes to the understanding of the persistence of cooperative outcomes in the face of contrary individual incentives.

The second part of the dissertation (Chapter 3) studies the phenomenon of double moral hazard that arises when two agents interact in order to produce a common outcome. We focus our analysis on the seller-buyer relationship in the market for durable goods with warranties. In this environment with asymmetric information on both sides of the market (only the seller knows the intrinsic quality of the product, and only the buyer knows her "real" characteristic in terms of maintenance effort of the product), double moral hazard arises. The presence of a warranty affects the incentives to properly maintain the product and the incentives to produce a high quality product. The case of durable goods with warranties is interesting for explanation of the double moral hazard phenomenon and, more generally, of the behavior of economic actors in a context of asymmetric information. Indeed, asymmetric information characterizes most economic relationships. In fact, it is often the main rationale for these relationships. The principal cases of double moral hazard are contractual arrangements involving profit (revenue) sharing, such as franchising (see Rubin, 1978; Lafontaine and Slade, 1998; Mathewson and Winter, 1985), share cropping (see Reid, 1977; Gupta, 1989), licensing (see: Morasch, 1995), buyout agreements (see Demsky and Sappington, 1991), wholesaler/retailer relationships (see Romano, 1994), shopping centers/customers (see: Golosinski and West, 1995), incentives for workers inside the organization (see Berkowitz and Kotowitz, 1993), money-back contracts (see Mansoob, 1994), commercial leasing and author/publisher contracts, and the more general case of joint production. The papers by Rubin (1978) and Reid (1977), for instance, refer, respectively, to franchising and share cropping analysis. Building on previous work by Alchian and Demsetz (1972) and Jensen and Meckling (1976) on monitoring and control with the firm, Rubin (1978) proposes an explanation of franchising that is an alternative to the capital market explanation. He shows that franchising is frequent when it is not possible for the franchiser to monitor the franchisee.[1] In his view, franchising is a form of solution to the monitoring and control problems. Reid (1977) analyzes the landlord/ tenant farmer relationship, arguing in contrast for traditional theory that sharecropping is an efficient contract.[2]

More recently, there has been discussion of the double moral hazard focusing on contracts that ensure the best outcome for the two parties. Romano (1994) and Bhattacharyya and Lafontaine (1998) and Slade (1995) suggest the solution of simple linear contracts for double moral hazard, and Kim and Wang (1998) suggest that a linear

---

[1] The franchisor is a parent company that has developed some product or service for sale; the franchisee is a firm that is set up to market this product or service in a particular location.

[2] In the traditional theory, share-farmed lands yield less, for share tenants stint their effort.

contract is not optimal when the agent is risk neutral. Both the theoretical and applied literatures on double moral hazard have not yet fully explored this complex phenomenon.

The third part of the dissertation (Chapter 4) is concerned with games of conflict (zero-sum games). Game theory is committed to the concept of mixed strategies (i.e. probability distributions over actions). In particular, von Neumann's (1928) theoretical solution for two-person zero-sum games requires the decision maker to have the ability to randomize over pure strategies. The theoretical solution for the two-person zero-sum game that von Neumann proposed is call "Minimax." Using the minimax strategy, the first decision maker will choose, after evaluating all the possible consequences of her opponent's strategies, a strategy that maximizes the minimum expected value. The rationale for this strategy is the achievement of a maximum "security level." The minimax theorem requires the second decision maker to choose a strategy that minimizes the maximum outcome achievable by the first decision maker. Von Neumann proved the existence of a minimax equilibrium (in pure or mixed strategies) for every two-person zero-sum game. For the equilibrium in mixed strategies, the decision maker achieves the maximum security level by randomizing over pure strategies.

The concepts of randomization and security level seem to contradict each other. The first implies the use of a "mental" device analogous to physical devices like rolling a die, with the number of faces equal to the available pure strategies. The second behavior, i.e. the intent to achieve a security level, implements a sort of minimal-risk strategy. The contradiction arises, i.e. the same decision maker rationally chooses to assign the consequences of her future to a device that could be out of her control (risky choice), and at the same time she implements a minimal-risk strategy. A possible solution to this contradiction could be found in the strategic value of randomizing. Therefore, when a decision maker randomizes over her pure strategies, she gives no opportunity to her opponent to detect and exploit any regularity in her choices. With this interpretation of randomization, both behaviors (randomization and minimax) have the same rationale, i.e., strategic choice.

An experimental paper by O'Neill (1987) provides support for the minimax solution in iterated two-person zero-sum games. After criticizing previous work that assumed risk neutrality, the author proposes an original design in which the decision makers' equilibrium strategy is independent of their risk attitude. The design of this experiment includes a 4x4 matrix with just two types of outcomes (+5 and –5). Payoffs are asymmetric (decision maker 1 had just 6 over 16 positive outcome). The theoretical minimax solution that implies that decision maker 1 will win 40% of the time has been confirmed. However, the results indicate the presence of an excess of alternating decisions (serial correlation).

These results have been criticized, and replication of the data analysis shows rejection of the minimax solution (see Brown and Rosenthal, 1990; Walker and Wooders, 1999). Walker and Wooders (1999), using a limited information test, reject minimax play at the 5% level for ten of the fifty subjects in O'Neill's experiment.

An experimental design for testing the generation of random series in two-person games is presented by Rapoport and Budescu (1997). The first task of the experiment is an iterated matching pennies game (2x2 matrix), and in the second task subjects are asked to simulate the outcome of an unbiased coin tossed 150 times. Results show no evidence of random behavior in either task. The weaker hypothesis of differences between one-person and two-person games is also tested. Results show smaller deviation from randomness in the two-person zero-sum game (matching pennies game) than in the single-person game (simulation of tossing a coin).

The experimental paper by Budescu and Rapoport (1994) analyzes the differences between subjects' generation of random sequences in one and two-person games. Two experiments are presented. In the first experiment the authors present a within-subjects design that imposes a generation of trinary random series in order to solve a two-person zero-sum game with asymmetric players and a second task in which subjects have to simulate 200 responses of a sequence of three equally likely alternatives. The second experiment requires the subject to generate binary series in two different situations: one-person and two-person games. Results of the first experiment that show 50% of the subjects deviated from the minimax solution. A large part of this deviation is due to an "anchoring" effect of the player to the preceding two choices (t-1, t-2), i.e., subjects do not achieve statistical independence in their choices. Comparison between the first and the second task of the first experiment shows a greater deviation from randomness in the second task (one person game). The authors conclude that this result is caused by cognitive limitations of memory. Even if this explanation is consistent with the data, our idea is that memory limitation is just one of the possible explanatory variables. An interesting conclusion is the identification of the presence of two different cognitive processes in one-person and two-person games, considering that the presence of the second person induces strategic interactions.

Walker and Wooders (1999) present an empirical study that shows how serve-and-return plays by several tennis champions are consistent with the minimax hypothesis. The two authors also provide a justification for deviation from equilibrium play in experiments (see experiments cited in this session). Their justification refers to the inexperience of the subjects that participated in these experiments. In particular, their inability to be unpredictable in a situation that requires this behavior. They interpret the serve-and-return play in tennis as a 2x2 constant-sum game with a unique equilibrium in mixed strategies. The results of this empirical study differ from the results of several experiments for three reasons (authors' interpretation): the top tennis players are expert at this game; they have knowledge of the opponent's characteristics; and they have financial motivation. The serve-and-return play of the tennis players is consistent with the theory of mixed strategy equilibrium, but the players exhibit a tendency to switch the direction of their serves too often, i.e. they do not randomize.

Mixed equilibrium solutions are also studied in a paper by Rapoport and Amaldoss (2000). The two authors study the behavior in an iterated two-person investment game in different experimental settings. Rapoport and Amaldoss note that in the aggregate there is evidence in favor of the mixed strategy equilibrium solution, but at the same time they show evidence for deviation from the mixed strategy equilibrium at the individual level. Their explanation of this phenomenon is that subjects do not randomize but they reach equilibrium by a process of adaptive learning. In summary, the experimental literature on minimax has emphasized the significant differences between results on the aggregate and individual levels; and presented strong evidence of non-random behavior. These two topics are not conclusively explained, and they are not well connected from a perspective of strategic interactions. This conclusion motivates our last experimental work.

In summary, this dissertation focuses on human interactions of the strategic type. In chapter 2 we investigate the determinants of strategic cooperation in games with underlying reciprocity responses. Chapter 3 studies strategic behavior in consumer/seller interaction in the presence of an "artificial" incentive mechanism (a warranty). Chapter 4 analyses the nature of strategic dependency in games of pure conflict. Chapter 5 concludes the dissertation. In our work, we implement the Behavioral Game Theory methodology (see Camerer, 1997): (i) test game theory predictions with experiments; (ii) if unconfirmed, find a plausible explanation; and (iii) extend standard game theory.

CHAPTER 2

THE INVESTMENT GAME WITH ASYMMETRIC INFORMATION

An increasing body of literature in experimental economics has provided evidence of cooperative behavior in situations where non-cooperation is a dominant strategy, and there are no enforcing mechanisms such as reputation concerns, repeated interactions, contractual precommitments, or punishment threats to support a cooperative equilibrium.

In a previous investigation of the investment game, Berg et al. (1995) argued that "trust can be viewed as a behavioral primitive," and that an agent's decision to reward trust may depend on this agent's subjective interpretation of the inherent motives of the trustor. In accordance with the social contract hypothesis one may, for instance, believe that economic agents are evolutionarily predisposed to produce cooperative outcomes, e.g., by their ability to "ratify one another's volitional states" (Hoffman et al., 1998).

Choosing different levels of "trust" can be seen as a way to signal some kind of "cooperative predisposition," which, in turn, increases reciprocal behavior. In the experiment reported here, our aim is to test whether trust and reciprocity survive as patterns of behavior even in a setting where individual decisions have very low informational content about any predisposition to be cooperative. This is achieved by using an asymmetric information structure in an investment game, in which only the player who is in charge of dividing the surplus is aware of its true size.

The investment game is a sequential two-person game. The first mover can send any amount of his or her initial endowment to an anonymous counterpart. The amount received by the second mover equals the amount sent multiplied by a factor greater than one. The second mover can return to the first mover any amount taken from his or her initial endowment plus the amount received. Backward induction suggests that opportunistic players would not voluntarily engage in any transaction, unless they expect trust and reciprocity to play a role in determining the behavior of their counterparts.

In our experiment only the trustee is aware of the size of the surplus obtained, so the trustor cannot tell if a low return corresponds to a low or high level of reciprocity. Additionally, we ask for subjects' expectations about the behavior of their counterparts. Since trust in reciprocity in an investment game is risky for the trustor, we also elicit risk preferences of the subjects.

The chapter is organized as follows: in Section 2.1 we describe our behavioral hypotheses for the investment game with asymmetric information; Sections 2.2 and 2.3 describe the design and the procedures of our experiment; Section 2.4 reports the results and the analysis of the data; Section 2.5 introduces a plausible explanation and a new theoretical model, called "reciprocal intentionality" model, that are consistent with our experimental findings; and Section 2.6 contains concluding remarks.

2.1 The investment game with asymmetric information: Behavioral hypotheses

We modify the investment game (Berg et al., 1995), in which two players, A and B have equal initial endowment ω. The value of the initial endowment is common information. In the first stage of the game, player A (the "trustor") may send any amount $0 \le a \le \omega$ from his or her endowment to player B (the "trustee"). The amount sent is then multiplied by a stochastic factor m, which takes the value $m=2$ with probability p, or $m=4$ with probability $(1-p)$. Only player B learns the true value of the multiplier m.

In the second stage, after observing how much surplus has been generated, player B decides which amount of money b to send back to A[1]. The amount of money B may send to A is $0 \le b \le ma+\omega$. The theoretical solution of the game (perfect Bayesian Nash equilibrium) is: $a=0$ for the first mover, and $b(a)=0$ for the second mover. Thus, the original version of the investment game and the investment game with asymmetric information described here have the same equilibrium solutions. The first hypothesis of our analysis refers to the consistency of the subjects' behavior with the theoretical prediction: Hypothesis 1: $a=0$, and $b(a)=0$.

We extend the definition of trust given by Coleman (1990) and Berg, et al. (1995) imposing some considerations on the subjects' expectations about each other's actions. If the first mover sends a positive amount of money ($a>0$) and when she expects to receive back more or the same than what she sends (expectation of $b \ge a$), we say that she is "trusting" the second mover. In response to a trusting behavior and to the extent in

[1] The second stage of the game is equivalent to a dictator game; i.e. the player that has to move at this stage must decide how much to send to his/her counterpart. This decision will end the game, and the interaction between the two players.

which the amount received is greater than the amount expected, the second mover may send back an amount greater than or equal to the amount the first mover sent to him or her. This behavior could be based on reciprocity, altruism, and inequality aversion.[2] Hypothesis 2 states: when expectation of $b \geq a$, then $a>0$; and when (a - expectation of a) >0, then $b \geq a$.

The third hypothesis concerns the type of correlation between the amounts sent and returned: Hypothesis 3: a and b are positively correlated.

The fourth hypothesis is exclusively related to our design, which allows trustees with multiplier $m=4$ to hide their opportunism by pretending that $m=2$. If so, the reward of trust should not depend on the value of the multiplier: Hypothesis 4: the reward $b(a)$ of trust level a is the same for $m=2$ and $m=4$.

The first mover's decision of trusting the second mover (sending him a positive amount of money) is risky. In terms of risk, a standard hypothesis is that risk-averse people should send a lower amount of money to the second mover compared to risk-lovers. In our comparison between risk attitude and actual decision, we test Hypothesis 5: risk-aversion is negatively correlated with the amount sent.

Hypotheses 1, 4, and 5 are standard in the sense that they claim opportunistic behavior. Hypotheses 2, and 3 predict other-regarding preferences and strategic cooperation.

[2] Our experimental design, eliciting expectations about other's behavior, allows us to define trust behavior of the first movers; but it does not allow us to discriminate the motives of the second movers' behavior.

2.2 Experimental design

Subjects were randomly paired. We refer to any two interacting participants as A and B. The A participants are the first movers and the B participants the second movers in the investment game. Each participant receives an initial endowment of 100 Experimental Currency Units (ECU). The amount of initial endowment is common knowledge (see Instructions in Appendix A). Participant A can send any amount (multiple of 10 from 0 to 100) of his or her initial endowment to B. Participant B receives the amount sent by A, multiplied by a factor that we call the multiplier. The multiplier (m) can be either 2 or 4. Each of these two values are equally likely. Only participant B knows the value of m, whereas A knew the (binomial) distribution of m. B can send to A any amount (not necessarily a multiple of 10) taken from his or her initial endowment *plus* the amount received from A multiplied by 2 or 4. This ends the interaction.

We implemented the strategy method introduced by Selten (1967). The decision form differs for participants A and B. Participant A has to state his or her expectation about the amount B will send back for any amount he or she might send; and his or her choice of the amount to be actually sent. Participant B has to state his or her expectation about the amount A will send, and his or her choice of an amount to return for every possible amount he or she might receive from A for the two possible multipliers. The monetary payments depend on the amount A has sent, the amount B has returned, and the multiplier. Participant A earns 100 ECUs *minus* the amount sent *plus* the amount returned by B. Participant B earns 100 ECUs *plus* the amount A has sent, multiplied by 2 or 4, *minus* the amount returned. The experimental earnings are converted at a rate of 25 ECU to 1 British pound. If a subject's expectation results are correct, the subject earns one extra pound.

2.3 Experimental procedures

Like Berg et al, we implemented a double blind procedure. Neither the experimenters nor the other participants could identify a decision maker.

The experiment proceeded as follows. First, the subjects entered a common room. They were randomly seated. They read the instructions and filled out a control questionnaire. The objective of the control questionnaire was to check whether the subjects understood the instructions before proceeding with the experiment. After everybody finished reading the questionnaire, participants were requested to draw a card from a bag that contained as many cards as the number of participants in the experiment. Each card was marked with a code number that they were required to keep secret. One of the cards was marked with the name "monitor." The monitor did not actively participate in the experiment. He or she just verified that the instructions were followed, distributed the decision forms, collected them, and then supervised the monetary payment procedure. The monitor earned an amount equal to the average earnings of all the other participants. This information was provided to the monitor privately.

The decision forms of A and B participants, once collected, were randomly paired, and the payments were determined according to the amount sent by A, the amount returned by B, and the multiplier, as described above. This was done by first choosing the multiplier randomly, and then checking for B's response to the choice made by the corresponding A. During the calculation of the subjects' earnings they were invited to fill out an anonymous questionnaire marked with the same code as the decision form (see questionnaire in Appendix A). In the questionnaire the subjects had to specify the minimum amount of money they would prefer to receive for sure, instead of a gamble. The questionnaires were collected and finally the subjects received an envelope marked with their codes and containing their final earnings. We conducted 3 sessions of the experiment with 11 subjects each (10 subjects plus a monitor). The subjects were undergraduate students at the University of York, UK. They were all first year students with no previous participation in economics experiments. Sessions lasted approximately one hour.

2.4 Results

The data collected consist of the amounts, a that A participants want to send, the amounts, b(a) that B participants want to return for each feasible value a, the A participants' expectations about the amount, b(a), and the amount, a that B participants expect to receive from their counterparts. In addition, we collected data about subjects' risk preferences. The analysis of the results is divided into three parts: choice, expectations, and risk attitude.

2.4.1 Choice

The results of the experiment strongly rejected Hypothesis 1. Figure 2.1 shows that only one subject (in pair 15) sent zero to his or her counterpart, and only three subjects (in pairs 7, 12, and 14) returned zero to the first mover. The average amount sent was 38 ECUs (with a standard deviation of 24.84); the average amount returned was 47.33 ECUs (with a standard deviation of 42.14).

Figure 2.2 reports the box plots of the amounts sent by A and the paybacks by B. The two medians (represented in the box plot by the solid lines) are very close (two-sided Wilcoxon rank-sum test, r=-0.4795, p-value=0.6316, i.e., the two means are not significantly different from each other). There is more dispersion in the amount of payback than the amount sent. This is explained in part by the fact that B can send any amount, not only multiples of 10 to A, and in part by the increase of the feasible range due to the multiplier.

Figures 2.3 and 2.4 show the amount paid back by B as a function of the amount received from A when the multiplier was 2 or 4, respectively. These two figures exhibit the same trend, namely, an increase of payback with respect to an increase of amount received. The Kolmogorov-Smirnov goodness-of-fit tests (K-S) comparing the samples of less than or equal to 40 ECUs sent and more than 40 ECUs sent, reject the hypothesis of same distribution (K-S =1, p-value=0.0079) for both levels of the multiplier (m=2, and m=4). There is significant difference in payback when trust is higher; therefore, the amounts sent and returned are positively correlated, in support of Hypothesis 3. On the other hand, there is no significant difference between the amount of payback for the two multipliers when the amount sent is less then or equal to 40 ECUs (K-S =0.4, p-value=0.873), but there is a significant difference between the amount of payback for the two levels of multipliers when the amount sent is higher than 40 ECUs (K-S =0.83, p-value=0.026). In the last case the paybacks for m=4 are higher than paybacks for m=2. These results illustrate the fact that the second movers do not take advantage of their information about the effective value of the multiplier (Hypothesis 4 is unconfirmed); and that the choice on payback is sensitive to the amount of trust and to the total return.

Table 2.1 presents two contingency tables, one for the amounts sent and one for the amounts returned. The two contingency tables compare our result with the results of Berg et al. (1995). We consider in the tables the data of an analogous experiment that we conducted in Amsterdam during the ENDEAR Summerschool (2001). The results indicate no difference in the amount sent between our experiments and Berg et al. The Chi-square test cannot reject the hypothesis of independence between the rows (Berg et al.; Coricelli) and the columns (category 1: $a=0$; category 2: $a>0$, where a is the amount sent). The second contingency table indicates a significant difference between our results and Berg et al.; in our experiments the second movers return more. The number of subjects that payback more than the amount that the first mover sent is significantly higher in our experiment. The Chi-square test rejects the hypothesis of independence between the rows (Berg et al., Coricelli) and the columns (category 1: $a>0$ and $b \geq a$; category 2: $a>0$ and $b<a$; where b is the amount returned). In our experiment, only 5 of 24 second movers that received a positive amount paid back less than the amount sent to them by the first mover.

2.4.2 Expectations

Figure 2.5 indicates how the expectations of the second movers about the amount they would receive from the first movers were very close to the observed ones (two-sided Wilcoxon rank-sum test, r=0.86, p-value=0.938, i.e. we cannot reject the hypothesis of equal means). This result confirms the extraordinary human ability of predicting other people's behavior in situations involving reciprocal interactions (see Coricelli, McCabe, and Smith, 2000).

As' expectations about the amount they would receive back for every possible amount they could choose and for both possible values of the multiplier are shown in Figure 2.6 (m=2) and Figure 2.7 (m=4). Their expected payback increases with the amount they might send to B. Indeed, the Kolmogorov-Smirnov goodness-of-fit tests comparing the samples of payback expectations for possible amounts sent less than or equal to 40 ECUs and more than 40 ECUs reject the hypothesis that both samples have the same distribution (K-S =1, p-value=0.0079) for both levels of the multiplier (m=2, and m=4).

There is no significant difference between the expectations of payback for the two multipliers. We cannot reject the hypothesis that the distributions for m=2 and m=4 are the same (K-S =0.455, p-value=0.211). Therefore, the first movers expect a defecting behavior from the second movers, meaning that they expect the second mover to exploit their private information on the effective value of the multiplier.

2.4.3 Risk attitude

Risk attitude was elicited through a post-experiment questionnaire. In the questionnaire (see Appendix A) we asked for 10 certainty equivalents. With the data of the questionnaire we can estimate a value function (Prelec, 2000) and a probability weighting function for each subject.[3] The psychological probability weight is the result of the cognitive perception of objective probabilities. The psychological probability weight is represented by a nonlinear function. Therefore, this function is concave for probabilities close to zero and convex for probability values close to 1 (the other extreme). The convex region is larger than the concave region. This asymmetry of the function is shown also in the value of the inflection point; therefore, this value is estimated to be equal to a probability of .37 that is less than .5 (the symmetry case). The form of this function is determined by a series of cognitive factors. The nonlinearity of the probability weighting function is determined by the observed (experimentally and empirically) over-weighting of small probabilities (the function is concave) and under-weighting of large probabilities (the function is convex). The function expresses the phenomenon of sub-additivity (i.e. the value of a prospect changes more when we change the probability close to the two extremes). For this factor, the slope of the function increases near a probability equal to

---

[3] We proceed as follows. We assume that the value function is a power function, $V(x)=x^{\alpha}$ and the weighting function is the compound invariant (S-shaped), $W(p)=\exp(-(-\ln p)^{\beta})$. If a person estimates that x is equivalent to a p-chance of y, then $x^{\alpha}=(y^{\alpha})\exp(-(-\ln p)^{\beta})$. Taking logarithms twice of both sides of this equation (and rearranging terms) gives a linear equation: $-\ln(-\ln(x/y)=\ln(\alpha)+\beta(-\ln(-\ln p))$. We can estimate this with linear regression, provided we have at least two certainty equivalent judgments. We just set up a linear regression, with the x-variable being values of $(-\ln(-\ln p))$ and y-variable the corresponding values of $-\ln(-\ln(x/y))$. The slope and intercept of the regression equation give us respectively, the value of β and the value of $\ln(\alpha)$. So then we have the weighting and the value functions fully specified. In terms of the questionnaire, we just need to ask for a couple of certainty equivalents for p-chances at y (changing both p and y). Thus 10 estimates are enough to give stable estimates of the slope-intercept.

zero, and near the probability equal to one (certainty). Another cognitive factor that determines the shape of the function is the subproportionality (i.e. the same relative increase in the probability of winning is weighted more for higher probability). There are also differences in the form of the function for the domain of gains vs. the domain of losses. The concept of a psychological probability weight strictly depends on the way it is measured. The weighting function is determined by considering the prospect theory model of Kahneman and Tversky (1979) (and more recently the cumulative prospect theory model of Wakker and Tversky, 1993) as the background model. This implies that the weights are constructed with the evidence of choices over prospects. In this way, we implement risk attitude behaviors. Therefore, risk attitude explains the shape and the characteristics of the weighting function. The use of both the value function and the weighting probability function gives us a better understanding of subjects' risk preferences.

We can find (checking subjects' codes) the corresponding decision form for each questionnaire on risk attitude. In this way we can compare the decisions of the first and second movers with their risk attitude. Table 2.2 shows the subjects' risk attitudes in our experiment. Risk-averse subjects sent more than risk-lovers and risk neutral subjects (Hypothesis 5 is unconfirmed). Risk-lover subjects paid back more than risk-averse ones. Figure 2.8 shows the average payback expectations of risk-averse A subjects and risk-lover A subjects. This figure together with Table 2.3 show a significant difference in their payback expectations, i.e., risk lovers expected less payback. The gap between expectations and observed amount received is higher for the risk-lover second movers than for the risk-averse second movers, i.e. risk lovers were more pessimistic (see Figure 2.9 and Table 2.3).

2.5 The determinants of first movers and second movers' behavior in the investment game: The "reciprocal-intentionality" model

The results of our experiment are consistent with the predictions of the Psychological Games and Sequential Rationality model introduced by Geanakoplos, Pearce and Stacchetti (1989): "...the players' payoffs depend not only on what everybody does but also on what everybody thinks... each player's payoffs depend on his hierarchy of beliefs. A player's beliefs specify what he thinks will happen (that is a probability measure over the product of others' strategy spaces), what he thinks each other player thinks will happen, and so on" (pp. 61). In the intentional reciprocity model that we introduce, the individual's beliefs are determined through an introspection process. The individual thinks what she would do in the situation in which her counterpart is involved. The subjects of our experiments are not following a self-interested behavior based exclusively on their own payoffs. Rather, they behave consistently with a social utility function that includes concerns for fairness and the (perceived) intentions of other subjects. Social payoff model can be represented by the following equation:

$$U_i(x_i, x_{-i}) = v(x_i) + \phi\, v(x_{-i}) \qquad (1)$$

where x_i indicates the player's own payoffs, and x_{-i} indicates other players' payoffs. A value of $\phi>0$ indicates that player i benefits also from other players' consumption, and when $\phi<0$ she suffers from the other players' consumption (see Camerer, 1997). In the standard social payoff model (of preferences over outcomes) ϕ does not depend on the observed or predicted intentions of the others. The linearity of the model follows from the contribution of Edgeworth (1881), and the components of the model represent Adam Smith's (1790) insight that one's utility depends also on the utility of others.

In our experiment (Chapter 2) we elicited choices, expectations, and risk preferences. In what follows we incorporate our results into the social payoff model, transforming it into an intention-based model. From our results (see Table 2.2 and Table 2.3) we can distinguish the behavior of two groups of subjects: risk-lovers and risk-averse subjects. The risk-lovers (first-movers) trust less and payback (second movers) more than the risk averse. These behaviors are consistent with their expectations (see Table 2.3); therefore, risk-averse first-movers have significantly higher expectations about the amount they will receive back from the second movers. It is, indeed, the level of expectations (beliefs) that determines the choice of trust by the first movers; i.e., the coefficient ϕ in the social utility function is positive and greater for the subjects that express higher expectations (risk-averse subjects). The behavior of the second movers is consistent with the subjects' considerations about the difference between the amount they received from the first mover and the amount they expected to receive; i.e., the coefficient ϕ is positive when this difference is positive and is negative otherwise (when they receive less then they expected). These results are shown in Table 2.4 and Table 2.5. Table 2.4 reports Probit estimates and marginal effects (evaluated at the mean) of the regression about the relation between amount sent and payback expectation. The dependent variable, "Send" takes a value of one when the first mover sends an amount greater than or equal to forty ECUs

(High), and value of zero when the first mover sends less than forty ECUs (Low). In Table 2.5 the dependent variable, "Return" takes a value of one when the second mover returns an amount greater than or equal to the amount received, and value of zero when the second mover returns less than the amount received. The independent variable "a - expected a" represents the difference between the amount received from the first mover and the amount expected. In both tables the estimated parameters are positive and significantly greater than zero (Hypothesis 2 is confirmed). These results support our conclusions about the effect of expectations on choices.

We hypothesize that the behavior observed in our experiment is generated by a mental simulation-based mechanism that we call "reciprocal-intentionality." The subject predicts and interprets the behavior of her counterpart by imagining being in her situation (in terms of her mental state). Individuals simulate other individuals' behavior on the basis of their own motives and social predisposition, through a process of introspection,[4] in the sense that "we use ourselves as a model for the person we are describing or predicting" (Stich and Nichols, 1995). They "put themselves in the other's shoes," in the sense that they project themselves into the other's situation without any attempt to project themselves into the other's mind (see Gordon, 1995). Simulation theory states that we predict and explain the behavior of other individuals by a simulative process, i.e. we simulate the decision-making process of the other individual by using part of our cognitive systems "off-line" (Goldman, 1995; Gordon, 1995). "The simulation approach

[4] We use the term "introspection" in a non-Cartesian fashion. For Descartes mental states are immediately manifest to the self, which implies completeness and infallibility. In current cognitive psychology "mental states are invoked in explanations of behavior as mediators between experience and behavior, and as such there is no necessity that they be conscious" (see Derek Bolton, 1995).

postulates that the heuristics or material employed in mentalizing make essential use of the attributer's own psychology. In the standard lore of simulation theory, an attributer who wishes to predict a target's decision begins by creating pretend states in himself that correspond (he thinks) to prior states of the target. He feels these pretend states into his own decision-making mechanism, and sees what decision the mechanism outputs." (cf. Goldman, 2001 pp 2).

The first mover in the investment game (following our hypothesis) simulates the behavior of her counterpart (the second mover) on the basis of what she would do if she were in her position. During this process the first mover calls on her motives, her social predisposition, and her perception of the "social risk" (possibility of a defecting behavior) in the interactive context in which she is involved. Our additional hypothesis is that the individual's perception of social risk is based on her past experience in analogous interactive contexts. The results on the first movers' choices of trust, expectations of reciprocity, and risk attitude,[5] are consistent with our hypotheses. The risk-lover first-movers expected lower payback than did risk-averse first movers. Risk aversion is a good indicator of a subject's past experience in social interaction; indeed risk-loving people tend to engage in more frequent and cynical interactions. They tend to be more experienced and less naïve; i.e., they have a more structured perception of the social risk. Consequently, they trust less than the risk-averse subjects. The second mover in the investment game (following our hypothesis) simulates the first mover's behavior in order

[5] Our data show the following regularities for risk-loving, and risk-averse subjects: (i) risk lovers trust less and reciprocate more; (ii) risk lovers (first movers) have lower expectations of payback; (iii) risk lovers (second movers) have lower expectation of the amount they will receive.

to define her expectation about the amount she would receive. The result of the mental simulation (the expected amount) is then compared with the amount sent by the first mover. This comparison determines the reciprocal behavior: i.e. payback more than the amount sent if the amount received is higher than the amount expected. The risk-loving second movers expected less and paid back more than the risk-averse the second movers. In the case of the risk-loving second movers, the subjective (introspective) perception of social risk (less trust and more defection) determines their pessimistic expectations.

2.5.1 Standard Risk vs. Social Risk

In our analysis we distinguish between the concepts of "standard risk" and "social risk." Experimental evidence in favor of this distinction is found in the research by McCabe, et al. (2000), and Coricelli, et al. (2000). In these two related studies subjects play two-person extensive form games called Trust, Punishment, and Mutual Advantage game. These games are played both with human (human-human condition) and computer counterparts (human-computer condition). The computer plays a fixed and known probabilistic strategy. We focus our attention on the Trust game (see Figure 2.10), in which the first player can move right ending the game with a small payoffs for both players (10, 10), or she can move down giving to the second player the opportunity to choose between an outcome in which she and the first player get more than the first possible outcome (15, 25) or choose down ending the game with her maximum payoff and with a payoff of zero for the first player (0, 40). In this game the first player plays cooperatively (moving down), trusting the second player not to move down, i.e., to reciprocate. In the human-computer condition (when the subject plays first) the subject knows that the computer has been programmed to play randomly, such that 75% of the time it will play right, and 25% of the time it will play down (see Figure 2.11). In this experimental design we hypothesize that in the human-human condition the first player incurs the "social risk" of defection, whereas in the human-computer condition the first player incurs the "standard risk" (25% of the time the computer will play down), earning zero if the computer plays down.

The neuroimaging study by McCabe, et al. (2000) found that different areas of the brain are activated when subjects are playing against another subject than against the computer.[6] They found more activation in an area called Broadman Area 8 in the human-human condition than in the human-computer condition. This difference is significant for the subjects that behave cooperatively. This particular area of the brain has been said (Fletcher et al., 1995) to be involved in theory-of-mind tasks (ability to predict and interpret the others' behavior in terms of their mental states); therefore, the mental processes involved in playing human (social risk) are different than the ones in playing the computer (standard risk). By distinguishing these two components of our model, we

[6] The ability to infer the mental states of others, that is, "menatlizing" has been the focus of much recent research. Autistic humans are hypothesized to lack this ability, and as a consequence are unable to engage in normal social discourse. This paper reports a functional neuroimaging study using fMRI in which we studied brain activity in normal subjects while they performed joint decision-making tasks (extensive form games) with a subject outside the scanner. The resultant brain activity was compared with that measured in a control task: joint decision-making with the computer following a fixed probabilistic strategy. Comparison of the decision-making with another human to that of playing the computer revealed a specific pattern of activation in the orbitofrontal cortex, left medial frontal gyrus (Broadmann's area 8), and the posterior cingulate. These are the same areas where recent studies have found activations associated with mental state attribution in individual choice settings. The localization of brain regions involved in normal attribution of mental states is feasible within the context of two-person decision-making and may have implications for understanding how normal persons infer the strategic behavior of others.

can better explain the relationship between the data on risk preference, expectations, and choice.

2.6 Concluding remarks

The results of our experiment strongly rejected the "standard" hypotheses; i.e. our data are inconsistent with the self-regarding preference model. The introduction of asymmetric information in the investment game does not reduce the amounts sent and returned when compared with a previous experimental study of the investment game (under complete information). Moreover, average payback levels increase with the average amount sent. The second movers did not exploit their informational advantage about the value of the multiplier. The data on expectations show a remarkable ability of the subjects to predict other subjects' behaviors. The first movers expected an increasing amount of payback for an increasing amount of money sent. The second movers guessed (on average) correctly the amount they would receive. The comparison of risk attitude and decision yielded a counterintuitive result (if we only consider the comparison between risk and choice): risk averse people are the ones that send more, and risk lovers are the ones that return more. This observation is similar to the result in the experiment by Gunnthorsdottir, et al. (2002). Comparing the trust behavior of subjects that have scored high or low in the Christie and Geis's Machiavellianism scale (Mach-IV), they found that high Machs did not send (trust) significantly more than low Machs. The high Machs tend to be more risk lovers than low Machs (Allsopp et al., 1991); therefore, our results are similar to their results. Our interpretation of this finding refers to the fact that high Mach-risk lover individuals, due to their intrinsic nature, engage in more frequent and cynical interactions compared with low Mach-risk averse individuals. The experience and the attitude of risk lovers determine their expectations and beliefs about the others' behavior. Our analysis of expectations shows that risk-lover senders have lower expectations about payback, and risk-lover second movers have pessimistic expectations about the amount they will receive from the sender. This explains the first-mover risk-lover reluctance to send money to the second movers, and the second movers' over-generous behavior.

Decisions and expectations in our experiment deviate from the standard model of self-regarding preference and rationality. Our experimental data are consistent with a model based on subjects' beliefs about the intentionality of the other players' actions (see Rabin, 1993; and the "reciprocal intentionality" model introduced in Section 2.4). The first movers' choices are functions of their expectations about the second movers' payback. The second movers' choices depend on the difference between the amount the first movers have sent to them and their expectations about this amount.

We show the necessary condition, for a better understanding of the subjects' behaviors, of eliciting expectations and risk attitudes in experiments involving reciprocal interactions.

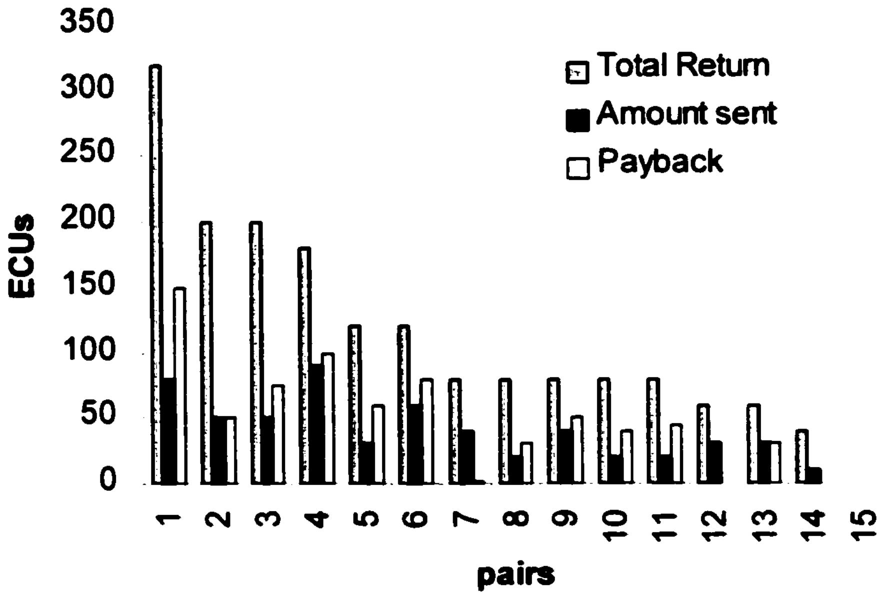


Figure 2.1: Observation sorted by the total return

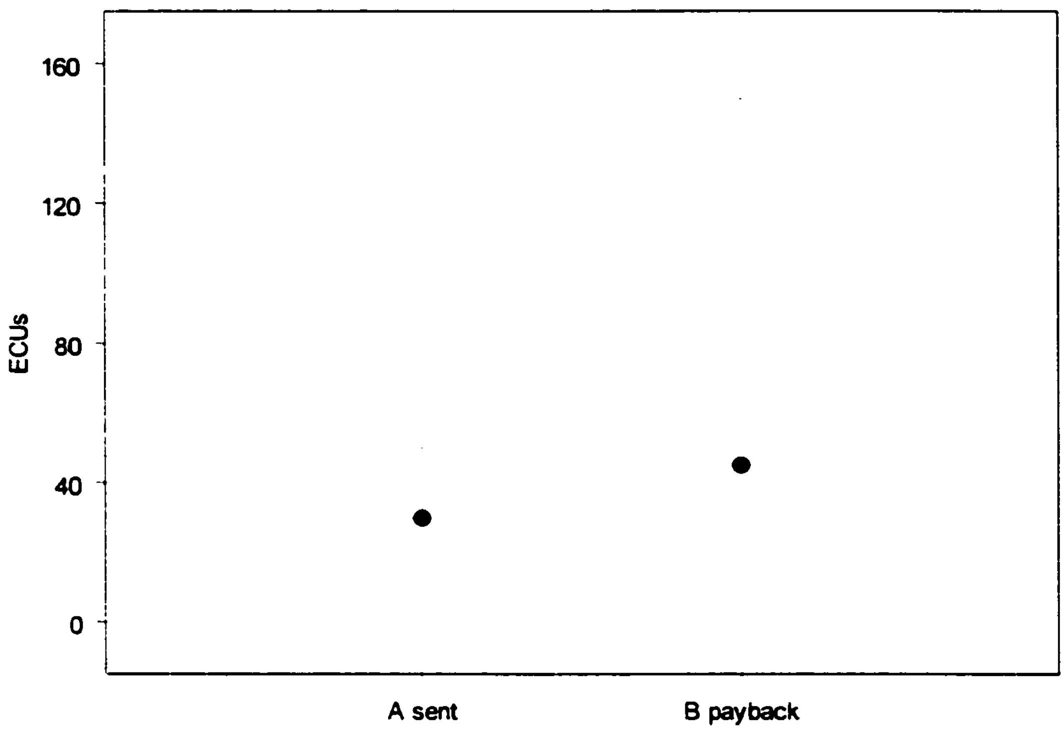


Figure 2.2: Observed amount sent and payback

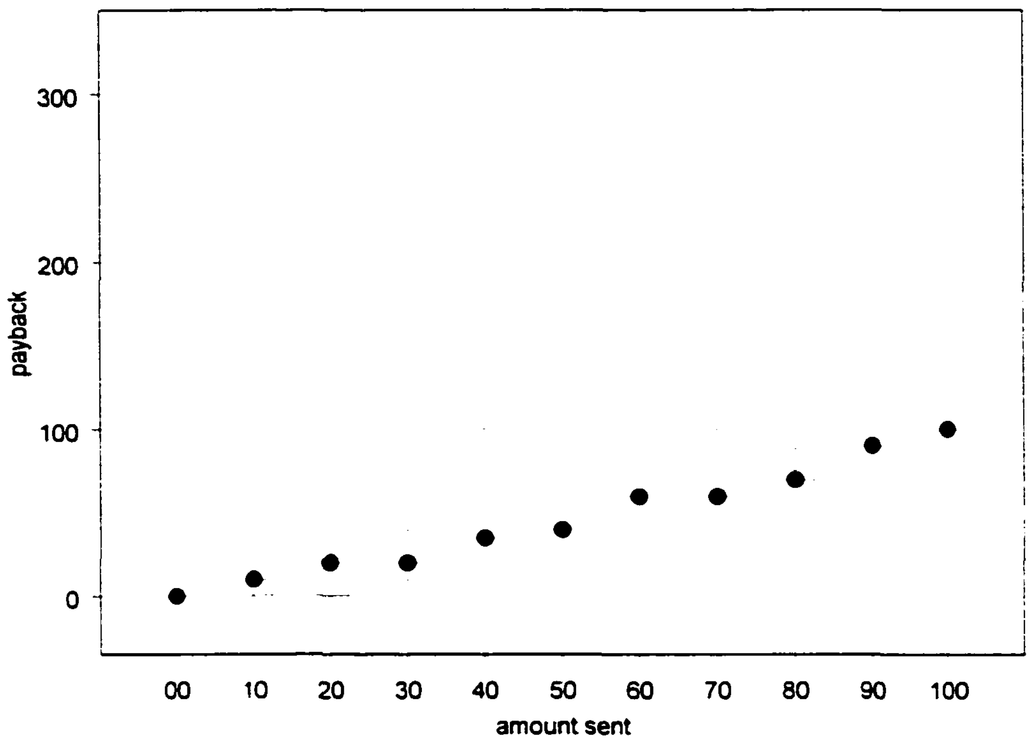


Figure 2.3: B's payback as a function of amount sent (m=2)

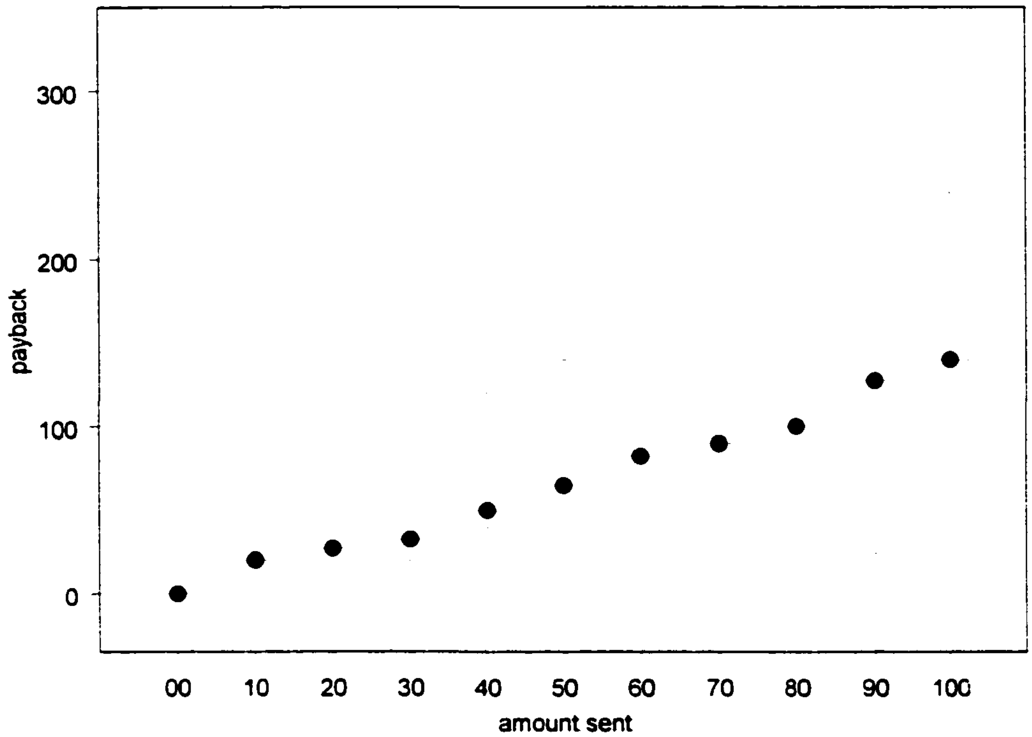


Figure 2.4: B's payback as a function of amount sent (m=4)

	Contingency table 1 Send Data		Contingency table 2 Return Data	
	$a = 0$	$a > 0$	$a > 0, b \geq a$	$a > 0, b < a$
Berg et al.	2	30	14	16
Coricelli	3	24	19	5
Chi-square test	0.45 p-value=0.50		5.93 p-value<0.01	

Table 2.1: Contingency tables: send and return data, Berg et al vs. Coricelli

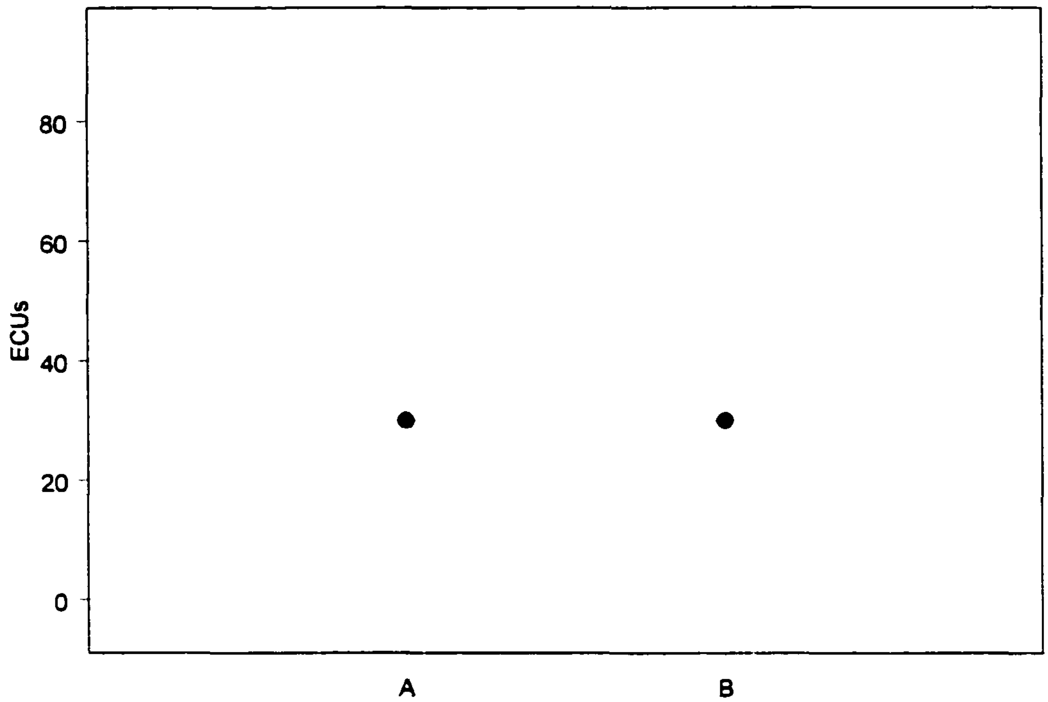


Figure 2.5: A's decisions and B's expectations regarding the amount sent

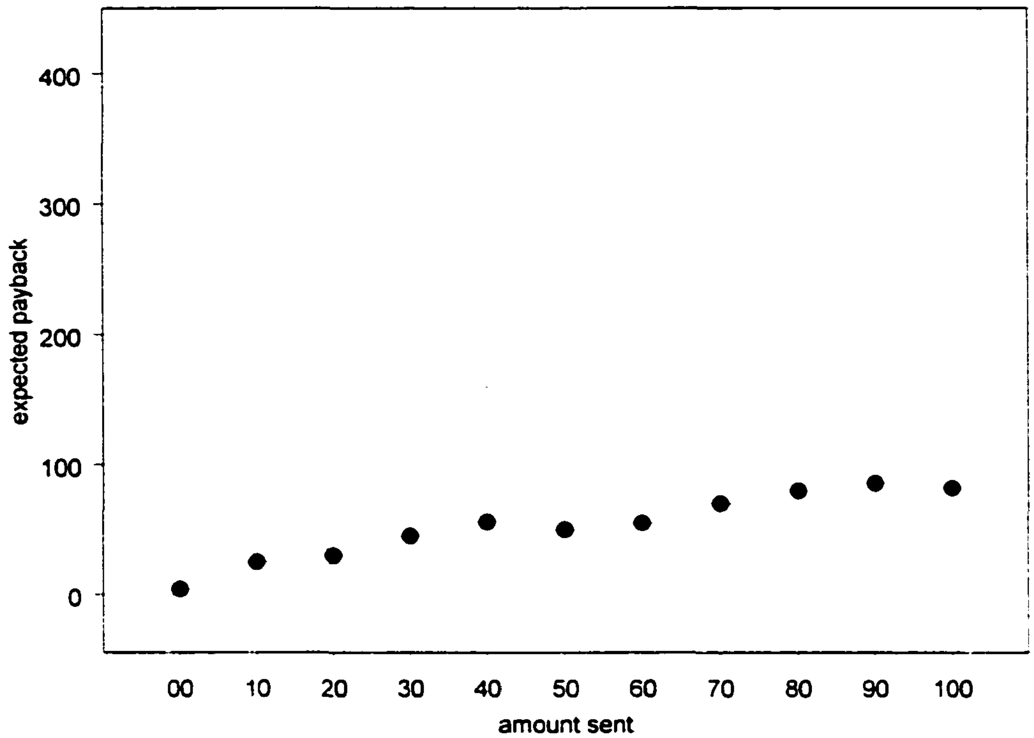


Figure 2.6: A's expectations about B's payback (m=2)

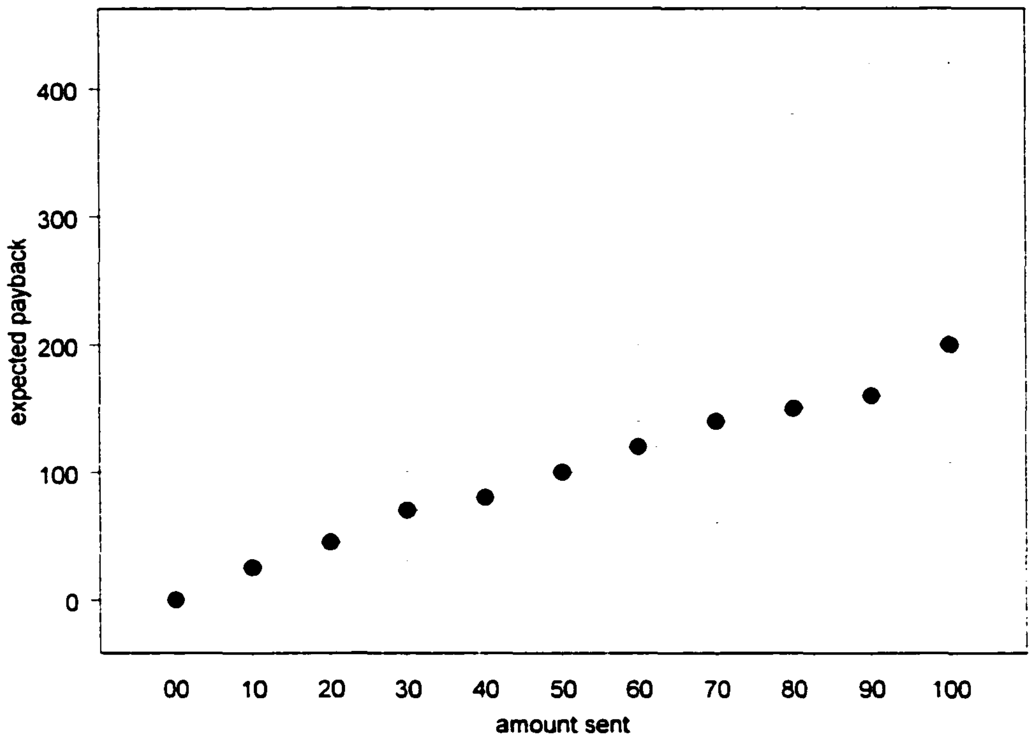


Figure 2.7: A's expectations about B's payback (m=4)

Risk attitude	**Amount sent** $< 40ECUS$	$\geq 40ECUs$	**Payback** $\leq 50ECUs$	$> 50ECUs$
Risk averse	0.375	0.6	0.5	0.4
Risk neutral	0.125	0	0.1	0
Risk lover	0.5	0.4	0.4	0.6

Table 2.2: Proportion of risk attitude for ranges of amount sent and payback

Samples	Risk Averse μ_x	Risk Lovers μ_y	$\mu_x - \mu_y$	t -stat	p-value
b expected	70.857	28	42.857	2.052	0.033
a – expected a	-6	16.667	-22.667	-2.946	0.016

Table 2.3: Fisher Exact test for differences between samples means of risk averse and risk lovers subjects payback "b" expectations and differences between amount received and amount expected

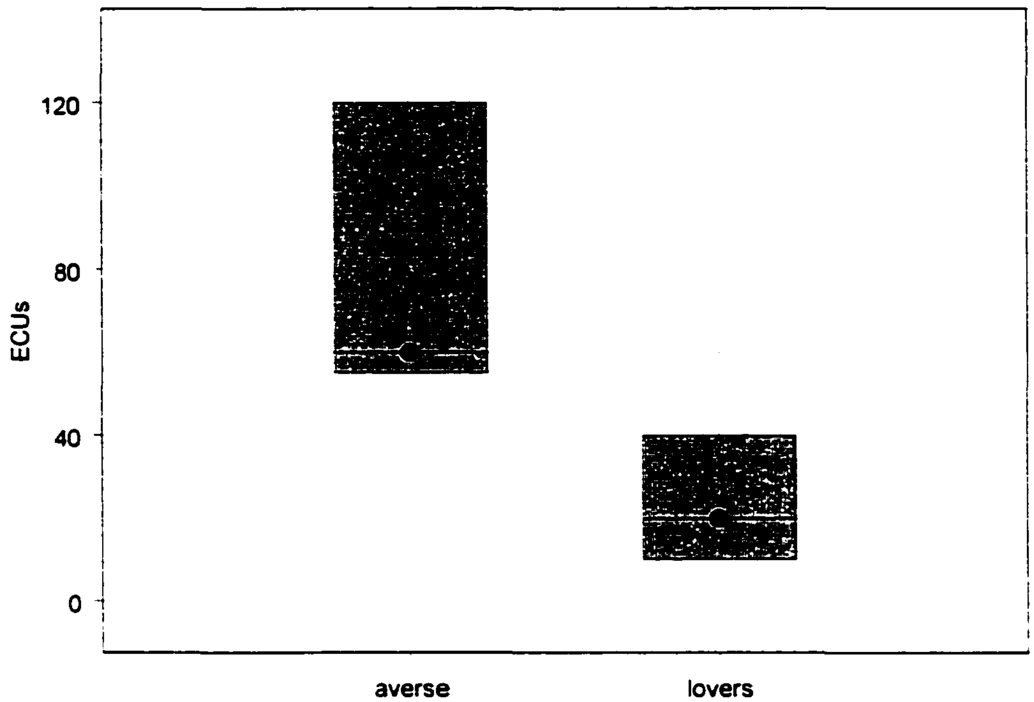


Figure 2.8: Payback expectations. As risk averse vs. As risk lovers subjects

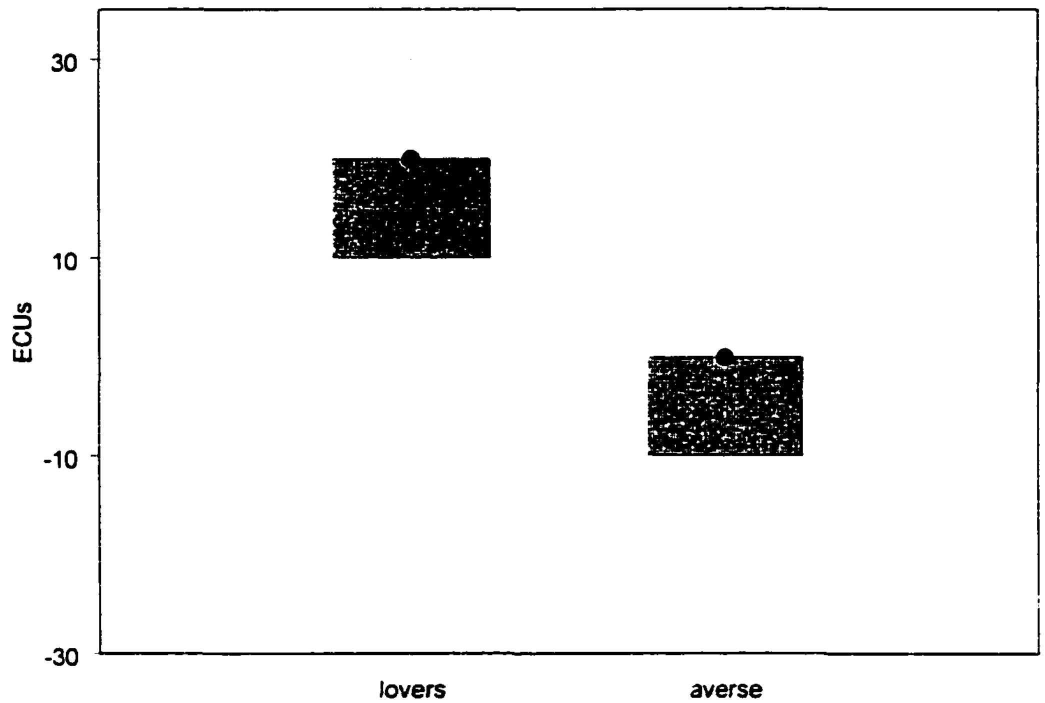


Figure 2.9: Differences between amount received and amount expected. Bs risk lovers vs. Bs risk averse subjects

Regression Analysis
Dependent variable: "Send"
PROBIT estimation

VARIABLE NAME	COEFFICIENT	MARGINAL VALUE
Constant	-4.04 (1.99)*	-0.14 (0.06)*
Expected Payback	0.69 (0.31)**	0.23 (0.08)**

Table 2.4: Regression Analysis

Regression Analysis
Dependent variable: "Return"
PROBIT estimation

VARIABLE NAME	COEFFICIENT	MARGINAL VALUE
Constant	-14.48 (0.13)**	-0.23 (0.004) **
a -expected a	0.72 (0.34)*	0.12 (0.06)*

Table 2.5: Regression Analysis

Numbers in parentheses are Standard Errors.

* Significant at 10% confidence
** Significant at 5% confidence

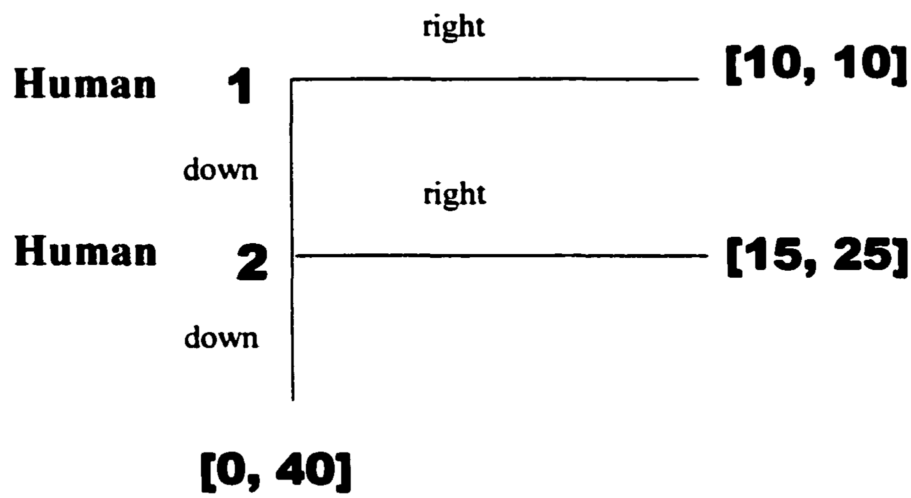


Figure 2.10 Basic Trust Game. condition 1 human-human. Player 1 moves first by playing rigth or down. If player 1 moves down then player 2 can play right or down. ending the game. Wherever the game ends. player 1 gets the first payoff and player 2 gets the second payoff.

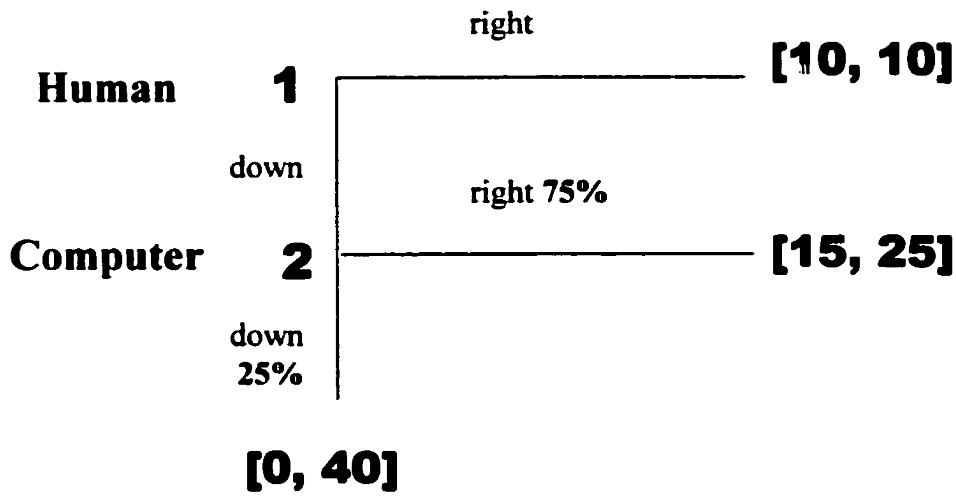


Figure 2.11. Trust Game, condition 2 human-computer. The subject is informed that the computer program will make the decision as the second mover. The subject will be paid her payoff, and neither the computer program, nor anyone else, will be paid the computer program's payoff. The computer has been programmed to play randomly, such that 75% of the time it will play right, and 25% of the time it will play down.

CHAPTER 3

THE EFFECTS OF A WARRANTY ON BUYER-SELLER INTERACTIONS

This chapter carries out a theoretical and experimental analysis of the problem of double moral hazard arising in a context of asymmetric information. We focus on the seller-buyer relationship in a market for a durable good. The buyer does not know the "intrinsic" (initial) quality of the product at the time of purchase. By contrast, the seller does not know the true "identity" (characteristics) of the buyer. This asymmetric information determines a double moral hazard. Both producers and buyers take actions that influence the failure rate of the product, and both have an incentive to lower their inputs. Indeed, producers can reduce their costs by decreasing the initial quality of the product, while consumers can reduce their costs by reducing the maintenance effort. The analysis focuses on the incentive effects associated with the introduction of a warranty.

The focus of this chapter differs from that of the previous literature on double moral hazard (described in Chapter 1), as we consider the relationship between sellers and buyers of a warranted durable product. Section 3.1 reviews the theory of double moral hazard. Section 3.2 introduces our model of buyer seller interaction in the presence of a warranted good. Sections 3.3 and 3.4 describe the design and the result of our experimental analysis. In Section 3.5 we conclude the chapter.

3.1 Survey of the literature on Double Moral Hazard

Double moral hazard may occur when two or more economic actors are engaged in a joint production, which is in the determination of a common outcome. We focus on the market for a durable good with a warranty. In this environment the performance of the product is determined by the actions of the two agents (buyer and seller).

The effects of warranties have four main dimensions. Warranties may act as (1) an incentive mechanism (for both sides of the market); (2) a risk-sharing contract; (3) a signal about product quality; and, finally, (4) a quality-assurance contract. We review in turn these four dimensions.

3.1.1 Incentive mechanisms

The role of warranties as incentive contracts is studied by Cooper and Ross (1985), who developed a model in which the performance of a warranted durable product is jointly determined by the actions of consumers and producers. They discuss the effects of imperfect information and the attendant double moral hazard on the levels of effort exerted by consumers and on the quality offered by producers. Focusing on the second-best non-cooperative solution, they show that the inefficiencies brought about by the double moral hazard crucially depend on whether the initial quality of the product and the effort devoted by the buyer are complements or substitutes.

Their analysis highlights three main characteristics of contracts with warranties: (i) warranties represent a partial coverage for the failure of the product; (ii) warranties are generally offered by the producer and not by independent insurance companies; (iii) there is no explicit link between quality supplied and warranty offered.

Cooper and Ross focus on the non-cooperative solution, as the first-best cooperative solution is not feasible because of asymmetric information. The solution of the model is a contract between the seller and the buyer that defines both the price of the product and the warranty. Cooper and Ross assume that both producers and consumers are risk neutral. There is no certainty that the product will work after the purchase; and the probability that the product will work is a function of the initial quality selected by the producer and of the maintenance effort by the buyer after the purchase. Both inputs (quality and effort) have positive but decreasing marginal productivity. In the event of failure of the product, the warranty guarantees compensation to the buyer. Expected total costs for producers are the sum of production costs and the expected payout under the warranty. The choice of maintenance effort and of initial quality affect both parties directly through their respective cost functions and indirectly through the probability of product failure.

The full information cooperative solution is defined by the situation in which all elements of the contract (price, warranty, effort, and quality) are determined cooperatively and thus jointly maximize the sum of the expected utility of consumers and the expected profits of producers. The cooperative solution is simply given by the combination of effort and initial quality that satisfies the equality between marginal costs and marginal benefits for both parties in the contract. It is worth noting that, in general, a cooperative solution is not necessarily unique and may not even exist.

When the determinants of the contract are not observable there is a problem of double moral hazard. As a cooperative solution is not feasible anymore, it is necessary to introduce agreements that serve as incentives to adopt "correct" behavior. This system of incentives is endogenously determined by the price and warranty. Cooper and Ross consider a two-stage game. In the first stage the level of prices and the value of the warranty are determined by a cooperative solution, while in the second, non-cooperative, stage prices and the warranty are taken as given and the players choose their supply of inputs in terms of effort and initial quality of the product. Because of the linearity of the problem, the equilibrium in the second stage of the game is independent of the level of prices, and only depends on the value of the warranty.[1]

When the effort and the initial quality are determined non-cooperatively, the solution is given by the equilibrium reaction functions. For a given level of the warranty, a buyer selects the effort level that maximizes her expected utility, given her conjecture on the quality of the product. Similarly, the producer selects the level of quality that maximizes its benefits, for a given level of the warranty and its conjecture on the effort exerted by the consumer. The slopes of the reaction functions depend on the sign of the partial cross-derivatives of the probability of failure with respect to effort and quality. Therefore, the slopes depend crucially on the degree of complementarily or substitutability between effort and initial quality.

[1] It is thus possible to analyze the second stage of the game for an arbitrary couple of prices and warranty.

For a given level of the warranty, the model reproduces the results obtained by Kambhu (1982) and Mann and Wissink (1988).[2] For a value of the warranty between zero and one (that is when the warranty is offered but its coverage is not complete), the second best solutions are inferior to the first best when quality and effort are complements (the partial cross derivative is positive), because both parties have incentives to lower their supply of inputs that affect the probability of product success or failure. The same result applies when the cross partial derivative is zero. By contrast, when quality and effort are substitutes results are ambiguous. Our contribution in this chapter is to research the empirical relationship between quality and effort in the presence of a warranty.

The analysis can be extended to an explicit dynamic setting in which the level of quality is endogenously determined and the dynamics of the warranty can be explained. Indeed, to address key aspects of warranties, such as their duration and value, it is crucial to analyze a dynamic model in which incentives are derived through an intertemporal optimization. In several cases the coverage of the warranty is strictly a function of time, because it falls from a constant level to zero at a given point in time. In some contracts, the warranty depreciates only gradually. In any scheme, a key question to be answered is why the duration of the warranty is limited? To answer to this question we next examine a few examples of multiperiod incentive problems.

Cooper and Ross (1988) show that under certain conditions, a "two-period warranty" theoretically implies the first-best solution. This is the first model that highlights the

[2] The results by Cooper and Ross do not need the additional assumptions made by Kanbhu.

intertemporal effects of the presence of warranties. The authors emphasize the presence of an asymmetry between the care applied by the consumer and the quality controlled by the producer. Indeed, consumers decide about their maintenance effort during the whole life of the product, while producers choose the level of quality only at the moment of design and production of the good. This implies that the probability of success of the product essentially depends on the choice of effort. As a consequence of this asymmetry, the optimal warranty contract is given by a full-coverage warranty applied to a short time interval. In such a way the warranty maintains its function as a positive signal of quality of the product at the time of purchase, while because of its short life it is a deterrent to lowering the maintenance effort. The model is again a two-stage model, and the stages now represent two different periods. In the first period, the good is sold, and it will be repaired by the producer if it breaks down. The producer establishes the initial quality that will influence the performance of the product in both periods. Effort by the buyer is the other element affecting the performance of the product. The consumer picks two levels of effort, for period one and period two. The initial quality and effort enter separately in the probability function of success of the product. The assumption of separability (adopted as well in their first paper, Cooper and Ross, 1985) greatly simplifies the analysis of incentives. Indeed, separability allows them to solve separately the equations resulting from the joint maximization of the expected utility of consumers and expected benefits of producers. This implies the absence of strategic interaction between the two parties to the contract. Thus, they construct a Nash equilibrium in dominant strategies. The contract specifies the price and the value of the warranty for the first and the second periods. It is shown that the first-best solution cannot be implemented, in the presence of asymmetric information, if all three inputs, that is initial quality and effort levels in the two periods are productive.

A warranty with decreasing coverage, ending before the death of the product, is an optimal solution. Therefore, only a differentiated structure of warranties is consistent with the solution of the incentive problem. In their example, an optimal solution arises only when the level of warranty in the second period is zero. However, as we will show below, their result does not appear very robust, because it hinges upon the concept of asymmetry, which is their only motivation for the study of incentives in an intertemporal setting. Furthermore, their assumption on separability appears inconsistent with empirical evidence that suggests that the effort level is not independent of the intrinsic quality of the product.

The literature suggests other possible explanations for the life of warranties actually offered in the market. Emons (1989 a, b) studies how a competitive market distributes warranty contracts when firms are not able to distinguish different types of consumers in terms of their maintenance effort. He shows that the problem of adverse selection determines a duration of the warranty that is shorter than the actual life of the products. As stated above, most warranty contracts imply a high coverage during a limited period. This structure is called "block warranty."[3]

Dybvig and Lutz (1993) develop a continuous time version of a dynamic model of warranties in the context of asymmetric information and double moral hazard. Within

[3] In the USA both the Mignuson-Moss Warranty and the Federal Trade Commission Act of 1978 establish that all consumer products with a price above 15 US$ should carry a written warranty.

the set of multiple equilibria of the games, they focus on the Nash equilibrium of the original game with elimination of strategies that are weakly dominated. Their main result relates to the optimality of the block warranty. Similarly to Cooper and Ross, they also indicate the asymmetry between the moral hazard for the consumer and for the producer, as the impact of the maintenance effort on the probability of failure of the product is cumulative.

In sum, the theoretical contributions model the presence of the warranty as a mechanism to solve the problem of double moral hazard. The block warranty is optimal because by concentrating the coverage in the first period it maintains unaltered the incentives for producers (as the loss associated with low quality may be very high, given the short-lived but total coverage) and induces the incentives of consumers and the social incentives to coincide. The results of our empirical analysis confirm this conclusion.

We turn now to a brief discussion of the possibility of implementing a first best solution in the presence of asymmetric information. It is very important to consider the role of incomplete information in the principal-agent relationship. In such a case, it is interesting to verify the effects of additional information. All forms of moral hazard arise because of the non-observability of actions and results.

In extremely simple situations it is possible to carry out an effective monitoring. In such cases, incorporating all information obtained in the contract, it is possible to reach the first best solution. However, information is usually very costly to obtain, and thus imperfect information is the rule. Nevertheless, empirically we can observe that imperfect information is used in the attempt to solve problems of moral hazard. As stated by

Holmstrom (1982): "it is shown that any additional information about the agent's action, however imperfect, can be used to improve the welfare of both the principal and the agent."[4] These results explain the use of imperfect information in contracts (as described as well by Rogerson (1985), who shows that when a given public information can be used to infer, albeit imperfectly, the actions of one of the parties, it is optimal to use it when one designs and stipulates a contract). Kambhu (1982) discusses the problem of observability, introducing two types of mechanisms: a balanced mechanism and an unbalanced mechanism.[5] He shows that it is possible to reach a solution "optimum optimorum" through an unbalanced mechanism. This type of mechanism is equivalent to a situation in which there is a third party who receives compensation from the other two in exchange for a monitoring action (see Macho and Castrillo, 1991, for a similar view). Furthermore, Kambhu shows that in the class of unbalanced mechanisms it is possible to design an optimal contract that transforms the third agent into a voluntary participant and that produces payoffs higher than those for a balanced mechanism.

Mann and Wissink (1988) analyze cases of money-back contracts.[6] They develop a three-stage game. In the first (cooperative) stage players establish the price and a refund share; in the second stage (non-cooperative) players choose inputs in terms of quality and effort, while in the third and final stage consumers decide whether to return the product. This process minimizes the information necessary for the formulation of the contract and determines incentives in the presence of double moral hazard. The purchase price, the

[4] Holmstrom presents a formulation that is similar to that in Mirlees (1974).

[5] In the balanced mechanism the price paid by the buyer equals the price obtained by the seller, while in the unbalanced mechanism the two prices differ.

[6] In which sellers promise to give back to consumers part of the price paid for the product when the product is returned.

refund share, and inputs are endogenously determined in the three-stage game, and the presence of a third agent is not necessary. Finally, they show that only in the case of moderate uncertainty it is possible to establish a contract that determines incentives that support the first best solution.

The models analyzed above (Kambhu, and Macho and Castrillo) assumed that the performance of the product is observable without costs. This assumption seems to contradict the empirical evidence. If one assumes that performance is not perfectly observable or that there is a cost associated with observation, the above models cannot be applied.

3.1.2 Optimal risk sharing

Warranties may represent a form of insurance for risk-averse consumers (as argued by Heal, 1977). The motivations for risk-aversion may play a crucial role in the explanation of warranty contracts. The main point of the models discussed above was that the incentive effect rather than the insurance effect determines the warranty. For this reason they assume risk-neutrality.

Uncertainty affects the demand function. Heal (1977) studies two distinct situations: one in which consumers and producers share the same information on the quality of the good, and another in which there is asymmetric information with an advantage for producers. The first situation refers to a market in which the quality is a random variable whose probability distribution is known to both consumers and producers. Thus, the probability of failure is known but there is uncertainty on which of the products will actually fail. The second situation resembles the second-hand market, where the producers know perfectly the quality of the product (Akerlof, 1970). When there is a warranty, one can distinguish the incentive and the risk-sharing effects. Defining the optimal warranty of the one that yields an optimal distribution of risk, a main result of Heal is the tendency to excessive warranty offered by firms. Indeed, consumers are likely to be risk-averse, while firms being large are likely to be risk-neutral. According to Heal, the optimum is achieved only after redistribution of risk toward consumers, as firms tend to assume excessive risk. However, not all consumers are risk-averse and those who are would ask a warranty with full coverage instead of the partial coverage offered by producers. Therefore, the model by Heal cannot explain a fundamental characteristic of warranties, namely, the fact that they always offer partial coverage.

3.1.3 Signaling mechanism

According to Emons (1989, a), firms that cannot build a reputation do not have incentives to produce high-quality products if there is no warranty. This is due to the fact that "lemons" can be produced at lower costs. Thus, Emons argues that warranties represent a deterrent for production of lemons, because they penalize bad behavior on the part of producers. The main result of Emons is, therefore, that warranties are an incentive for producers to produce high-quality goods.

The literature on signals suggests that warranty and quality are positively related. For instance, Lutz (1989) shows the existence of an equilibrium in which a warranty with limited coverage and a low price signal high quality. This type of equilibrium is also found in our experimental analysis (experiment 1, section 3.4.1), in which in a signaling game we find the presence of non-intuitive equilibria. Empirical evidence seems inconsistent with the use of a warranty as a signaling device. Most warranties offer partial coverage, and high-quality products are not always sold with warranties higher than those offered on low-quality goods. In Lutz (1989) a risk-neutral monopolist produces a good with exogenous and fixed quality and sells it to risk-averse consumers. The probability of failure of the product depends on its quality and on the effort exerted by consumers. This effort cannot be observed by producers or by a third party, and thus the warranty offered cannot be related to effort. The results of the model confirm that the presence of a warranty does not imply a positive relation between warranty and quality.

3.1.4 Quality-assuring mechanism

Whenever consumers cannot evaluate the quality of products prior to their purchase, producers might find it convenient to reduce the quality of their products in order to get a short-term gain, before consumers have the chance to assess their actual quality. The only way to keep this quality decrease under control is by introducing a price-based premium.

In the frequent and realistic occurrence that the quality of products cannot be assessed prior to their purchase, it might be surmised that consumers will use the quality of the firm's past production to judge present quality. In this situation, the choice to produce at different quality levels is made through a dynamic process. Past production quality is used as a signal to determine present quality. In this sense, reputation making can be considered a signaling process. Thus, firms define their own quality standard, which we might call "reputational quality." The price for high-reputation products is higher than the price for products of the same quality but lesser reputation. This situation is an instance of market failure and a negative social externality. In the short term, the high-reputation firm can have extra benefits from a decrease in the quality of its production that implies a reduction in production costs. Thus, the opportunity cost of keeping a certain quality level must be integrally offset by an increase in the product prices compared to its actual value.

The concept of warranty can be treated like the variable that in Shapiro's (1983) model represents the minimum quality (under which it is illegal to produce). Thus, one can show that this concept is completely marginal within a quality-assuring mechanism. But reputation rather than warranty is the sole quality-assuring mechanism.

Product warranties have not always been interpreted in a double moral hazard environment. At first we have a one-way asymmetric information relationship between seller and buyer: if bad products cost comparatively less than good products then there is the possibility that bad products drive out good products (Heal, 1976). A similar presentation had been proposed by Kambhu (1982) and Laffont and Maskin (1987), with an *ex ante* informative advantage by the seller (and in the extreme case of seller's (absolute) monopoly power, which comes about when the quality is unverifiable by the customer); if "lemons" can be produced at a lower cost, they yield higher profits to the seller.

However, in order to obtain a solution it is necessary to postulate the impossibility of *ex post* verifiability of product quality by the customer; and in this way it is necessary to assume the irrelevance of reputation building.

The argument goes as follows on this *ex post* basis. If expectation on quality can be confirmed after buying, reputation is established (or increased) (see Shapiro, 1983).

The presence of a warranty is one out of many possible signals, and anyhow the pure existence of a warranty is not necessarily a good signal for reputation (see again Shapiro, 1983).

Let q_1 and q_2 represent the quality (*ex ante* unknown by the customer) of the product without and with a warranty, respectively, and p_1 and p_2 the respective prices. If

$$Dq = q_2 - q_1 < p_2 - p_1 = Dp \qquad (1)$$

then the warranty is not a proper signal to reputation. In any case, a risk-averse customer can choose the warranted product when the risk-aversion premium exactly compensates for inequality (1):

$$r \cdot Dq = Dp \qquad (2)$$

where $r \geq 1$ is a measure of the customer's risk aversion. So warranties can possibly insure a risk-averse consumer when (1) can be converted into equation (2).

Let us now suppose that q is a variable for the producer, and by lowering the quality level of the product the possibility of product failure increases. Then, the cost for the producer for providing an additional unit of warranty will also increase. In this case we have a "single" moral hazard.

According to Spence (1977), a "sufficiently large" warranty will provide producers the incentive to supply high quality products. With reference to the quality of goods, Gale and Rosenthal (1994) present a model for an "experience" good in which once a reputation was built by a firm with respect to a customer, the decay process of reputation goes slower than the correspondent process of consumer fidelity. In this case, once the reputation has been built it cannot be reversed by any customer's behavior if the cycle high quality/low price, high quality/high price, low quality/high price is *ex ante* planned by the firms. So, if all firms start producing high quality products they will start selling them at low price. Then, they will increase the price and finally they will decrease the quality maintaining the high price.

However, the pure existence of a given *ex ante* level of warranty w constitutes an incentive device for the customers to adjust (by reducing it in case of full insurance) the care using the product when this care cannot be *ex post* observed by the seller.

The presence of warranties with different lengths can be interpreted by the customers as signals related to different quality q (see Lutz, 1989); moreover the customers can also reduce the maintenance effort when the disutility of choosing high effort is larger than the increase in probability of product failure after the warranty expiration.

3.2 The model

We investigate a simplified model of a situation in which a single producer/seller offers a good to a single buyer. The producer chooses a level of quality (high or low) and also whether to offer a warranty. Then the buyer acquires the product for sure and decides whether to maintain it properly or not. We represent the situation by a game in extensive form.

Our purpose is to study the effects of the presence of a warranty on the buyer – seller relationship. We expect that the introduction of a warranty will influence the decision of these two agents. Both producer and buyer will take actions that influence the failure rate of the product, and both will have an incentive to lower their inputs. Indeed, producers can reduce costs by decreasing the initial quality of the product, while consumers can reduce costly maintenance effort. Our model attempts to describe the direction and the amount of this effect.

The seller (S) moves first. He can choose to offer a high (H) or low (L) quality product. He can also decide whether to offer a warranty or not. We represent this decision as a binary choice. The seller can either decide to offer a warranty of amount $\overline{w}$ or not offer a warranty at all. $\overline{w}$ is the amount of money that the seller gives to the buyer if the product fails. The price of the product with the warranty is p^{w} and without the warranty is p^{0}. The seller incurs a cost of c^{H} if he produces a high quality product and c^{L} if he produces a low quality product.

The buyer (B) moves second. She buys the product and observes its quality. She values the high quality product at v^{H} and the low quality product at v^{L}. Both v^{H} and v^{L} express the "intrinsic" quality of the product in terms of how long it will last with no maintenance on the part of the buyer. Knowing the quality of the product and the amount of the warranty, the buyer decides to put in a high (h) or low (l) level of maintenance effort gaining respectively g^{h} and g^{l} in utility. These variables represent the difference between the gain in value from increasing expected life of the product and the disutility of maintenance effort.

Unless the buyer decides on a high level of maintenance activity, Nature (N) moves third. Its action expresses the fact that there is a positive probability (π^H or π^L depending on the quality of the product) that the product will fail if it is not properly maintained. We refer to π^H and π^L as failure rates.

Consider a game in which the set of players is given by {S, B, N}. The set of pure strategies for the seller is: $S_S = \{(\bar{w}, L), (\bar{w}, H), (0, L), (0, H)\}$, and for the buyer: S_B = {(h, h, h, h), (h, h, h, l), (h, h, l, h), (h, h, l, l), (h, l, h, h), (h, l, h, l), (h, l, l, l), (h, l, l, h), (l, h, h, h), (l, h, h, l), (l, h, l, h), (l, h, l, l), (l, l, h, h), (l, l, l, h), (l, l, h, l), (l, l, l, l)}. The seller's utility depends on the price of the product he sells, the cost associated with its production, and the amount of the warranty in case the product fails. It is given by:

$$U_S = \begin{cases} p^0 - c^I, & I \in \{H, L\}, & \text{if } w = 0 \\ p^w - c^I, & I \in \{H, L\}, & \text{if } w = \bar{w}, & \text{and the product works} \\ p^w - c^I - \bar{w}, & I \in \{H, L\}, & \text{if } w = \bar{w}, & \text{and the product fails} \end{cases}$$

The buyer's utility depends on the value of the product, its quality, price, maintenance activity, and the amount of the warranty in case the product fails.[7] It is given by:

[7] It might be strange at first glance that when the product fails, we still have g^I as a positive gain in utility. This is explained in Assumption 3.

$$U_B = \begin{cases} v^I + g^j - p^k, & I \in \{H, L\},\ j \in \{h, l\},\ k \in \{0, w\}, \quad \text{if the product works} \\ g^l - p^w + \overline{w}, & \text{if } w = \overline{w}, \quad \text{and the product fails} \\ g^l - p^0, & \text{if } w = 0, \quad \text{and the product fails} \end{cases}$$

Our model is based on the following assumptions:

Assumption 1: The product is priced higher if it has a warranty,[8] i.e., $p^w > p^0 > 0$.

This assumption reflects the fact that the presence of a warranty is usually considered as a sign of high quality by the buyers. Therefore, their willingness to pay for a product with a warranty is higher. This tendency has been confirmed in our experimental studies (see section 3.4.2).

Assumption 2: The cost associated with the high quality good is higher than the cost associated with the low quality one, i.e. $c^H > c^L > 0$.

Assumption 3: The net gain in utility for the buyer from the maintenance activity is positive, and is greater for a high level of maintenance activity, i.e. $g^h > g^l > 0$.

We look at two separate aspects of product maintenance. On one hand, maintenance effort decreases buyer's utility. It takes time and money to maintain a product. On the

[8] Note that prices are exogenous.

other hand, the fact that the product will last longer increases buyer's utility. We assume that the net utility effect of maintenance effort is positive for both levels, i.e., the gain in utility from increasing life span of the product is greater than the disutility of maintenance effort (g^h, $g^l > 0$). It is also realistic to assume that a lower level of maintenance effort causes less net increase in utility than a high level of maintenance effort ($g^h > g^l$). If the product fails during the period of coverage, the consumer still gets some utility from using it. Without loss of generality we assume that g^l represents that utility also, i.e., the product did not fail for a while because of the maintenance activity.

Assumption 4: The buyer has some initial positive valuation of the product. The lower quality product has lower value than the high quality one, i.e. $v^H > v^L > 0$.

Assumption 5: The failure rates are a positive fraction between 0 and 1, i.e., $0<\pi^H< \pi^L<1$.

We assume that when the level of maintenance activity is low, there is some positive probability that the product will be damaged and will fail. This probability is lower when the product is of high quality. The failure rates also depend on the level of maintenance, because if the buyer decides to maintain the product, π^H and π^L are both equal to 0, i.e., Nature does not get to move.

Assumption 6: The price with warranty is higher than the sum of the price without warranty and the expected warranty payment, i.e, $p^w > p^0 + \pi^L \cdot \bar{w}$.

Assumption 7: The difference between the cost of a high and low quality product is greater than the expected warranty payment, i.e., $c^H - c^L > \pi^L \cdot \bar{w}$.

Assumptions 6 and 7 represent the fact that the cost of the warranty is completely transferred to the buyer (see Result 7 in Chapter 3).

Assumption 8: The buyer and the seller are risk-neutral.

3.2.1 Equilibrium Analysis

We notice that the solution of the game depends on the level of the warranty.

Proposition I: If $\bar{w} < v^L + \dfrac{g^h - g^l}{\pi^L}$ (1), then the optimal action of the buyer is h and the optimal strategy for the seller is ($\bar{w}$, L).

Proposition II: If $v^H + \dfrac{g^h - g^l}{\pi^H} > \bar{w} > v^L + \dfrac{g^h - g^l}{\pi^L}$, then the buyer chooses h if the product is of high quality and l if the product is of low quality. The seller chooses ($\bar{w}$, L).

Proposition III: If $\bar{w} > v^H + \dfrac{g^h - g^l}{\pi^H}$, then the buyer always chooses action l. The seller's optimal strategy is ($\bar{w}$, L).

We report the proof only for Proposition I. Proofs for Propositions II and III are similar to the one described.

Proof of Proposition I

The seller has four pure strategies so we have to look at the buyer's response in four different cases. We look at different subgames where each subgame is a decision problem for the buyer.

Case 1. If the seller decides to offer a high-quality product with warranty, the payoffs for the buyer are the following (e.g., $U_B(h)$ signifies buyer's utility of action h, and so on):

$$U_B(h) = v^H + g^h - p^w$$

and

$$U_B(l) = \pi^H (g^l - p^w + \bar{w}) + (1 - \pi^H)(v^H + g^l - p^w)$$

The buyer will choose h if U(h) > U(l) (Assumption 8), or if

$v^H + g^h - p^w > \pi^H(g^l - p^w + \bar{w}) + (1 - \pi^H)(v^H + g^l - p^w)$, which is equivalent to

$$\bar{w} < v^H + \frac{g^h - g^l}{\pi^H}$$

The last inequality is true by (1) and by Assumptions 4 and 5. Therefore, the buyer will choose action h.

Case 2. If the seller decides to offer a high quality product without warranty,

$U_B(h) = v^H + g^h - p^0$

and

$U_B(l) = \pi^H (g^l - p^0) + (1 - \pi^H)(v^H + g^l - p^0)$

The buyer will choose h if U(h) > U(l) (Assumption 8). Again, it is easy to check that $U_B(h) > U_B(l)$ using just Assumption 3. Therefore, the buyer will choose action h.

Case 3. If the seller decides to offer a low-quality product with warranty, the case is very similar to 1. The only difference is that we replace v^H with v^L, and π^H with π^L. So

$U_B(h) = v^L + g^h - p^w$

and

$U_B(l) = \pi^L (g^l - p^w + \overline{w}) + (1 - \pi^L)(v^L + g^l - p^w)$

The buyer will choose h if U(h) > U(l) (Assumption 8). Here (1) guarantees that U(h) > U(l).

Case 4. The last possible scenario is that the seller chooses a low-quality product without warranty. We have

$U_B(h) = v^L + g^h - p^0$

and

$$U_B(l) = \pi^L (g^l - p^0) + (1 - \pi^L)(v^L + g^l - p^0)$$

The buyer will choose h if U(h) > U(l) (Assumption 8). In this case Assumption 3 guarantees that U(h) > U(l). Therefore, the buyer will choose action h.

Now, it becomes evident that under the underlying assumptions action h of the buyer is the best response to every possible strategy of the seller. We can use backward induction to determine what the seller will do, knowing that the buyer will always maintain the product well. We notice that (e.g., $U_S(\bar{w},H)$ signifies the seller's utility of strategy $(\bar{w},H)$, and so on):

$$U_S(\bar{w},H) = p^w - c^H$$

$$U_S(\bar{w},L) = p^w - c^L$$

$$U_S(0,H) = p^0 - c^H$$

$$U_S(0,L) = p^0 - c^L$$

Using Assumptions 1, 2, and 8, it is easy to see that the optimal strategy is $(\bar{w},L)$ because $U_S(\bar{w},L)$ is the maximum achievable utility level. Thus the proof is completed.

In words, if the amount of warranty is not enough to cover the expected negative effect on utility that arises when the level of maintenance effort is low, then the buyer is better off if he decides to maintain the product no matter what its quality is. Knowing that the buyer prefers to maintain the product, the seller will choose to produce a low quality product and offer a warranty for it (Proposition I). The equilibrium analysis of our model shows how the behavior of the buyer (effort) and the seller (quality of the product) strictly depend on the level of the warranty.

In such a framework we have designed two experiments in order to obtain reasonable answers to questions Q_1- Q_6:

Q_1: Are quality and effort complements or substitutes?

Q_2: Is it possible to design an optimal contract under DMH conditions?

Q_3: If it is possible, does this contract correspond to a block warranty?

Q_4: Why does coverage fall over time?

Q_5: Why is the life of a warranty usually shorter than the expected life of the product covered?

Q_6: Is the warranty a good signal about quality?

In particular, we have designed the first experiment to find an answer to Q_6, and the second experiment to answer questions Q_1-Q_5.

3.3 Experimental Analysis

3.3.1 Procedures and design for experiment 1

There is a tentative answer to question Q_6 that works as follows: suppose that we have several distinct sellers that provide goods of different qualities. In this case, the firms offering high quality goods will also offer a more complete warranty because of the lower probability of default for the high quality goods. The warranty will also be less costly if buyers cannot influence the quality of the product. Thus, it is considered exogenously given. Under these particular conditions, a warranty must be considered from the point of view of a high quality firm as a cheaper signaling.

Our experiment presents a one-way information process from producer/seller to buyer/customer. Under this peculiar condition (of an exogenously given quality) it is possible to derive a signaling equilibrium solution.

Fifty-four undergraduate students, half of them having the role of sellers and the other half having the role of buyers, were distributed in two rooms.[9] In each room participants had the same role. Subjects were randomly paired, and they did not know the identities of their counterparts. The experiment consisted of a two-stage game. First, the seller decided whether to assign the warranty or not, and then the buyer determined the maintenance level. The seller knew the real quality of the product (high/low quality). The buyer knew only the market distribution of low (1/3) and high (2/3) quality products. The payoffs of the game were common knowledge, and they were given at each terminal node (8 nodes).[10]

We considered an application of the Brandts and Holt (1992) experimental design, considering the analogy with the job-market (Spence, 1973).[11] Theoretical analyses indicate that there are often many sequential equilibria in these signaling games due to the many inferences that the second player could make after observing the first player's signal choice. We tested two possible signaling equilibria: separating equilibrium and

---

[9] Subjects were recruited from undergraduate classes at The University of Siena, Italy.

[10] The payoffs were made in Italian currency. Subjects received 5,000Lire as initial payment in addition to all cash earnings obtained during the sessions.

[11] We explicitly used terms such as: high quality, low quality, warranty, no warranty, maintenance, and no maintenance, to indicate all possible options.

pooling equilibrium. If the cost of signaling is significantly lower for the high quality seller, then a separating equilibrium occurs in which the buyer can infer the unobservable quality from equilibrium signals. Separating equilibrium allows for discrimination amongst unknown qualities. In this situation, the payoffs distinguish perfectly, through a signal, the two types of sellers, high and low quality, in terms of dominant strategies. In this context, a warranty is perfectly correlated with quality. In order to detect the effects on the agents' behavior under different equilibria, we presented two different output schemes (see Table 3.1(a)). The subjects were randomly assigned to two groups. In Group 1 we present the experimental task (see Table 3.1(b)) with the separating equilibrium payoffs, and in Group 2 we present the pooling equilibrium payoffs (see Table 3.1(c)). The payoffs were given at each terminal node. Given the product quality, each combination of decisions leads to an outcome and an associated pair of payoffs.[12] Separating equilibrium payoffs differentiated the two types of sellers in terms of best responses: "no warranty" is the best response for a low quality seller; "warranty" is the best response for a high quality seller.

By reducing the marginal value of the warranty that represents the cost of signaling (from 1000 to 400), we determined two (theoretical) pooling equilibria:

(i) both types of sellers (high/low quality) choose "warranty," and buyer responds to "warranty" with "maintenance", and to "no warranty" with "no maintenance";

---

[12] Where: (seller's earnings, buyer's earnings).

(ii) both types choose "no warranty" and buyer responds to "no warranty" with "maintenance" and to "warranty" with "no maintenance." Both are sequential Nash equilibria in terms of consistency of beliefs and best responses.

The second pooling equilibrium can be ruled out by applying the notion of equilibrium dominance on which the "intuitive criterion" is based (Cho and Kreps, 1987). Thus, the equilibrium elimination criterion is based on the notion of "reasonability." Equilibrium dominance involves an analysis of out-of-equilibrium beliefs by making a comparison of a player's equilibrium payoff with the best payoff that could be obtained by deviating.

The first equilibrium (i) is supported by reasonable beliefs that a deviant sending the message "no warranty" (out-of-equilibrium message) is more likely to be of the type. "low quality."

The second (ii) pooling equilibrium is unintuitive because the "no maintenance" response of the buyer to deviation is unreasonable. The implicit out-of-equilibrium beliefs are that a deviant that offered a warranty is a "low quality" seller. However, the high quality seller is more likely to be a deviant, because he could increase his payoffs by deviating to "warranty." In the pooling equilibrium context, the signal is useless, and the buyer has to rely on prior beliefs (in our case, they are expressed in terms of a market distribution of low (1/3) and high (2/3) products).

3.3.2 Procedures and design for experiment 2

We designed and conducted a laboratory experiment in order to study a market for durable goods.[13] There was only one good in the market, and it was offered at each session with different warranty levels (see Instructions in Appendix B).[14] The market was composed of three participants. The subjects (39 students) were randomly assigned to one of the markets. The good could be of high or low quality. The quality was expressed in terms of the life of the good. The initial quality and the maintenance decision defined the potential life of the good and its consumption value (which is represented by the participant redemption value).

A high quality good had a potential life of 10 years (periods), with "good maintenance," and a life of 8 years with "bad maintenance"; a low quality good had a potential life of 7 years with "good maintenance," and 5 years with "bad maintenance." The participants did not know the real quality of the good prior to purchase (see Appendix B1). However they knew from the outset all the possible values of the good through its potential life. Once the good was on sale in the market, they have to make a

---

[13] The experiment was run on a local area network, with no external access. The agents were connected to a server with a browser (Netscape Navigator 3.0). The transactions were registered in real time in a database residing on the server.
For each transaction the offer value and the name of the agent were recorded on the occasion of a purchase, the database also archived the information relative to the maintenance of the product. The screen was designed with technology that permits interactions between agents, shows the information relative to an agent's status (for example whether an agent has a product in a particular moment), and provides immediate connection with a remote database, both in writing and in reading. In the specific case we used Microsoft Access 97 on a server with Windows NT 4.0.Place on the interface, we used various scripting programs: JavaScript, for the form's validation and the cash flow, ASP (Active Server Pages, by Microsoft) in order to detect agent information; and Internet Database Connector (Microsoft) for the connection to the database with query SQL.

[14] The warranty level is exogenously determined. And it is of 0-2-3-5 periods.

purchasing offer based on conjectures relative to the initial quality of the good, knowledge on the warranty level, and the redemption value scheme.

The participant that offered the highest price obtained the good. After purchasing, the owner learned the real quality and the potential life of the good; he then had to decide how long he wanted to hold the good and had to define the maintenance effort for each period (see Appendix B2). He could sell the good after at least one period, obtaining the highest price offered in that period. It was possible that the good broke before its normal life, and this probability was higher for the low quality good.

Each participant had a starting bank, which could be spent to purchase a new good (in the first period) and a used good (in the following periods). The starting bank devaluated at a constant rate in all periods in which the participant did not obtain the good.

The life of the good depended on the initial quality and on the owner's maintenance decisions. In other words, the maintenance effort was productive in terms of the final quality. A "good maintenance" had a cost for the owner, while the "bad maintenance" did not imply any further expense. The owner would receive the money back (the purchasing price) if the good broke before the warranty expiration.

The experiment consisted of a preliminary competition (bidding) for the good offered by the "machine auctioneer" and following trades for the second-hand good. If the good was not broken, the session continued until trade was verified. The participant's final earnings depended on the value of the final bank. The final bank was: $FB = P_s + \textit{total redemption values} - P_p - \textit{maintenance costs}$, in the case in which the participant resold the good; $FB = \textit{total redemption values} - P_p - \textit{maintenance costs}$, in the case in which the participant held the good for all its life; *FB=IB* (devaluation rate)*(total product life)*, in the case in which the participant did not succeed in purchasing the good through its entire life (where: *FB* indicates the final bank, P_s = selling price, P_p = purchasing price, and *IB* = initial bank).

3.4 Experimental Results

The first experiment confirmed the result of Spence (1977) and Grossman (1981):

(a) a warranty is a signal of high quality; and (b) firms with high quality goods offer more complete warranties. However, this result crucially depended on the assumption of exogenous quality. The second experiment endogenized quality. Incentives for the sellers were affected by the interaction between quality and the effort of maintaining the product.

3.4.1 Results for experiment 1

Table 3.2 shows how:

Result 1: All high quality products are offered with a warranty.

Result 2: 33% of low quality products are offered with a warranty.

Result 3: 17% of buyers respond to a warranted product with "no maintenance."

Result 4: Only one buyer responds to a non-warranted product with "maintenance."

Results 1 and 2 derive from sellers' choices, while Results 3 and 4 derive from buyers' responses to sellers' signals.

We considered two signaling equilibria: separating equilibrium and pooling equilibrium. Table 3.2 shows that 88% of the sellers and 78% of the buyers played according to the equilibrium solution. The predicted equilibrium outcome was achieved by 67% of the pairs.

3.4.2 Results for experiment 2

We used a Probit analysis of the data in order to study the relation between effort and quality (see Table 3.3). The dependent variable, "Effort" assumes a value of one when the buyer chooses high effort, and a value of zero when she chooses low effort. The variable, "Quality" equals one when the product is a high quality product and zero when it is a low quality product. Additional variables are "Warranty" and "Trials." The variable, Warranty assumes a value of one when the product is covered by a warranty, and assumes a value of zero in absence of a warranty. The variable, Trials indicates the period in which a decision is taken. The variable, "QW" is the interaction term between Quality and Warranty.

These results confirm that quality and effort are complements. Having a good of high quality increases, on average, the probability of high effort by 13.36%.

This value has been calculated as follows:

$$\phi(0.22 \cdot \overline{Q}) \cdot 0.22 + \phi(-0.32 \cdot \overline{QW}) \cdot (-0.32)\overline{W}$$

where ϕ is the density function of the normal distribution, $\overline{Q}$=0.59 is the mean value of Quality; $\overline{QW} = 0.13$ is the mean value of QW; and $\overline{W}$=0.27 is the mean value of Warranty.

Result 5: Quality and Effort are complements.

This Probit analysis (Table 3.3) suggests that the presence of a warranty does not affect the probability of increase in the effort on maintenance.

Result 6: Warranty does not increase Effort.

We tested the efficiency of the various scenarios determined by different warranty levels (in terms of duration). We considered more efficient a scenario with lower offer prices. We conducted a Tobit estimation of the "Offers" on the different levels of warranty (see Table 3.4). The reference group is No Warranty. The variables w2, w3 and w5 indicate, respectively, products with a two-year warranty, three-year warranty, and five-year warranty.

We conclude that the block warranty (w2) represents the most efficient scenario. The price offer increases with the length of the warranty. Considering the Price Dynamics analysis (Figure 3.1, Figure 3.2, and Figure 3.3) of different warranty levels:

Result 7: Full warranty represents an inefficient solution.

Result 8: The block warranty is the most efficient warranty-scheme.

3.5 Concluding remarks

Our theoretical analysis shows that both the seller and buyer have an incentive to reduce their inputs in the presence of a warranty. The seller's decision of never offering a high quality product is determined essentially by Assumptions 6 and 7. These assumptions represent an empirically and experimentally confirmed tendency of sellers to transfer the cost of the warranty to the buyer through the price of the product, as has been shown in our experimental analysis. The buyer's behavior is different depending on the size of the warranty. She compares the warranty with the expected negative effect on utility that arises when the level of maintenance activity is low. There are three different cases in this regard. She will choose to maintain the product if the warranty is not sufficiently high to cover the expected loss if she is careless. This model incorporates our experimental findings and accurately predicts the effects of different levels of warranties in a context of double moral hazard.

The results of the first experiment crucially depend on these three assumptions: (i) exogenous quality; (ii) the buyer selects the maintenance level before knowing the intrinsic quality of the product; (iii) the game has a single period. The result that a warranty is a good signal about quality is most readily applicable to the case in which product quality is exogenous. Indeed, to address key aspects of warranties, such as their duration and value, it is crucial to analyze a dynamic model in which incentives are derived through an intertemporal interaction. Empirical evidence seems inconsistent with the use of warranty as a signaling device, while the reputation mechanism is extremely more powerful than warranties, in the quality determination.

The second experiment provides experimental evidence that: (a) the warranty is not an unambiguous signal of quality, and (b) that only partial coverage is offered. Moreover, the second experiment is genuinely dynamic. Indeed, decisions about maintenance are repeated at different points in time. Results show that quality and effort are complements (see Table 3.3). Thus, for a value of the warranty between zero and one (that is when the warranty is offered, but its coverage is not complete), the second best solution is possible (see Cooper and Ross, 1988). Our main result relates to the optimality of the block warranty. Indeed, a warranty with decreasing coverage, ending before the death of the product, is an optimal solution. The block warranty is optimal because by concentrating the coverage in the first period it maintains unaltered the incentives for producers, and induces the incentives of consumers and the social incentives to coincide. The results of our empirical analysis confirm this conclusion.

The price for a full warranted product is higher than the price for products of the same quality but with a lower warranty level. This situation, clearly, is an instance of market failure and a negative social externality. This result indicates that buyers will accept deviation from equilibrium price induced by sellers of durable goods with warranties. The entity of the deviation from equilibrium price is proportional to the length of the warranty (see Table 3.4).

Quality	Seller's strategy	Buyer's strategy	Separating equilibrium payoffs	Pooling equilibrium payoffs
High quality	warranty	Maintenance	(2000, 1250)	(**1400**, 1250)
High quality	warranty	No maintenance	(1200, 750)	(**600**, 750)
High quality	No warranty	maintenance	(1000, 1250)	(1000, 1250)
High quality	No warranty	No maintenance	(200, 750)	(200, 750)
Low quality	warranty	maintenance	(1000, 750)	(1000, 750)
Low quality	warranty	No maintenance	(200, 1250)	(200, 1250)
Low quality	No warranty	maintenance	(2000, 750)	(**1400**, 750)
Low quality	No warranty	No maintenance	(1200, 1250)	(**600**, 1250)

Table 3.1(a): Separating and Pooling equilibrium payoffs schemes

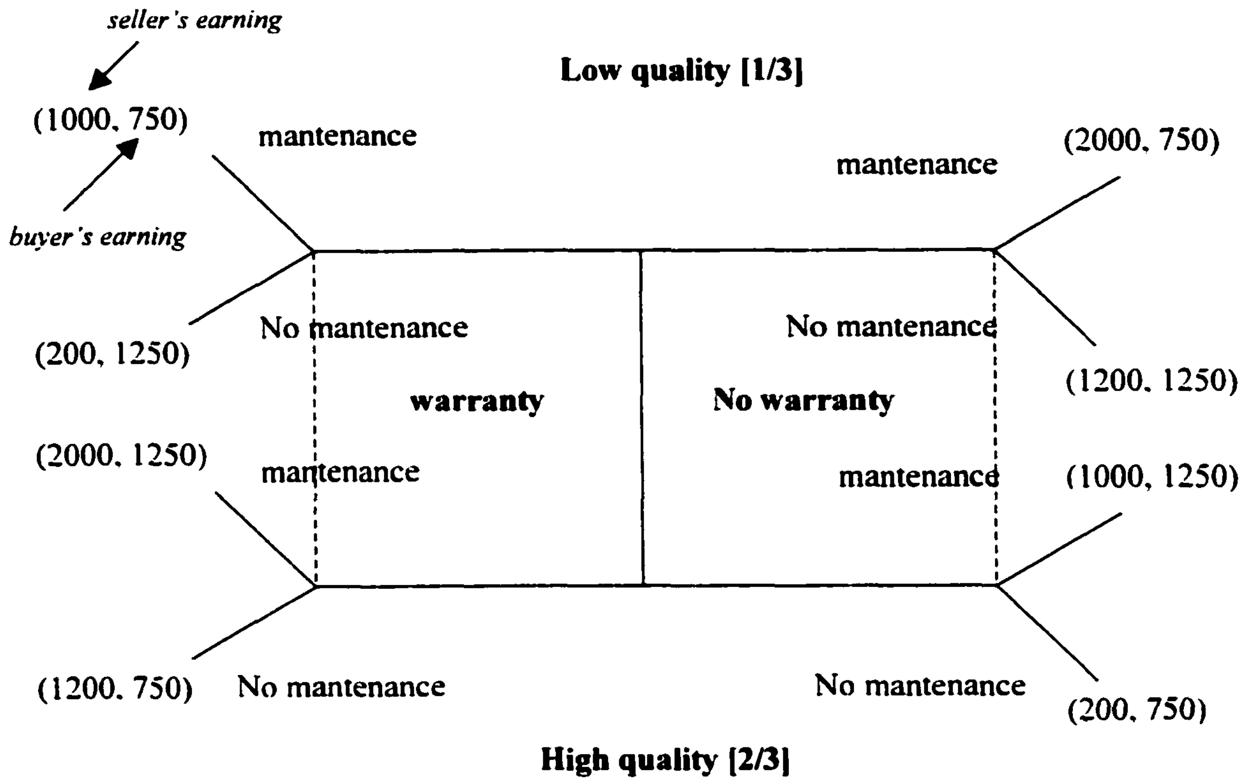


Table 3.1(b): Experimental Task (Experiment 1). Separating Equilibrium payoffs scheme

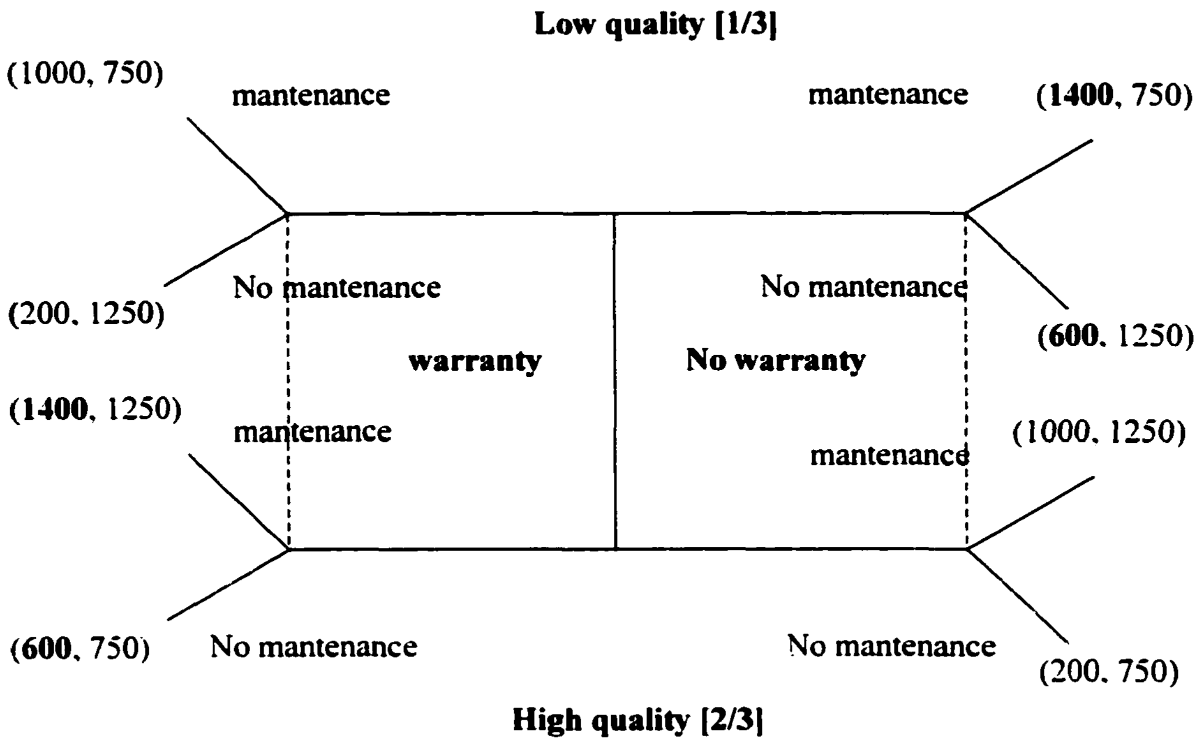
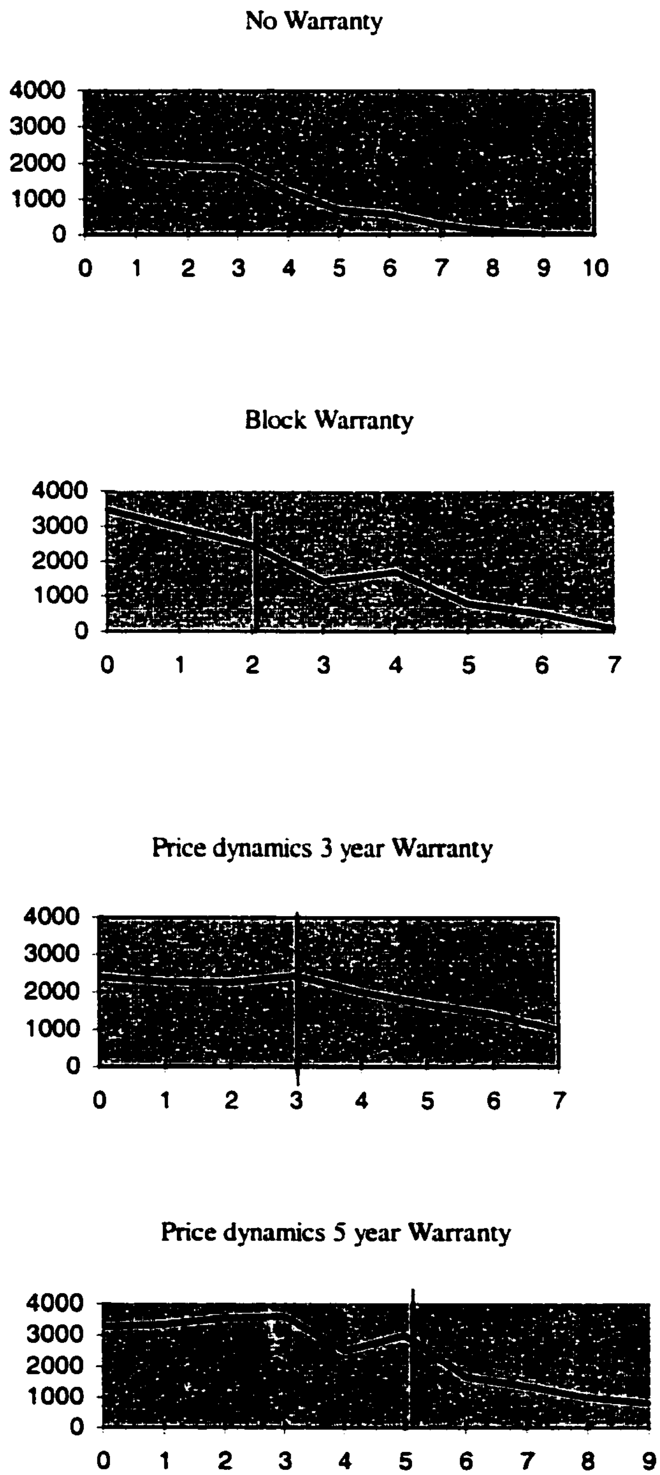


Table 3.1(c): Experimental Task (Experiment 1). Pooling Equilibria payoffs scheme

Equilibrium	Quality	Seller's choice	Buyer's choice	Pair
Pooling	low	no warranty	no maintenance	1
Pooling	high	warranty	maintenance	2
Pooling	high	warranty	maintenance	3
Pooling	high	warranty	no maintenance	4
Pooling	low	warranty	maintenance	5
Pooling	high	warranty	no maintenance	6
Pooling	high	warranty	maintenance	7
Pooling	high	warranty	no maintenance	8
Pooling	low	warranty	maintenance	9
Separating	high	warranty	maintenance	10
Separating	low	no warranty	maintenance	11
Separating	high	warranty	maintenance	12
Separating	high	warranty	maintenance	13
Separating	low	no warranty	no maintenance	14
Separating	high	warranty	no maintenance	15
Separating	high	warranty	maintenance	16
Separating	high	warranty	maintenance	17
Separating	low	no warranty	no maintenance	18
Pooling	low	warranty	maintenance	19
Pooling	high	warranty	no maintenance	20
Pooling	high	warranty	maintenance	21
Pooling	high	warranty	maintenance	22
Pooling	high	warranty	maintenance	23
Pooling	low	no warranty	no maintenance	24
Pooling	high	warranty	maintenance	25
Pooling	high	warranty	maintenance	26
Pooling	low	no warranty	no maintenance	27

Table 3.2: Observed choices. Experiment 1

Figure 3.1: Price Dynamics of different warranty levels. Experiment 2



Regression Analysis
Dependent variable: "Effort"
PROBIT estimation

VARIABLE NAME	COEFFICIENT	MARGINAL VALUE
Constant	1.29 (0.42)**	0.46 (0.14)**
Quality	0.62 (0.37)*	0.22 (0.13)*
Warranty	-0.17 (0.49)	-0.62 (0.18)
QW	-0.84 (0.64)	-0.32 (0.24)
Trials, t	-0.23 (0.77)**	-0.84 (0.28)**

Table 3.3: Regression Analysis

Numbers in parentheses are Standard Errors.
* Significant at 10% confidence
** Significant at 5% confidence
Observations adjusted for heteroskedasticity.

Regression Analysis
Dependent variable: "Offers"
TOBIT estimation

VARIABLE NAME	COEFFICIENT
Constant	2515.71 (138.89)**
w2	371.17 (149.72)**
w3	390.42 (139.74)**
w5	1191.56 (189.11)**
Trials, t	-296.22 (21.7)**

Table 3.4: Regression Analysis

Numbers in parentheses are Standard Errors.
* Significant at 10% confidence
** Significant at 5% confidence

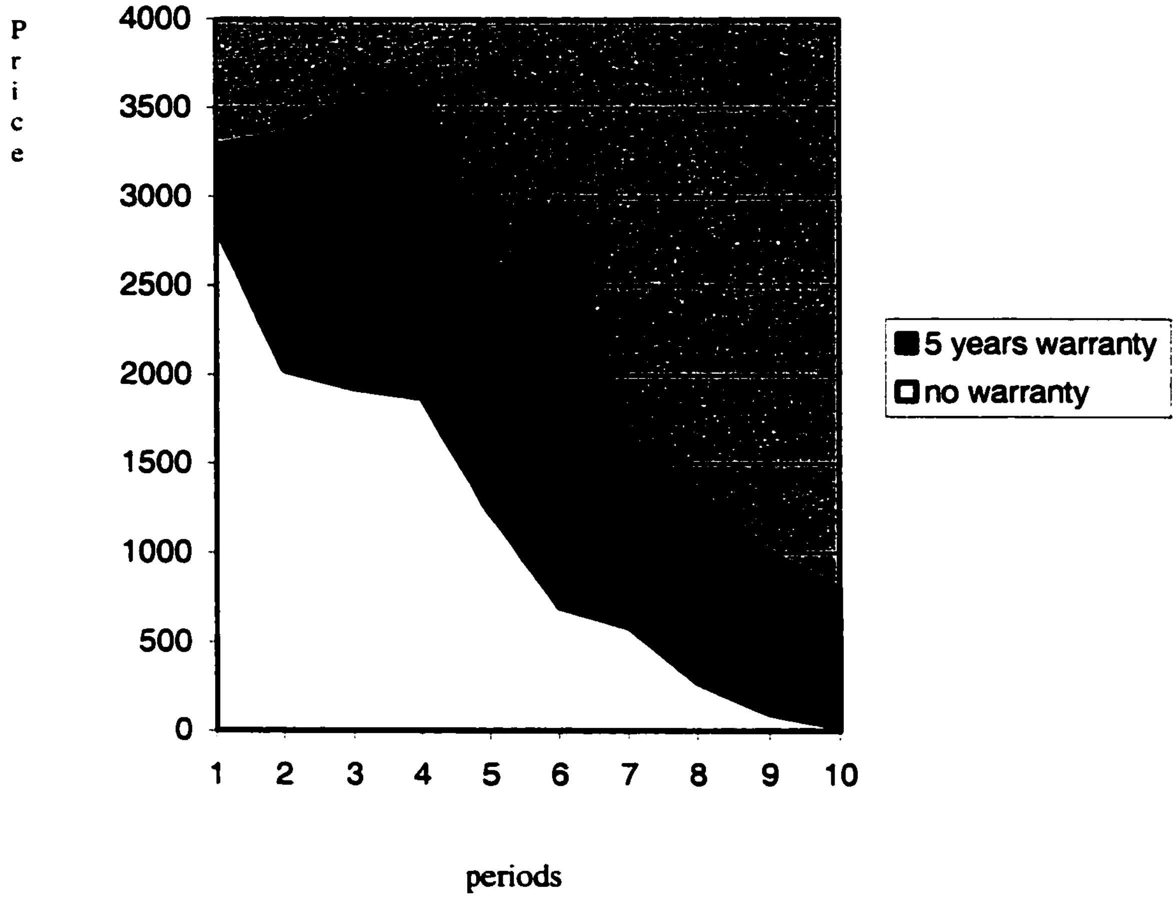


Figure 3.2: Price dynamics of 5year warranty and no warranty

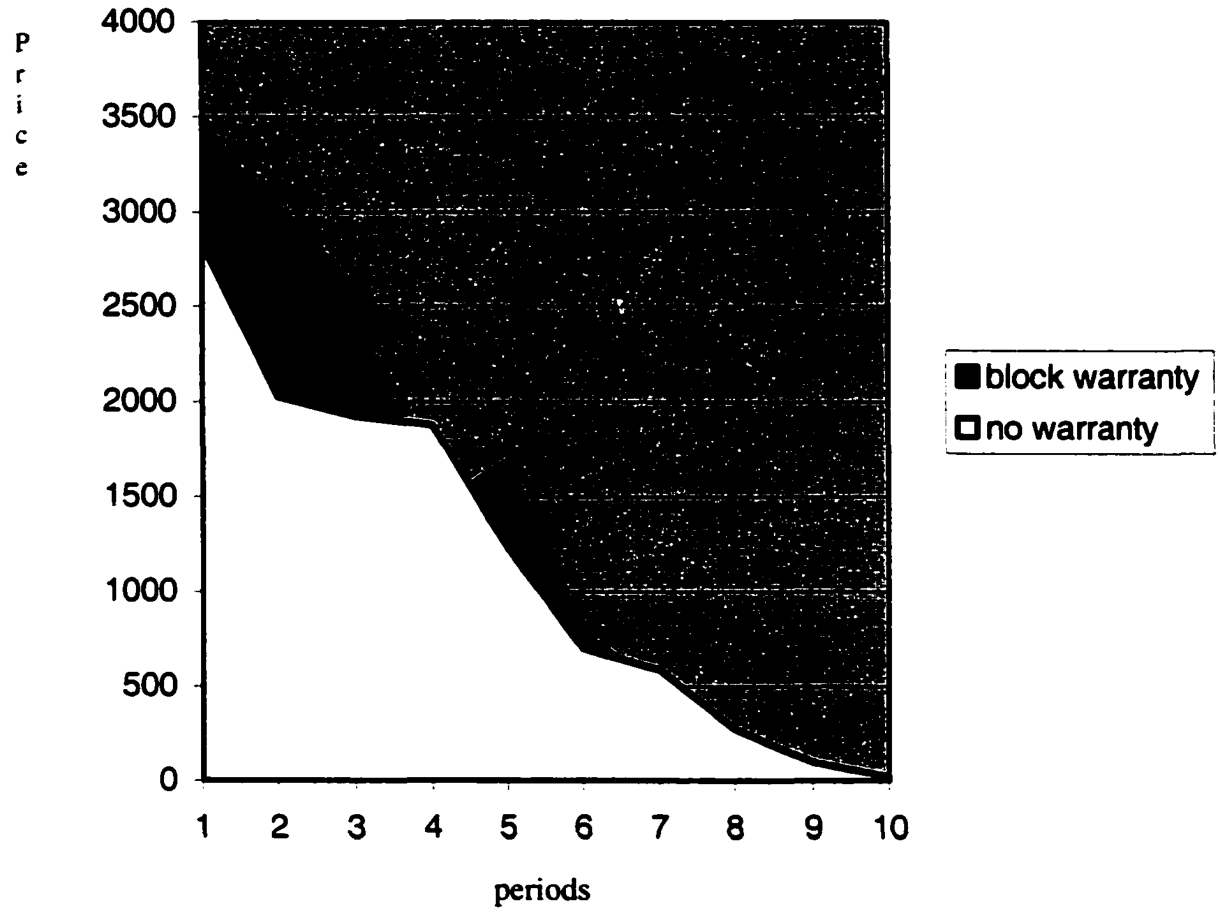


Figure 3.3: Price dynamics of block warranty and no warranty

CHAPTER 4

STRATEGIC INTERACTION IN ITERATED-ZERO SUM GAMES

In the experimental literature on minimax theory and mixed strategies there are several unanswered questions, as stated in Brown and Rosenthal (1990):

"... an objective for anyone studying these data [experimental data of iterated two-person zero-sum games], is to judge whether the departures observed in the data appear more likely to have been caused by intentional departures from the equilibrium strategies, rather than by chance or unintentional departures."

If players intend to play minimax, and if players believe their opponents to be playing minimax, then although a player's own lagged play might influence her current play through an inability to achieve randomness, the various terms involving the opponent's lagged plays should not influence that player's choices. The experimental evidence shows contemporaneous and serial correlation among players' choices (see Brown and Rosenthal, 1990; Budescu and Rapoport, 1994; Shachat, 2002). The nature of the dependency between players in these types of games is an important issue. Therefore, the aim of our research is to carry out an experimental study that analyzes strategic dependency in iterated zero-sum games, and also to explain the evidence for large variance in players' win rates across pairs of opponents. The experiment that we propose controls the structure of the interdependence between players. This is possible by introducing a computer program (robot) as one of the two players. Section 4.1 introduces the procedure and the design of our experimental analysis. In Section 4.2 we analyze the data at the aggregate and individual levels. Section 4.3 concludes the chapter with discussion of our results and previous experimental literature.

4.1 Experimental design and procedure

The subject is playing iterated games against a computer program. The experiment implements a within-subject design with two sessions and two conditions. The experimental analysis allows us to distinguish strategic dependence from non-strategic dependence in subjects' play. Implementing a computer program to play the role of one of the subjects, we can directly manipulate the nature of the dependency between the participants (computer/human). The computer is programmed in such a way that its responses are strictly dependent on the previous responses of the human subject. In this way, the interdependence between the players (computer/human) is maintained.

The experimental task is an iterated two-outcome zero-sum game. Subjects play a variation of O'Neill's experimental design introduced by Shachat (2002) (see Table 4.1). The game has a unique equilibrium, i.e., the row player and the column player each randomizes with probabilities .2, .2, .2, .4, respectively. The value of the game that corresponds to the probability of a win for the row player in equilibrium is equal to .4. This design does not rely upon the assumption of risk-neutrality or make any assumption on risk attitude of the subjects (see O'Neill, 1987).

The experiment is conducted on computer terminals. The game is presented with a matrix payoff framing. The same game matrix is used for all groups and sessions in the experiment. The elements of the action space are: {Green, Red, Brown, Purple}. Under the minimax hypothesis each player's choice of the Purple alternative should be independent of past Purple choices made by that player and by his opponent (see Brown and Rosenthal, 1990).

The payoffs in the game matrix in Table 4.1 are for the Row Player (human); Column's payoffs (computer) are the negative of Row's. Payoffs are in experimental dollars. At the end of the experiment subjects' total experimental dollar earnings are converted to US dollars at a rate of 10.00 experimental dollars to 1US dollar. The Subjects play 60 stage games for each session (2 sessions), for a total of 120 iterations over all the experiment. Subjects know they are playing against the computer. They are told that neither the computer program, nor anyone else, will be paid the computer program's payoff (see Instructions in Appendix C).

The computer is programmed to play the zero-sum game against human subjects. It plays the game according to two different strategies that determine the two conditions of the experiment. The human subject plays 60 trials against a computer programmed to play one strategy, and then she/he plays against the other strategy in the second sequence.

Following the first strategy (condition 1), the computer program computes a vector $C^{(t)}$, on each trial of the experimental session (t=2, ...,60). The components of the vector are the previous choices of the subject. Given the vector $C^{(t)}$, the computer program computes a matrix $T^{(t)}= C^{(t)}G$, where G is the game matrix (considering the subject's payoffs). It then sums the elements of all columns in the matrix, and defines a vector $L^{(t)}$.

[1] This vector has four elements, one for each available strategy. The computer then chooses the alternative for which the element is a minimum. If the minimum is not unique the computer chooses the first color that minimizes the payoffs starting from the left (Green, Red, Brown, Purple).

The vector $L^{(t)}$ may be seen to give the expected loss to the computer program for each of its alternative choices. Its decision rule is to choose always the action having the minimum expected loss.[2] The computer program has perfect memory for the proportion of times the subject has made her/his choices (see also Messick, 1967). Therefore, in condition 1 the computer program implements the fictitious player procedure with unlimited memory (see Brown, 1951; Fudenberg and Levine, 1998).

The second strategy of the computer program (condition 2) is identical to the first with one exception. In condition 2 the computer program updates the frequencies that each alternative is played in such a way that the probability (computed by the computer program) that the subject will choose Purple after he/she has just chosen Purple is reduced.[3] Doing so, we manipulate the type of deviation from random play, i.e. the computer program assigns over-alternation to the human subject's play of the Purple alternative. This behavior deviates from the minimax hypothesis in a way that has been shown in previous experimental data (see Budescu and Rapoport, 1994).

---

[1] The computer calculates payoffs for the colors that the subject chooses.

[2] In the first trial the computer program chooses the Green color, i.e. it predicts the subject's choice to be coherent with the minimax hypothesis. On successive trials the computer chooses the color that minimize subject's payoffs, given the subject's previous periods choices.

[3] The computer program computes the matrix $T^{(t)}$ assigning the value of zero instead of +5 to the fourth element of the rows corresponding to the subject choice of the Purple color. Subject's payoff for Purple from the computer viewpoint is 0.

If the subject's choices follow the same rule implemented by the computer, then the choice proportion for the subject and for the computer program will approach the prescribed minimax proportions (see Table C1 in the Appendix). The table presented in the appendix is a simulation of two agents playing fictitious play procedure. In 60 repetitions the simulated players play the four strategies with a frequency coherent with the minimax solution. The convergence to the minimax solution is indicated also by the stability of the difference between the maximum and the minimum values of the cumulative payoffs for each iteration (last column in Table C1).

If the subject deviates from minimax play (and to the extent that the subject's choices on trial k are independent of her/his previous choices and those of the computer), then the strategy of the computer program will outperform the subject in terms of expected gains. If the subject responds to the computer program with an appropriate counterstrategy, then the subject will outperform the computer program in terms of expected gains.

The restriction on behavior of the second strategy has the effect of enabling the subject to discover periodic choice sequences that constitute an effective counterstrategy (see Messick, 1967).

The participants were 60 undergraduate students from the University of Arizona. They were randomly assigned to two groups. In Group 1 (N=30) we present Condition 1 in Session 1 and Condition 2 in Session 2; in Group 2 (N=30) we present Condition 2 in Session 1 and Condition 1 in Session 2.

This experimental design gives rise to two hypotheses:

Hypothesis 1: Different behavior in the two conditions: the strategies that the subject will use depend on the strategy being used by the computer program.

Hypothesis 2: Higher variance in response to the first strategy of the computer program than to the second. Subjects playing against the first strategy will vary more in terms of the strategies they employ than will subjects playing against the other strategy. The availability of periodic choice sequences, by the computer, that can be used against it (second strategy), leads to less variability across subjects than when such periodic sequences are not available.

4.2 Data Analysis

The following data analysis examines the relative frequencies of color choices in condition 1 and condition 2, the percentage of row wins, the decomposition of the deviation of the winning rate, and the independence hypothesis test. We start the analysis by constructing contingency tables (see Table 4.2 and Table 4.3). We assume identically and independent distributed choices; of course, this assumption has limited validity considering that the computer program follows the fictitious play procedure. At the same time, the analysis of the contingency table still represents a good exercise in order to determine a first picture of the data and to compare alternative scenarios. The first contingency table uses data from the first condition in groups 1 and 2, and the second table uses data from the second condition for both groups of subjects. We can aggregate these data considering the results of two-sample Kolmogorov-Smirnov tests (K-S =.1 p-value =.9, i.e., we cannot reject the hypothesis that the choice in condition 1 for group 1 and group 2 come from the same distribution; K-S =.1 p-value =.9, i.e. we cannot reject the hypothesis that the choice in condition 2 for group 1 and group 2 come from the same distribution). A first test for contemporaneous correlation is the chi-square test of independence between row (human) and column (computer). Results of this test show strong contemporaneous dependency (chi-square = 593.4481 d.f.= 9 p-value=0; and chi-square = 554.2251 d.f.= 9 p-value=0, for the first and second contingency table, respectively.) We can reject the hypothesis of minimax play for both conditions. The relative frequencies of joint moves deviate more than two standard deviations from the minimax prediction.[4] As shown in Table 4.2, the marginal frequencies for condition 1 are less than one standard deviation away from the predicted values. This is conforming to the standard results (O'Neill, 1987; Shachat, 2002) on data analysis at the aggregate level. This result is not present in condition 2 (Table 4.3). In the second condition the marginal frequencies of purple choices are significantly away from the predicted value, i.e. subjects play purple significantly more frequently in the second condition. Binomial tests reject the hypothesis that the observed frequencies of choice conform to the specified predicted parameters. The contingency table also indicate that the results do not conform to the hypothesis of random play, i.e., choosing each color with probability .25 (joint probability .0625). A first conclusion is that subjects do not play minimax and do not randomize in this experiment.

[4] The standard deviations in the contingency table are calculated using the following formula: $\frac{\sqrt{np(1-p)}}{n}$, where n is the number of observation (3600 for each condition), and p is the probability predicted by the minimax solution.

Figures 4.1 and 4.2 illustrate the observed subjects' mean choice proportions for six consecutive blocks of ten trials in condition 1 and condition 2, respectively. In Figure 4.1, the color choice proportions converge to values close to the predicted ones after the second block. In Figure 4.2, the choice proportions diverge from the predictions after the first block. The proportion of purple play remains close to .6 after the second block. This result confirms Hypothesis 1 of different behavior in the two conditions.

In what follows we show how not playing minimax is profitable for the subjects. Table 4.4 shows the row win percentage for each condition. The row win percentages significantly deviate from the predicted value. The winning percentage of the row players (human) is higher for the second condition, and both are significantly higher than the percentage of row wins reported in analogous experiments (O'Neill, 1987, the row player's percentage of win is .41; and Shachat, 2002, first Treatment, the row player percentage of win is .43). Figure 4.3 shows the average win rate for both conditions along the 60 trials. This figure shows more variability in the average win rate for the first condition.

Tables 4.5 and 4.6 report the play of both the subjects and the computer program. These two tables show the winning percentages of the (human) row player. The variability is significantly lower than that observed in previous experiments (O'Neill, 1987; Shachat, 2002). The second condition seems to induce minimal variability in row player win percentages. This can be explained by the fact that the second condition leads to less variability in strategies response. This confirms Hypothesis 2.

We construct Tables 4.7 and 4.8 following Brown and Rosenthal's (1990) decomposition of the deviation of the winning rate from the predicted equilibrium (minimax rate). In these tables, the expected row winning percentage is calculated assuming independence between row and column players. The *mixture effect* is the difference between the expected row winning percentage and .4, the minimax prediction. The *correlation effect* is the difference between the observed percentage and the expected row winning percentage (as defined above). The results of both tables show that the correlation effect explains the greater part of the deviation of the winning percentage from the minimax prediction. This shows the non-independence between players' choices, i.e., the subjects' choices are dependent on the computer's choices. This finding is also illustrated in Figure 4.4. In this figure we represent the computers' color choices in condition 1 (C1) and condition 2 (C2), respectively (the two figures at the top), and a simulation of the computer algorithm implemented in C2 conditional on the humans' choices in C1 (1^{st} figure at the bottom), and a simulation of the computer algorithm implemented in C1 conditional on the data of humans' choices in C2 (2^{nd} figure at the bottom). The comparison between the computer's observed choices in C1 and the simulation with the computer's C2 algorithm and observed human choices in condition 1 (1^{st} figure at the top and 1^{st} figure at the bottom) shows how the second algorithm would have behaved differently compared to the first one conditioning on the human observed choices, i.e., it would have always played purple. The same difference in computer behavior follows from the comparison between the observed computer choices in C2 and the simulated computer choices using the C1 algorithm and human choices observed in

C2, i.e. the computer C1 would have never played purple. These observations illustrate the strong dependency of subjects' behavior on the computer's behavior.

In what follows we further investigate the nature of this dependency. We focus on the choice between the purple and not-purple (green, red, brown) cards in both conditions. The data from our experiment show that it is appropriate to consider the color choices of green, red, and brown as strategically equivalent (see Table 4.9).

The subjects' choices of the P:urple card are a consistent indicator of the type of intertemporal dependency between players (human/computer). We conducted a Logit analysis in order to study the intertemporal correlation in subjects' play. The dependent variable, y_{rt} assumes a value of one when the human row player plays Purple in period t and a value of zero when she does not choose Purple. The variable, y_{ct} assumes value of one when the computer column player plays Purple, and value of zero when it does not choose Purple. We use the following logit equation (implemented in Brown and Rosenthal, 1990):

$$\begin{aligned} y_{rt} = F[\beta_0 + \beta_1 y_{rt-1} + \beta_2 y_{rt-2} + \beta_3 y_{ct} + \beta_4 y_{ct-1} + \\ + \beta_5 y_{ct-2} + \beta_6 y_{rt-1} y_{ct-1} + \beta_7 y_{rt-2} y_{ct-2}] \end{aligned} \qquad (1)$$

The function F[x] denotes the function exp(x)/[1-exp(x)].

Results from the likelihood ratio tests for restrictions on the parameters are reported in Table 4.10 and Table 4.11 for conditions 1 and 2, respectively. We ran a Logit analysis with estimating equation 1 with data for each subject for the two conditions of the experiment. The rejections illustrated in Table 4.10 and Table 4.11 are determined by a likelihood-ratio test. The tables present resul:s of 6 tests.

Test 1. The result of this test shows the inconsistency of the minimax hypothesis with the data of my experiment (see Table 4.10 and Table 4.11), i.e. subjects do not use i.i.d. strategies. For the minimax model, no one of the explanatory variables should be a significant determinant for the current choice of the Purple color.

Test 2. The results of this test are significantly different for the two conditions. In condition 2 the current choice of the Purple color is highly correlated with own past choice. The result of this test confirms Hypothesis 1 and Hypothesis 2 above. Subjects play in a more autocorrelated way when the opponent's strategy is more "vulnerable." This result can explain non-random behavior in this type of game. Therefore subjects' non-random behavior is strictly related to the strategic interaction.

Test 3. The results of the third test show the predominant influence of the computer's lagged choices on the current subjects' decisions. This result is consistent for the two conditions, even though it is more accentuated for the second condition.

Test 4. The results of the fourth test show a significant difference in behavior between the two conditions of the experiment. The higher number of rejections in the second condition indicates a stronger dependency of the subjects in that condition on the choices of their opponent (the computer program), past choices, and past outcomes. In the case of the second condition, the subjects strategically under-alternate their choice of the Purple color. They play Purple for longer sequences than in the first condition.

Test 5. The fifth test confirms the dependency of the subject's choices on their opponent's lagged decisions. The subjects try to anticipate their opponent's choices by using its past decisions. This result is consistent for the two conditions, and it is significantly stronger than the analogous result for related experiments (O'Neill, 1987, and Shachat, 2002).

Test 6. This test check for contemporaneous correlation between choices by the subjects and the computer program. The results show a significant difference between the two conditions. A possible explanation of this result is that in the first condition the subjects are less "attached" to the computer's lagged decisions. This because the choice sequence of the computer program in the first condition is less achievable by the subjects. This also causes higher variability in the subjects' behavior (Hypothesis 2).

We tested a routine learning model based on the average payoff realized from the choices of purple and non-purple in the past. The logit equations below indicate the probability of the purple choice as a function of the average payoffs realized from the purple choice (A_{purple}) and the non-purple choice ($B_{non\text{-}purple}$) until time t-1. The numbers in parentheses indicate absolute t-values.

$$y_{rt} = F[\beta_0 + \underset{(10.79)}{1.86}\, A_{purple,t-1} - \underset{(1.34)}{0.28}\, B_{non-purple,t-1}] \qquad (2) \qquad \text{Condition 1}$$

$$y_{rt} = F[\beta_0 + \underset{(14.37)}{2.74}\, A_{purple,t-1} - \underset{(3.85)}{0.94}\, B_{non-purple,t-1}] \qquad (3) \qquad \text{Condition 2}$$

The logit estimations show (for both conditions with the exception of the non-purple choice in Condition 1) that subjects' moves are significantly related to the average past payoffs. We can conclude that subjects' learning corresponds to a routine learning model when the environment is "minimally stationary," meaning that the opponents (in our case the computer algorithms) maintain their strategy for an entire session of the experiment, or at least maintain a certain strategy after a process of learning. In every iterated multi-person game the subjects must learn how to best respond against opponents who are learning how to best respond against opponents who are learning, and so on. This process induces a non-stationary environment that is tedious, and sometimes impossible to investigate. The experimental evidence of learning in non-stationary environments is hard to interpret. Even implementing the more sophisticated statistical tools, we cannot detect when the subjects change their strategies. Subjects could switch strategy at each iteration and there would be no learning model that could fit this "absolute" instability.

4.3 Summary of the results

The results of our experiment confirm the two hypotheses of differences in strategic behavior between the two experimental conditions, and of higher variability in subjects' behavior in the first condition. The result of different proportions of subjects' choices for the four available strategies and the two conditions are impressive if we consider that the subjects have minimal information about the characteristics of the computer program (their opponent). The subjects are not informed about the computer program's strategies. They are not informed in the instructions that they are playing with two different computer programs in the two sessions of the experiment. The results are consistent for both groups of subjects, the one that started with condition 1 and the one that started with condition 2. Considering also the subjects' percentage of wins in both conditions, we can conclude that the subjects in this experiment implemented effective counterstrategies.

They had the ability to detect the computer's behavior and find winning strategies. This is what we mean by strategic dependence. We want to remark that the subjects are inexperienced subjects with no training in this type of game.

The results on the variability in terms of strategies implemented and winning percentages show that condition 2 of the experiment leads to less variability between subjects. This result shows that the observed (O'Neill, 1987) excessive variance of win percentages across subjects is strictly related to the nature of the strategic interaction between the players.

As stated by Messick (1967), "...the fact that subjects react differently to different opponents suggests that the determinants of human decision strategies in interdependent contexts are not exclusively those dealt with by the classical theory of games."

		Column Player (Computer)			
		Green	Red	Brown	Purple
Row Player (Human)	Green	L	W	W	L
	Red	W	L	W	L
	Brown	W	W	L	L
	Purple	L	L	L	W

Table 4.1: Experimental Task
W=5, and L=-5

Subject's choice		Computer's choice: green	red	brown	purple	Marginal Frequencies
	green	**0.032**	**0.050**	**0.057**	**0.061**	0.200
		(0.040)	(0.040)	(0.040)	(0.080)	(0.200)
		0.003	*0.003*	*0.003*	*0.005*	*0.007*
	red	**0.048**	**0.021**	**0.075**	**0.057**	0.201
		(0.040)	(0.040)	(0.040)	(0.080)	(0.200)
Subject's choice		*0.003*	*0.003*	*0.003*	*0.005*	*0.007*
	brown	**0.067**	**0.049**	**0.036**	**0.068**	0.220
		(0.040)	(0.040)	(0.040)	(0.080)	(0.200)
		0.003	*0.003*	*0.003*	*0.005*	*0.007*
	purple	**0.048**	**0.042**	**0.044**	**0.245**	0.379
		(0.080)	(0.080)	(0.080)	(0.160)	(0.400)
		0.005	*0.005*	*0.005*	*0.006*	*0.008*
Marginal Frequencies		0.195	0.162	0.212	0.431	
		(0.200)	(0.200)	(0.200)	(0.400)	
		0.007	*0.007*	*0.007*	*0.008*	

Table 4.2: Relative Frequencies of Color Choices in Condition 1
Numbers in parentheses are predicted relative frequencies (minimax hypothesis).
Numbers in italic are standard deviations for observed relative frequencies under the minimax hypothesis.

Subject's choice		Computer's choice: green	red	brown	purple	Marginal Frequencies
	green	**0.010**	**0.023**	**0.038**	**0.062**	0.137
		(0.040)	(0.040)	(0.040)	(0.080)	(0.200)
		0.003	*0.003*	*0.003*	*0.005*	*0.007*
	red	**0.023**	**0.011**	**0.053**	**0.064**	0.145
		(0.040)	(0.040)	(0.040)	(0.080)	(0.200)
Subject's choice		*0.003*	*0.003*	*0.003*	*0.005*	*0.007*
	brown	**0.043**	**0.044**	**0.024**	**0.064**	0.176
		(0.040)	(0.040)	(0.040)	(0.080)	(0.200)
		0.003	*0.003*	*0.003*	*0.005*	*0.007*
	purple	**0.048**	**0.049**	**0.059**	**0.385**	0.542
		(0.080)	(0.080)	(0.080)	(0.160)	(0.400)
		0.005	*0.005*	*0.005*	*0.006*	*0.008*
Marginal Frequencies		0.132	0.118	0.172	0.578	
		(0.200)	(0.200)	(0.200)	(0.400)	
		0.007	*0.007*	*0.007*	*0.008*	

Table 4.3: Relative Frequencies of Color Choices in Condition 2
Numbers in parentheses are predicted relative frequencies (minimax hypothesis).
Numbers in italic are standard deviations for observed relative frequencies under the minimax hypothesis.

Experiment	Row Win %	Predicted %	# of Observation	Standard Deviation
O'Neill	0.410	0.400	2625	0.010
Shachat T1	0.433	0.400	900	0.016
Condition1	0.590	0.400	3600	0.010
Condition2	0.609	0.400	3600	0.010

Table 4.4: Percentage of Row Wins

Condition 1

Subject	win %	Subject's Action				Computer's Action			
		green	red	brown	purple	green	red	brown	purple
1	0.650	0.200	0.217	0.200	0.383	0.167	0.117	0.283	0.433
2	0.517	0.117	0.250	0.267	0.367	0.117	0.250	0.217	0.417
3	0.533	0.117	0.267	0.250	0.367	0.033	0.283	0.233	0.450
4	0.667	0.217	0.167	0.217	0.400	0.183	0.117	0.300	0.400
5	0.467	0.250	0.233	0.167	0.350	0.233	0.267	0.000	0.500
6	0.600	0.217	0.217	0.183	0.383	0.217	0.100	0.283	0.400
7	0.667	0.200	0.200	0.200	0.400	0.200	0.233	0.183	0.383
8	0.600	0.200	0.183	0.233	0.383	0.250	0.200	0.217	0.333
9	0.600	0.167	0.217	0.233	0.383	0.067	0.217	0.283	0.433
10	0.650	0.217	0.200	0.200	0.383	0.250	0.217	0.150	0.383
11	0.550	0.000	0.333	0.333	0.333	0.033	0.333	0.400	0.233
12	0.600	0.233	0.200	0.183	0.383	0.317	0.117	0.233	0.333
13	0.600	0.217	0.217	0.183	0.383	0.150	0.117	0.333	0.400
14	0.583	0.200	0.217	0.183	0.400	0.250	0.167	0.067	0.517
15	0.550	0.150	0.217	0.250	0.383	0.133	0.250	0.117	0.500
16	0.533	0.200	0.183	0.217	0.400	0.217	0.133	0.183	0.467
17	0.617	0.200	0.200	0.200	0.400	0.117	0.300	0.100	0.483
18	0.567	0.267	0.150	0.233	0.350	0.283	0.017	0.283	0.417
19	0.650	0.200	0.200	0.200	0.400	0.200	0.150	0.267	0.383
20	0.583	0.267	0.100	0.267	0.367	0.217	0.117	0.250	0.417
21	0.583	0.167	0.217	0.217	0.400	0.133	0.150	0.333	0.383
22	0.567	0.333	0.000	0.350	0.317	0.350	0.000	0.383	0.267
23	0.633	0.200	0.183	0.217	0.400	0.083	0.150	0.433	0.333
24	0.633	0.167	0.233	0.217	0.383	0.183	0.283	0.200	0.333
25	0.633	0.217	0.183	0.233	0.367	0.167	0.150	0.267	0.417
26	0.567	0.217	0.233	0.167	0.383	0.183	0.183	0.250	0.383
27	0.433	0.167	0.200	0.250	0.383	0.017	0.083	0.250	0.650
28	0.583	0.150	0.217	0.250	0.383	0.183	0.100	0.267	0.450
29	0.583	0.200	0.217	0.200	0.383	0.267	0.000	0.233	0.500
30	0.533	0.200	0.217	0.200	0.383	0.233	0.033	0.233	0.500
31	0.567	0.100	0.267	0.283	0.350	0.100	0.150	0.317	0.433
32	0.617	0.200	0.200	0.200	0.400	0.283	0.300	0.050	0.367
33	0.583	0.267	0.217	0.167	0.350	0.183	0.133	0.033	0.650
34	0.617	0.200	0.183	0.233	0.383	0.117	0.183	0.217	0.483
35	0.650	0.200	0.217	0.183	0.400	0.250	0.267	0.100	0.383
36	0.600	0.167	0.217	0.217	0.400	0.267	0.150	0.200	0.383
37	0.550	0.200	0.183	0.217	0.400	0.183	0.133	0.133	0.550
38	0.650	0.150	0.233	0.233	0.383	0.067	0.317	0.250	0.367
39	0.550	0.200	0.217	0.183	0.400	0.183	0.083	0.183	0.550
40	0.550	0.183	0.217	0.200	0.400	0.083	0.083	0.333	0.500
41	0.533	0.200	0.183	0.233	0.383	0.133	0.000	0.183	0.683
42	0.600	0.150	0.233	0.233	0.383	0.150	0.100	0.383	0.367
43	0.583	0.267	0.250	0.117	0.367	0.383	0.283	0.017	0.317
44	0.567	0.233	0.217	0.167	0.383	0.450	0.150	0.000	0.400
45	0.750	0.217	0.217	0.167	0.400	0.233	0.250	0.117	0.400
46	0.533	0.350	0.000	0.333	0.317	0.383	0.000	0.317	0.300
47	0.817	0.200	0.217	0.200	0.383	0.133	0.117	0.367	0.383
48	0.650	0.200	0.200	0.217	0.383	0.350	0.217	0.000	0.433
49	0.550	0.217	0.167	0.233	0.383	0.167	0.150	0.200	0.483
50	0.433	0.300	0.083	0.283	0.333	0.117	0.000	0.133	0.750
51	0.567	0.217	0.233	0.167	0.383	0.267	0.033	0.183	0.517
52	0.533	0.250	0.233	0.133	0.383	0.250	0.217	0.117	0.417
53	0.583	0.233	0.133	0.250	0.383	0.200	0.050	0.250	0.500
54	0.567	0.183	0.200	0.233	0.383	0.233	0.100	0.233	0.433
55	0.550	0.217	0.183	0.217	0.383	0.067	0.083	0.300	0.550
56	0.583	0.200	0.183	0.217	0.400	0.233	0.233	0.167	0.367
57	0.650	0.183	0.217	0.233	0.367	0.183	0.400	0.050	0.367
58	0.600	0.217	0.183	0.217	0.383	0.183	0.183	0.267	0.367
59	0.667	0.050	0.300	0.317	0.333	0.083	0.350	0.300	0.267
60	0.633	0.200	0.183	0.233	0.383	0.350	0.200	0.067	0.383
average	0.590	0.200	0.201	0.220	0.379	0.195	0.162	0.212	0.431
Sdev	0.0630	0.056	0.054	0.045	0.021	0.093	0.097	0.107	0.098

Table 4.5: Relative frequencies of choices and subject wins

		Condition 2							
		Subject's Action				Computer's Action			
Subject	win %	green	red	brown	purple	green	red	brown	purple
1	0.617	0.150	0.150	0.167	0.533	0.150	0.100	0.067	0.683
2	0.533	0.000	0.267	0.250	0.483	0.017	0.100	0.333	0.550
3	0.617	0.150	0.150	0.150	0.550	0.033	0.167	0.200	0.600
4	0.583	0.133	0.133	0.167	0.567	0.217	0.083	0.117	0.583
5	0.600	0.100	0.167	0.183	0.550	0.067	0.033	0.200	0.700
6	0.633	0.133	0.183	0.133	0.550	0.250	0.067	0.033	0.650
7	0.583	0.133	0.150	0.167	0.550	0.117	0.250	0.133	0.500
8	0.600	0.133	0.150	0.167	0.550	0.050	0.150	0.233	0.567
9	0.633	0.150	0.133	0.150	0.567	0.150	0.033	0.250	0.567
10	0.617	0.150	0.150	0.150	0.550	0.117	0.150	0.133	0.600
11	0.583	0.033	0.217	0.250	0.500	0.033	0.233	0.133	0.600
12	0.617	0.150	0.150	0.133	0.567	0.117	0.133	0.183	0.567
13	0.617	0.150	0.133	0.150	0.567	0.267	0.167	0.050	0.517
14	0.617	0.133	0.150	0.167	0.550	0.067	0.200	0.100	0.633
15	0.583	0.033	0.233	0.250	0.483	0.017	0.317	0.233	0.433
16	0.617	0.150	0.133	0.167	0.550	0.200	0.100	0.150	0.550
17	0.600	0.167	0.133	0.150	0.550	0.217	0.000	0.300	0.483
18	0.583	0.167	0.183	0.117	0.533	0.167	0.167	0.200	0.467
19	0.617	0.117	0.167	0.167	0.550	0.067	0.250	0.117	0.567
20	0.600	0.117	0.167	0.167	0.550	0.017	0.067	0.200	0.717
21	0.583	0.133	0.133	0.200	0.533	0.133	0.117	0.217	0.533
22	0.600	0.200	0.050	0.217	0.533	0.283	0.000	0.200	0.517
23	0.567	0.100	0.167	0.200	0.533	0.167	0.183	0.067	0.583
24	0.617	0.117	0.150	0.183	0.550	0.133	0.117	0.117	0.633
25	0.633	0.133	0.150	0.183	0.533	0.083	0.183	0.150	0.583
26	0.600	0.150	0.167	0.133	0.550	0.267	0.067	0.067	0.600
27	0.583	0.133	0.150	0.167	0.550	0.033	0.167	0.200	0.600
28	0.617	0.000	0.250	0.250	0.500	0.017	0.133	0.400	0.450
29	0.667	0.150	0.133	0.167	0.550	0.150	0.133	0.167	0.550
30	0.583	0.150	0.133	0.150	0.567	0.117	0.083	0.200	0.600
31	0.550	0.000	0.250	0.250	0.500	0.033	0.200	0.283	0.483
32	0.567	0.083	0.200	0.183	0.533	0.167	0.083	0.100	0.650
33	0.650	0.167	0.167	0.117	0.550	0.183	0.067	0.000	0.750
34	0.617	0.133	0.167	0.150	0.550	0.083	0.183	0.117	0.617
35	0.600	0.150	0.133	0.150	0.567	0.067	0.283	0.100	0.550
36	0.583	0.117	0.183	0.150	0.550	0.133	0.150	0.083	0.633
37	0.617	0.100	0.167	0.183	0.550	0.083	0.133	0.217	0.567
38	0.617	0.050	0.217	0.217	0.517	0.033	0.200	0.200	0.567
39	0.633	0.117	0.167	0.167	0.550	0.050	0.200	0.167	0.583
40	0.550	0.133	0.133	0.150	0.583	0.283	0.083	0.150	0.483
41	0.617	0.117	0.167	0.167	0.550	0.067	0.233	0.083	0.617
42	0.700	0.017	0.233	0.250	0.500	0.017	0.283	0.300	0.400
43	0.633	0.150	0.150	0.150	0.550	0.050	0.183	0.167	0.600
44	0.600	0.167	0.183	0.100	0.550	0.183	0.233	0.083	0.500
45	0.600	0.150	0.150	0.150	0.550	0.167	0.133	0.067	0.633
46	0.600	0.217	0.050	0.200	0.533	0.183	0.050	0.183	0.583
47	0.683	0.150	0.133	0.183	0.533	0.083	0.000	0.250	0.667
48	0.600	0.150	0.150	0.150	0.550	0.100	0.117	0.200	0.583
49	0.633	0.167	0.100	0.183	0.550	0.183	0.067	0.233	0.517
50	0.633	0.250	0.000	0.250	0.500	0.283	0.000	0.150	0.567
51	0.633	0.133	0.150	0.167	0.550	0.050	0.100	0.300	0.550
52	0.650	0.167	0.117	0.167	0.550	0.167	0.033	0.217	0.583
53	0.550	0.233	0.033	0.233	0.500	0.233	0.000	0.333	0.433
54	0.633	0.133	0.150	0.150	0.567	0.100	0.000	0.367	0.533
55	0.583	0.233	0.017	0.250	0.500	0.350	0.000	0.217	0.433
56	0.633	0.200	0.100	0.183	0.517	0.150	0.133	0.133	0.583
57	0.650	0.133	0.150	0.167	0.550	0.050	0.217	0.117	0.617
58	0.617	0.133	0.167	0.150	0.550	0.117	0.050	0.183	0.650
59	0.600	0.133	0.150	0.150	0.567	0.050	0.267	0.117	0.567
60	0.600	0.150	0.133	0.167	0.550	0.083	0.033	0.117	0.767
Average	0.609	0.133	0.151	0.176	0.541	0.125	0.128	0.173	0.574
Sdev	0.030	0.052	0.050	0.038	0.022	0.083	0.083	0.084	0.075

Table 4.6: Relative frequencies of choices and subject wins

subject #	Observed %win H	Expected %win H	Mixture Effect	Correlated Effect
		Condition 1		
1	0.650	0.400	0.000	0.250
2	0.517	0.388	-0.012	0.128
3	0.533	0.376	-0.024	0.158
4	0.667	0.396	-0.004	0.271
5	0.467	0.379	-0.021	0.087
6	0.600	0.403	0.003	0.197
7	0.667	0.400	0.000	0.267
8	0.600	0.402	0.002	0.198
9	0.600	0.391	-0.009	0.209
10	0.650	0.400	0.000	0.250
11	0.550	0.344	-0.056	0.206
12	0.600	0.399	-0.001	0.201
13	0.600	0.404	0.004	0.196
14	0.583	0.398	-0.002	0.185
15	0.550	0.397	-0.003	0.153
16	0.533	0.399	-0.001	0.134
17	0.617	0.400	0.000	0.217
18	0.567	0.381	-0.019	0.186
19	0.650	0.400	0.000	0.250
20	0.583	0.386	-0.014	0.197
21	0.583	0.396	-0.004	0.187
22	0.567	0.335	-0.065	0.232
23	0.633	0.395	-0.005	0.238
24	0.633	0.399	-0.001	0.234
25	0.633	0.633	0.233	0.000
26	0.567	0.403	0.003	0.164
27	0.433	0.383	-0.017	0.050
28	0.583	0.396	-0.004	0.188
29	0.583	0.400	0.000	0.183
30	0.533	0.399	-0.001	0.134
31	0.567	0.567	0.167	0.000
32	0.617	0.400	0.000	0.217
33	0.583	0.372	-0.028	0.212
34	0.617	0.617	0.217	0.000
35	0.650	0.397	-0.003	0.253
36	0.600	0.403	0.003	0.197
37	0.550	0.400	0.000	0.150
38	0.650	0.389	-0.011	0.261
39	0.550	0.402	0.002	0.148
40	0.550	0.400	0.000	0.150
41	0.533	0.388	-0.012	0.146
42	0.600	0.396	-0.004	0.204
43	0.583	0.374	-0.026	0.209
44	0.567	0.567	0.167	0.000
45	0.750	0.396	-0.004	0.354
46	0.533	0.334	-0.066	0.200
47	0.817	0.402	0.002	0.415
48	0.650	0.402	0.002	0.248
49	0.550	0.396	-0.004	0.154
50	0.433	0.344	-0.056	0.089
51	0.567	0.400	0.000	0.167
52	0.533	0.391	-0.009	0.143
53	0.583	0.384	-0.016	0.199
54	0.567	0.398	-0.002	0.168
55	0.550	0.550	0.150	0.000
56	0.583	0.401	0.001	0.182
57	0.650	0.404	0.004	0.246
58	0.600	0.400	0.000	0.200
59	0.667	0.374	-0.026	0.293
60	0.633	0.405	0.005	0.228
Mean Absolute Value			0.010	0.183

Table 4.7: Decomposition of the deviation of the winning rate

Condition 2

subject #	Observed %win H	Expected %win H	Mixture Effect	Correlated Effect
1	0.617	0.464	0.064	0.153
2	0.533	0.388	-0.012	0.145
3	0.617	0.450	0.050	0.167
4	0.583	0.452	0.052	0.132
5	0.600	0.471	0.071	0.129
6	0.633	0.465	0.065	0.168
7	0.583	0.425	0.025	0.159
8	0.600	0.439	0.039	0.161
9	0.633	0.444	0.044	0.189
10	0.617	0.450	0.050	0.167
11	0.583	0.415	0.015	0.168
12	0.617	0.447	0.047	0.170
13	0.617	0.433	0.033	0.184
14	0.617	0.458	0.058	0.159
15	0.583	0.369	-0.031	0.214
16	0.617	0.437	0.037	0.180
17	0.600	0.417	0.017	0.183
18	0.583	0.416	0.016	0.167
19	0.617	0.438	0.038	0.179
20	0.600	0.475	0.075	0.125
21	0.583	0.426	0.026	0.158
22	0.600	0.401	0.001	0.199
23	0.567	0.445	0.045	0.122
24	0.617	0.459	0.059	0.158
25	0.633	0.633	0.233	0.000
26	0.600	0.450	0.050	0.150
27	0.583	0.447	0.047	0.136
28	0.617	0.367	-0.033	0.250
29	0.667	0.437	0.037	0.230
30	0.583	0.455	0.055	0.129
31	0.550	0.550	0.150	0.000
32	0.567	0.461	0.061	0.106
33	0.650	0.483	0.083	0.167
34	0.617	0.617	0.217	0.000
35	0.600	0.444	0.044	0.156
36	0.583	0.458	0.058	0.126
37	0.617	0.436	0.036	0.180
38	0.617	0.414	0.014	0.203
39	0.633	0.441	0.041	0.192
40	0.550	0.426	0.026	0.124
41	0.617	0.451	0.051	0.166
42	0.700	0.359	-0.041	0.341
43	0.633	0.450	0.050	0.183
44	0.600	0.600	0.200	0.000
45	0.600	0.458	0.058	0.142
46	0.600	0.427	0.027	0.173
47	0.683	0.453	0.053	0.231
48	0.600	0.446	0.046	0.154
49	0.633	0.422	0.022	0.212
50	0.633	0.392	-0.008	0.242
51	0.633	0.433	0.033	0.200
52	0.650	0.441	0.041	0.209
53	0.550	0.368	-0.032	0.182
54	0.633	0.436	0.036	0.197
55	0.583	0.583	0.183	0.000
56	0.633	0.435	0.035	0.198
57	0.650	0.453	0.053	0.197
58	0.617	0.464	0.064	0.153
59	0.600	0.445	0.045	0.155
60	0.600	0.490	0.090	0.110
Mean Absolute Value			0.042	0.159

Table 4.8: Decomposition of the deviation of the winning rate

c.d.f choice color sample	c.d.f. choice color sample	K-S statistic	p-value
green	red	.15	.513
green	brown	.2167	.1198
red	brown	.2	.1821

Table 4.9: Two-sample Kolmogorov-Smirnov test for equivalent distributions

Test	Null Hypothesis	Subjects for which the Null Hp. is rejected at the 0.05 level	Total
(1)	$\beta_1, \beta_2, \beta_3, \beta_4, \beta_5, \beta_6, \beta_7$ all=0	All rejected	60
(2)	$\beta_1, \beta_2 = 0$	5,12, 22, 23,35, 60	6
(3)	$\beta_4, \beta_5, \beta_6, \beta_7$ all=0	All rejected except: 33, 38, 42, 47, 51	55
(4)	$\beta_6, \beta_7 = 0$	9,10, 13	3
(5)	$\beta_4, \beta_5 = 0$	All rejected except: 5, 12, 13, 23,27, 31,33, 38, 41, 42, 47, 51, 54	47
(6)	$\beta_3 = 0$	2, 12 16, 21, 35, 38, 39, 41, 42, 47, 51, 63	12

Table 4.10: Independence Hypothesis Tests for Condition 1

Test	Null Hypothesis	Subjects for which the Null Hp. is rejected at the 0.05 level	Total
(1)	$\beta_1, \beta_2, \beta_3, \beta_4, \beta_5, \beta_6, \beta_7$ all=0	All rejected	60
(2)	$\beta_1, \beta_2 = 0$	2, 3, 12, 17, 21, 22, 28, 34, 42, 51, 57, 58	12
(3)	$\beta_4, \beta_5, \beta_6, \beta_7$ all=0	All rejected except: 36	59
(4)	$\beta_6, \beta_7 = 0$	11, 12, 15, 17, 27, 29, 44, 56, 58	9
(5)	$\beta_4, \beta_5 = 0$	All rejected except: 2, 5, 6, 8, 20, 22, 27, 28, 33 36, 42, 45, 47, 48, 50, 59	44
(6)	$\beta_3 = 0$	4, 12, 53	3

Table 4.11: Independence Hypothesis Tests for Condition 2

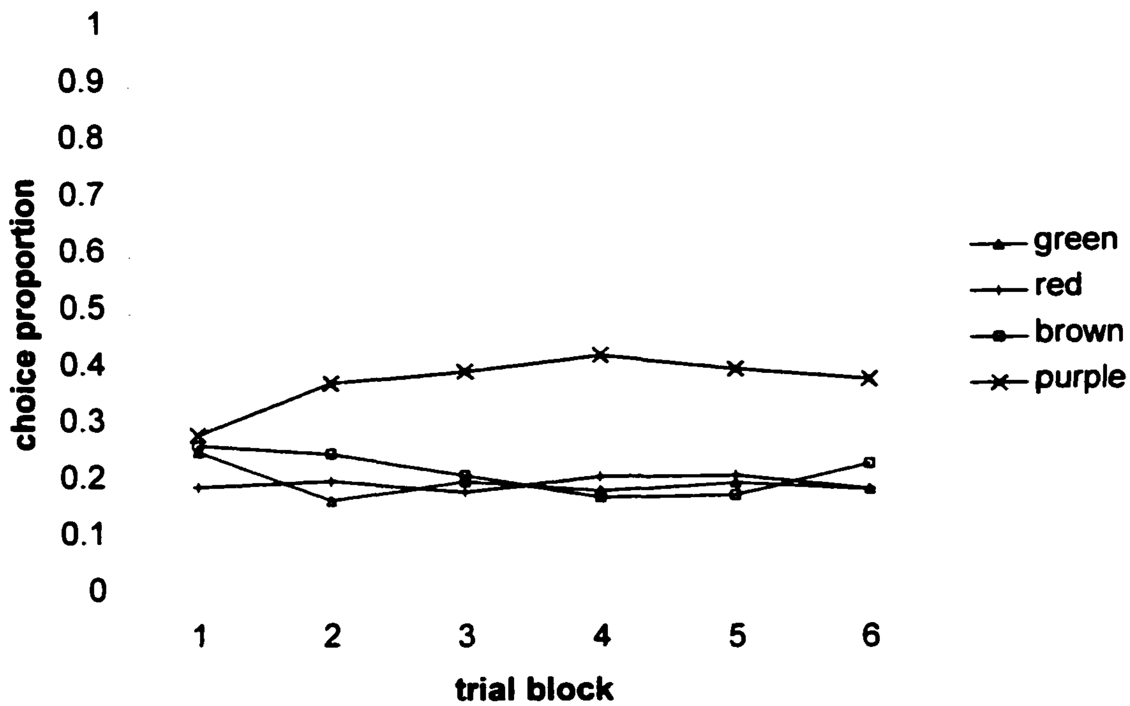


Figure 4.1: Subjects' mean choice proportion in condition 1

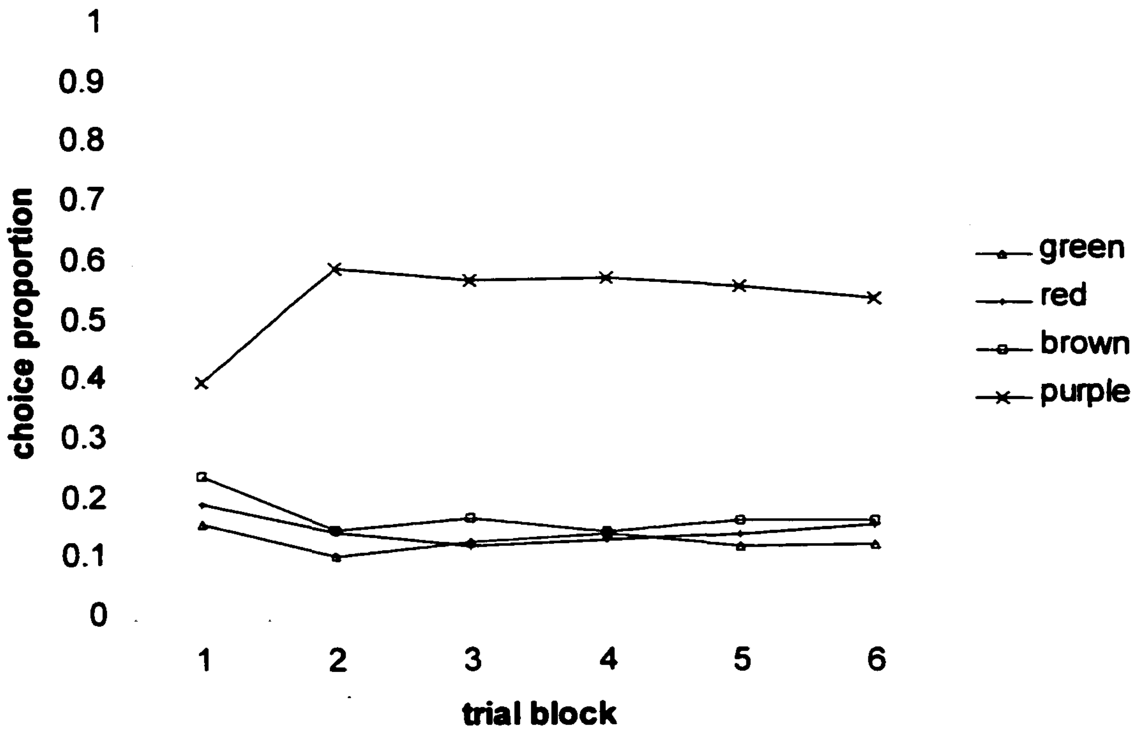


Figure 4.2: Subjects' mean choice proportion in condition 2

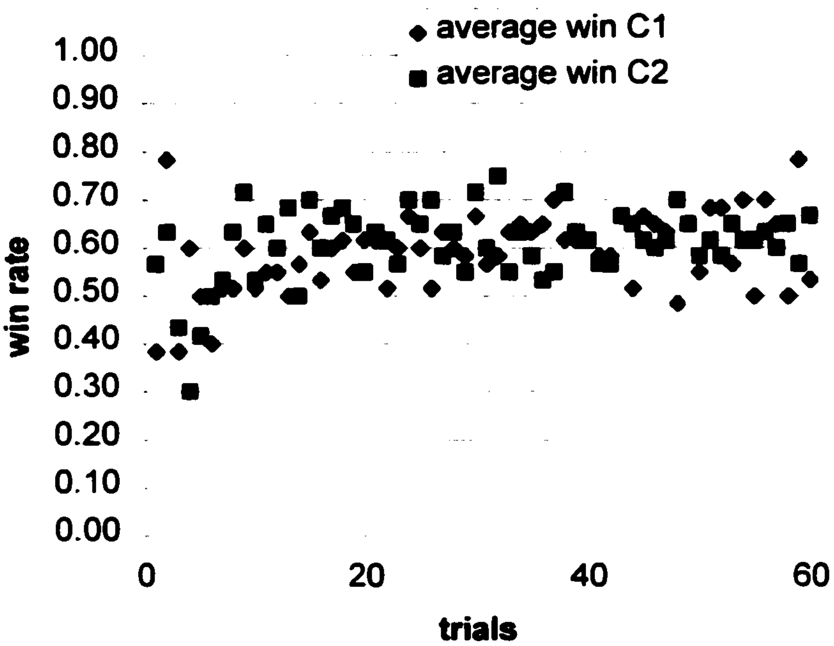


Figure 4.3: Subjects' average win rate in condition 1 and condition 2

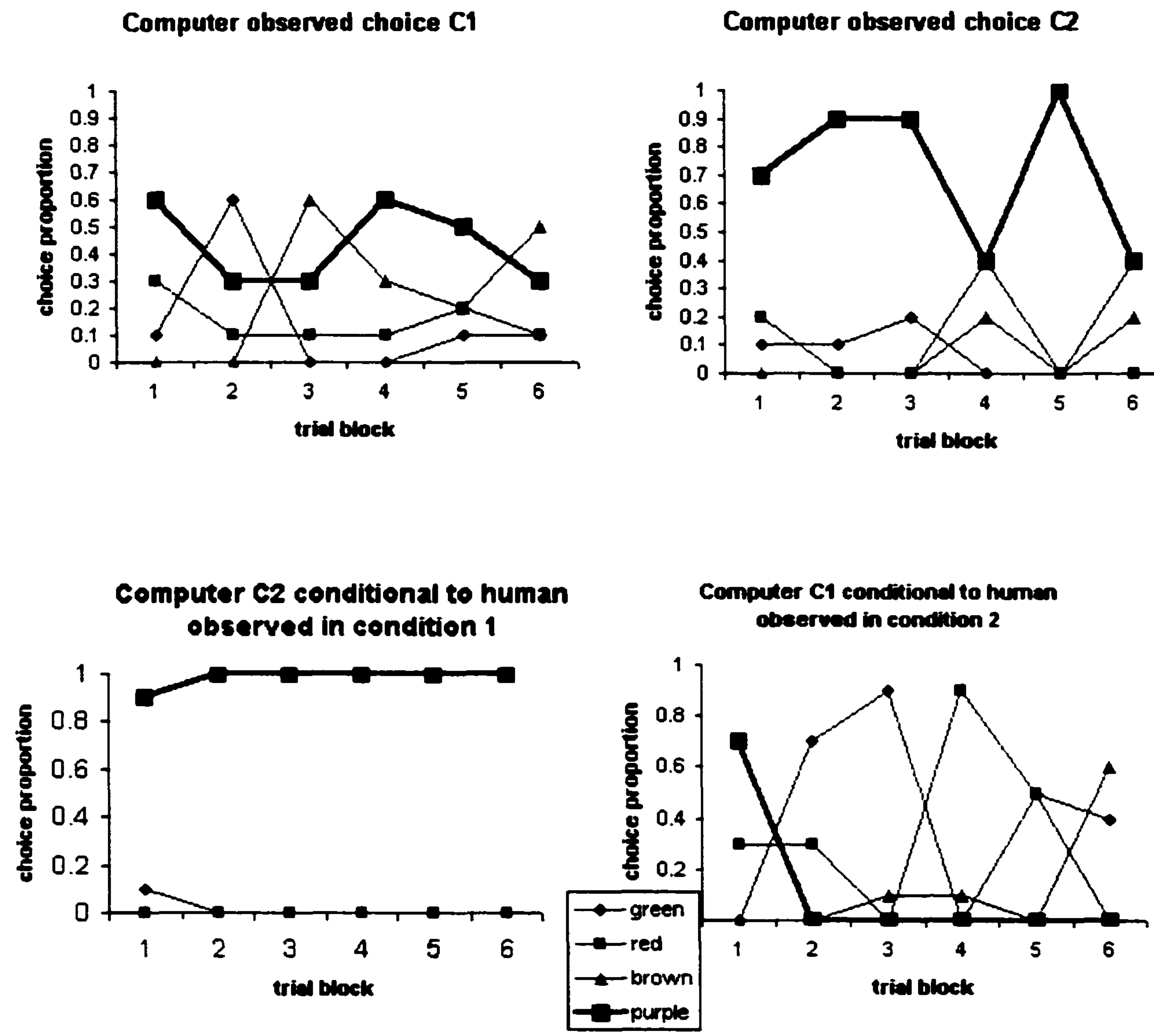


Figure 4.4: Computer observed choice and simulation of computer conditional to human observed choices

CHAPTER 5

GENERAL CONCLUSIONS: SUMMARY OF RESULTS AND POSSIBLE EXTENSIONS

The analysis of this dissertation is concerned with: (i) trust and reciprocal behavior, (ii) incentive mechanism in the presence of asymmetric information, and (iii) strategic interaction in games of pure conflict.

The first part of our work carried out an experimental analysis of the determinants of strategic cooperation in games with underlying reciprocity responses. Our contribution is characterized by the introduction of "one-way" asymmetric information in the investment game (Berg et al, 1995), in which only the second mover is aware of the size of the surplus obtained. In addition, we elicited subjects' expectations (beliefs) and their risk preferences. The results of our experiment are inconsistent with the self-regarding preference model. The introduction of asymmetric information does not reduce the amounts sent and returned when compared with Berg et al (1995).

Our experimental setting allowed us to distinguish the amount of trust from the other motives of the first movers' sending behavior. Indeed, we can determine the amount of trust as any positive amount the subject has sent expecting a greater amount in payback. This procedure (eliciting payback expectation)[1] solved the critique pointed out by Cox

[1] The first mover has to express his or her expectation about the amount the second mover will send back for any amount he or she might send.

(2001)[2] about the impossibility of distinguish between trust and altruism as determinants of the first movers' behavior in the investment game of Berg et al. We cannot distinguish between the motives that determine the reciprocal behavior of the second movers. We found that the positive amount of payback observed in our experiment could be explained by reciprocity, altruism, or inequality aversion. It is, indeed, the objective of our future research to change our experimental design in order to distinguish reciprocity from other motives for the second movers' cooperative behavior.

The experimental results in Chapter 2 are consistent with a model based on subjects' beliefs regarding the intentionality of the other subjects' actions. Inspired by this consideration, we introduced a new model called "reciprocal-intentionality" model (Section 3.4, Chapter 2). This model is based on the simulation theory introduced by Gordon (1995) and Goldman (1995). The theory states that individuals predict and explain the behavior of other individuals by imagining being in their situation, where 'imagining' is conceived of in terms of their mental state.

Our experimental results show that groups of subjects characterized by the same risk attitude behaved consistently.[3] In particular, risk attitude is consistent with subjects' expectation formation. Our explanation of this finding refers to the fact that risk attitude is related to subjects' past experience in social interaction. Indeed, risk-seeking people tend to engage in more frequent and cynical interactions. Their experience (both in terms of frequency and quality) determines their perception of the "social risk" involved in the

---

[2] Cox (2001) introduces a "triadic" design in order to distinguish between different motives of reciprocal behavior.

[3] Risk-averse subjects sent more, and risk lovers are the ones that return more.

interactive situation. By saying this, we are not arguing that risk attitude is the sole and fundamental determinant of people's belief formation. Rather, we should say that there are some personal characteristics that determine how people interact with each other, and risk attitude is one of them. Our hypothesis then is that an individual's perception of social risk is based on his or her past experience in analogous interactive contexts. In sum, we postulate a model of interactive cooperative behavior in which the individual makes inferences about others' beliefs.

A possible extension of our analysis would be to look for evidence (using in vivo brain imaging techniques and study of patients) of the implementation of this mechanism in the human brain. If interactive (social) behavior can be understood in terms of the biology of the human brain, this would accomplish two goals. First, it would provide a strong biological foundation for an important aspect of economic behavior, namely exchange; second, it would allow us to explore the capabilities and limitation of humans' ability to solve the problem of interpersonal interaction.

The second topic of this dissertation concerns the study of the effects of a warranty on buyer/seller interactions (Chapter 3). In an environment characterized by two-sided asymmetric information (in terms of unknown quality to the buyer, and unknown buyers' characteristics to the seller), a warranty can compound the moral hazard problem into a double moral hazard. The buyer and the seller determine the performance of the product. The seller determines the initial quality of the product and the buyer determines its final performance through its maintenance. Both sides of the market have incentives to reduce their inputs (which reduces their costs). Our analysis answers two major questions about the effect of a warranty to a buyer/seller interaction:

(i) Does a warranty always represents a high quality signal?

(ii) Does a warranty represent an incentive mechanism for both sides of the market?

The affirmative answer that we found for the first question crucially depends on the assumption of exogenous quality that is implicit in our first experiment. The second experiment endogenized quality. In this experiment, the performance of the product was determined also by the maintenance effort of the buyer. Results from our second experiment show that quality and maintenance effort are complements. On the other hand, a warranty does not increase a buyer's effort on maintenance; i.e., it is not an incentive for the buyer to increase his input. The results on price dynamics show that the price for a full warranted product is higher than the price for products of the same quality, but with a lower warranty level. This result indicates that buyers are willing to accept deviation from equilibrium price induced by sellers of durable goods with warranty. The size of the deviation is proportional to the length of the warranty. The sellers are able to transfer the entire cost of the warranty to the buyers. For this reason a warranty cannot be a credible signal of high quality.

These findings show that a warranty is not always a signal of high quality and that it does not work as an incentive mechanism for the solution of the double moral hazard problem, but it could be the major determinant of this phenomenon.

An improvement of our analysis would be the study of an experimental market in which we increase the number of buyers and sellers and the number of market periods. An interesting study would also involve a comparison of different auction institutions in an analogous environment.

The last topic of this dissertation is an experimental study of the strategic interaction in repeated zero-sum games. Von Neumann (1928) proved the minimax theorem, and found the theoretical solution for two-person zero-sum games. Since then, there have been many experimental tests of this theory (this is reported in Chapters 1 and 4). Binmore et al. (2001) stated that they found experimental support for minimax theory. They studied the convergence to minimax in many repeated zero-sum games, and found an extremely fast convergence to the equilibrium. We argue that their experimental analysis is biased by the fact that the experimenters provided the subjects information about "the median of the other players in the same situation as the subject" (Binmore et al., 2001, pp. 452). This procedural feature determined the contemporaneous convergence of the two types of subjects (row and column players). Notice that this paper is the only experimental work in favor of the minimax hypothesis. Another feature of Binmore et al. is that their analysis is totally lacking any consideration of the relation between minimax (in mixed strategies) and randomization.

In this dissertation, we present a radically different approach. We focus on the relationship between the minimax prediction and the ability of humans to randomize. We also explain subjects' heterogeneity in related past experiments. Our findings (Chapter 4) substantially deviate from the "pre-Nash" (Borel-von Neumann) concept of strategy, namely: that "the rational player can choose his strategy before the game begins, with no loss of generality, because a strategy lets him specify a different move for every situation in which he might find himself during the game...before any consequences of other players' decisions can be observed. Each player must choose his strategy without being informed of the other players' strategy choices" (see Myerson, 1999, pp. 1071, referring to von Neumann's 1928 "Zur Theories der Gesellschaftsspiele", "General Simplifications" section). The departures of our subjects from the equilibrium strategies have been intentional and profitable. The correlation effect explains the deviation of the winning percentage from the predicted (minimax solution). The subjects play the same game differently with different opponents, with the purpose of exploiting their serially correlated choices.

We conclude this dissertation believing that our contribution provides some original insights into the analysis of interactive economic behaviors.

APPENDIX A: Experimental Instruction, Decision Forms, and Questionnaire for Chapter 2

Instructions

You are about to participate in an experiment on decision making. In this experiment you will interact with another person, whose identity will remain unknown during and after the experiment. We kindly ask you not to talk or communicate with any other participant. If you have any question please raise your hand.

We refer to every two interacting participants as A and B. On the decision form you will be informed whether you are A or B.

In the experiment each participant will receive an initial endowment of 100 Experimental Currency Units (ECU). Participant A can send any amount (multiple of 10 from 0 to 100) of his/her initial endowment to B. Participant B will receive the amount sent by A multiplied by a factor we call the *multiplier*. The *multiplier* can be either 2 or 4, and each of these two values are equally likely. Only participant B will know whether the amount that he/she received has been multiplied by 2 or 4. B can send to A any amount (not necessarily a multiple of 10) taken from his/her initial endowment plus the amount received from A multiplied by 2 or 4. This ends the interaction.

The monetary payments depend on the amount A has sent, the amount B has returned and the *multiplier*, as follows:

A earns: 100 *minus* the amount sent *plus* the amount returned by B

B earns: 100 *plus* the amount A has sent multiplied by 2 or 4 *minus* the amount returned

We will proceed as follows:

1. You will be requested to answer a simple control questionnaire.
2. You will be asked to draw a card from a bag. The bag contains as many cards as the number of participants to the experiment. The card is marked with a code number that you must keep with you. One of the cards is marked with the name "monitor". The monitor will verify that the instructions have been followed as they appear here.
3. Everybody except the monitor will receive an envelope, containing the decision form, marked with your code number. The decision form, which varies according to whether you are participant A or B, has to be completely filled out. Participant A has to express his/her expectation about the amount B will send back for any amount he/she might send; and his/her choice of the amount he/she will send. Participant B has to express his/her expectation about the amount A will send, and his/her choice of an amount to return for every possible amount he/she might receive from A for the two possible *multipliers*.
4. The monitor will collect the decision forms.
5. The decision forms of participants A and B will be randomly paired, and the payments will be determined according to the values of the amount sent by A, the amount returned by B, and the *multiplier*, as described above. This is done by first choosing the *multiplier* randomly, and then checking for B's response to the choice made by the corresponding A.

6. The experimenters will calculate the payoffs for every participant without knowing your identities. You will receive an envelope marked with your code containing your final earnings. Your total experimental earnings will be converted to GBP at a rate of 25 ECU to 1 pound.

Control Questionnaire:

Note that the following values of the amount sent by A and the amount sent by B are completely arbitrary. We only want to check that you have understood the instructions before proceeding with the experiment.

1. Assume that A has chosen to send 30 ECU, that the *multiplier* is 2, and B has chosen to send 70 ECU. Earnings of A and B will be:

   A earns ______ ECU; B earns ______ ECU.

2. Assume that A has chosen to send 70 ECU, that the *multiplier* is 4, and B has chosen to send 30 ECU. Earnings of A and B will be:

   A earns ______ ECU; B earns ______ ECU.

3. Assume that A has chosen to send 20 ECU, that the *multiplier* is 2, and B has chosen to send 46 ECU. Earnings of A and B will be:

   A earns ______ ECU; B earns ______ ECU.

4. Assume that A has chosen to send 50 ECU, that the *multiplier* is 4, and B has chosen to send 18 ECU. Earnings of A and B will be:

   A earns ______ ECU; B earns ______ ECU.

CODE

Decision Form

You are an "A" participant.
Please remember your code and keep it secret.

Expectations
(Please note that your answers in this part will not affect your final earnings.)

Please express your expectation about the amount you will receive back for every possible amount that you could choose and for both possible values of the multiplier. (You are asked to fill in 22 feasible numbers in the 22 boxes.)

	if you send an amount of	0	10	20	30	40	50	60	70	80	90	100
Multiplier 2	you expect to receive back an amount =											
	(feasible range)	[0-100]	[0-120]	[0-140]	[0-160]	[0-180]	[0-200]	[0-220]	[0-240]	[0-260]	[0-280]	[0-300]
Multiplier 4	you expect to receive back an amount =											
	(feasible range)	[0-100]	[0-140]	[0-180]	[0-220]	[0-260]	[0-300]	[0-340]	[0-380]	[0-420]	[0-460]	[0-500]

Choice
(Only your answer in this part will influence your final earnings.)

Please choose the amount of ECU you want to send to B:

(Feasible range: multiples of 10 between 0 and 100)

Please put your decision form in your envelope and keep your code with you.

CODE

Decision Form

You are a "B" participant.
Please remember your code and keep it secret.

Expectations
(Please note that your answer in this part will not affect your final earnings.)

Please express your expectation about the amount A will send:
(Feasible range: multiples of 10 between 0 and 100)

Choice
(Only your answer in this part will influence your final earnings.)

Please choose an amount of ECU you will send for every possible amount you will receive from A and for both multipliers.
(You are asked to fill in 22 feasible numbers in the 22 boxes.)

	if A sent you an amount =	0	10	20	30	40	50	60	70	80	90	100
Multiplier 2	you will send an amount of =											
	(feasible range)	[0-100]	[0-120]	[0-140]	[0-160]	[0-180]	[0-200]	[0-220]	[0-240]	[0-260]	[0-280]	[0-300]
Multiplier 4	you will send an amount of =											
	(feasible range)	[0-100]	[0-140]	[0-180]	[0-220]	[0-260]	[0-300]	[0-340]	[0-380]	[0-420]	[0-460]	[0-500]

Note that A's choice determines the column which finally applies, whereas the row multiplier 2 or multiplier 4 is randomly selected after collecting the decision forms.

Please put your decision form in your envelope and keep your code with you.

Questionnaire

CODE

Please specify in the dotted spaces below the minimum amount of money that you would prefer to receive for sure, instead of each of the following gambles:

.... instead of 10,000 pounds with 50 percent chances or 0 pound with 50 percent chances.

.... instead of 1,000 pounds with 1 percent chances or 0 pound with 99 percent chances.

.... instead of 10,000 pounds with 20 percent chances or 0 pound with 80 percent chances.

.... instead of 100 pounds with 90 percent chances or 0 pound with 10 percent chances.

.... instead of 100,000 pounds with 0.1 percent chances or 0 pound with 99.9 percent chances.

.... instead of 1,000 pounds with 30 percent chances or 0 pound with 70 percent chances.

.... instead of 10,000 pounds with 80 percent chances or 0 pound with 20 percent chances.

.... instead of 100,000 pounds with 5 percent chances or 0 pound with 95 percent chances.

.... instead of 1,000,000 pounds with 99 percent chances or 0 with 1 percent chances.

.... instead of 1,000 pounds with 70 percent chances or 0 with 30 percent chances.

APPENDIX B: Experimental Instructions for Chapter 3 (Experiment 2)

Instructions (translated from Italian)

You are about to participate in an economic experiment. Each of you will be a consumer of a durable good. The machine-auctioneer will offer you the opportunity to buy one unit of a good at an initial price with a warranty for a determined length.

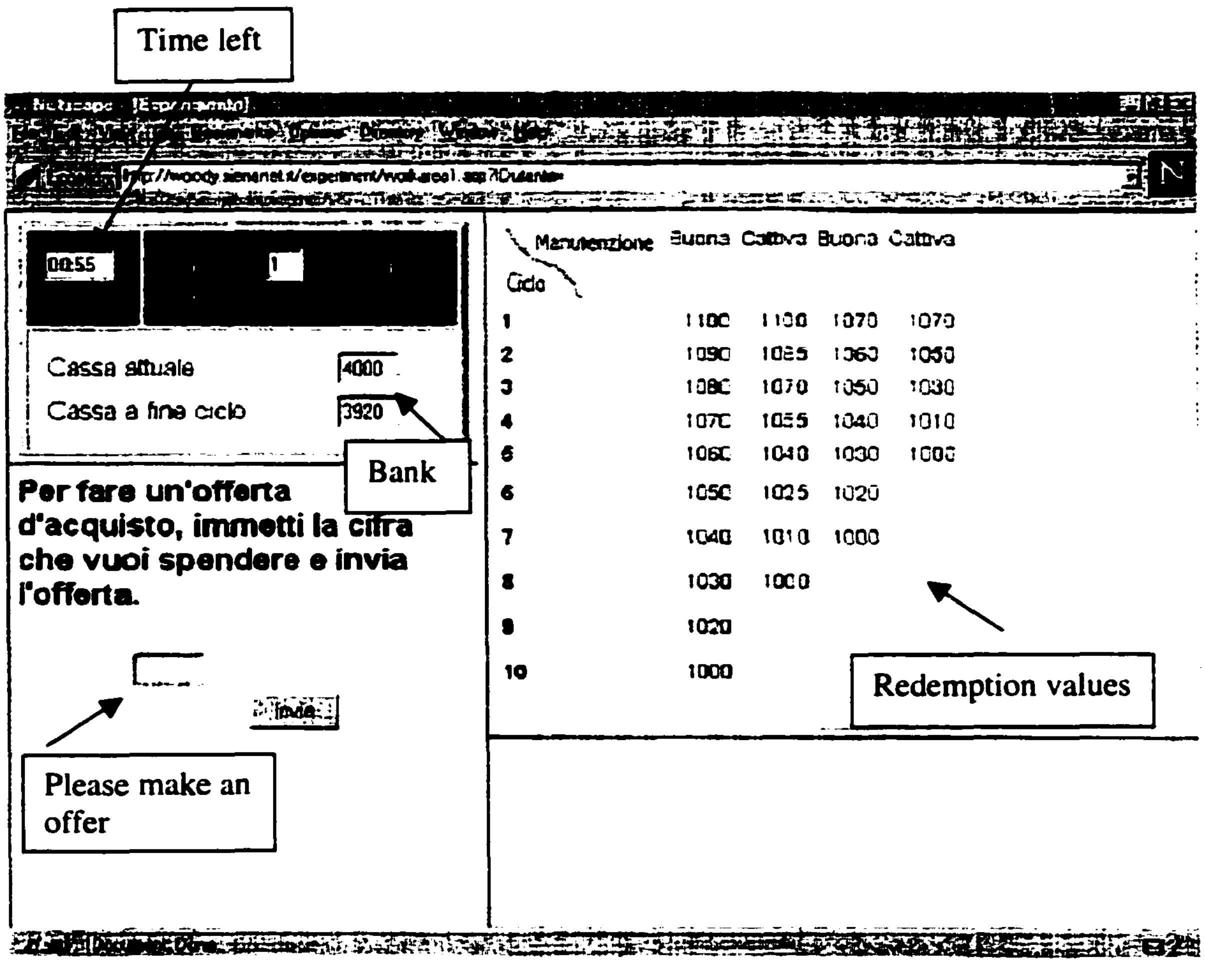
No one knows the quality of the good prior to purchase. The good can be of high or low quality. The quality of the good determines its life. There is the possibility of the good breaking before the end of its life. Each of you has a starting bank, which can be spend to purchase a new good (in the first period) and a used good (in the following periods). The initial bank devaluate at a rate of 3% in all periods in which you do not obtain the good. The participant that offers the highest price obtains the good.

Once known the quality of the product, the owner has to decide how long to keep the product and how to maintain it (high or low maintenance). High maintenance costs 4 experimental currency units. The owner can also resell the good.

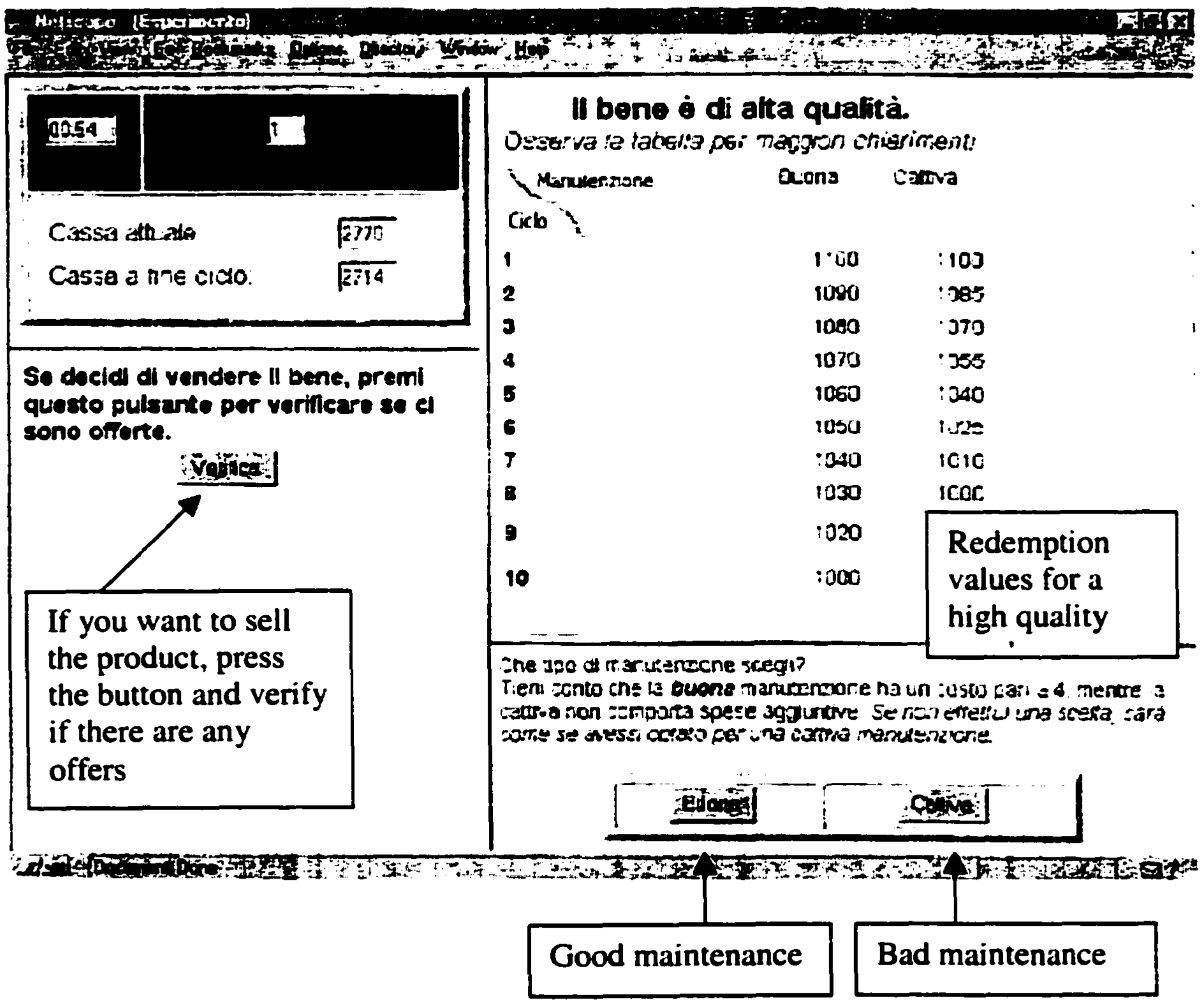
The life of the good depends on its initial quality and on the owner's maintenance decisions. The owner would receive the money back (the purchasing price) if the good broke before the warranty expiration.

Thanks for participating.

APPENDIX B1: Decision screen of the first period (Experiment 2). The subject has to make an offer based on the information about the possible (high or low quality good) redemption values



APPENDIX B2: Decision screen (Experiment 2). When the subject has obtained a high quality good



APPENDIX C: Experimental Instructions for Chapter 4

Instructions

1. You are about to participate in an economics experiment that involves making decisions. If you read the following instructions carefully and make good decisions, you may earn a considerable amount of money. This money will be paid to you privately at the end of the experiment.

2. In this experiment, you will participate in a series of decision rounds. For each of these decision rounds, your opponent will be a computer program. Neither the computer program, nor anyone else, will be paid the computer program's payoff.

3. All of your earnings will be denominated in "experimental dollars". At the end of the experiment, your total experimental dollar earnings will be converted to US dollars at a rate of 10.00 experimental dollars to 1US dollar.

4. In each decision making round, you and your opponent (a computer program) will play a simple "board game". The game will consist of you and your opponent each making one move. After these moves are made, you will find out how many experimental dollars you earned as a result of these moves. In addition, you will be told how many experimental dollars your opponent (a computer program) earned, and your opponent (a computer program) will be informed how many experimental dollars you earned.

5. The game board will be represented by a table similar to the one shown. The game will end up in one of the cells of the table, but which cell will be depend upon the moves you and your opponent (a computer program) make. The computer program (your opponent) is programmed to play so as to win as many times as possible.

→ Game matrix

6. You will get to choose the Row.
   Your opponent (a computer program) will get to choose the Column.

7. The number of experimental dollars you and your opponent receive is given by the number in the cells of the table. For a given row and column, the cell containing your payoff is found by intersecting the row you chose and the column your opponent (a computer program) chose. The white number is your payoff, and the red number is your opponent's (a computer program) payoff.

APPENDIX C1: Simulation of Human and Computer choices for 60 trials when both are playing fictitious player procedure

			Cumulative Payoff						Cumulative Payoff			
k	Human/ Computer	Green	Red	Brown	Purple	Vmin	Computer/ Human	Green	Red	Brown	Purple	Vmax-Vmin
1	**Purple**	-5	-5	-5	5	**-5**	**Green**	-5	5	5	-5	10
2	**Red**	0	-10	0	0	**-10**	**Red**	0	0	10	-10	20
3	**Brown**	5	-5	-5	-5	**-5**	**Red**	5	-5	15	-15	20
4	**Brown**	10	0	-10	-10	**-10**	**Brown**	10	0	10	-20	20
5	**Green**	5	5	-5	-15	**-15**	**Purple**	5	-5	5	-15	20
6	**Green**	0	10	0	-20	**-20**	**Purple**	0	-10	0	-10	20
7	**Green**	-5	15	5	-25	**-25**	**Purple**	-5	-15	-5	-5	20
8	**Green**	-10	20	10	-30	**-30**	**Purple**	-10	-20	-10	0	30
9	**Purple**	-15	15	5	-25	**-25**	**Purple**	-15	-25	-15	5	30
10	**Purple**	-20	10	0	-20	**-20**	**Green**	-20	-20	-10	0	20
11	**Purple**	-25	5	-5	-15	**-25**	**Green**	-25	-15	-5	-5	20
12	**Brown**	-20	10	-10	-20	**-20**	**Green**	-30	-10	0	-10	20
13	**Brown**	-15	15	-15	-25	**-25**	**Purple**	-35	-15	-5	-5	20
14	**Brown**	-10	20	-20	-30	**-30**	**Purple**	-40	-20	-10	0	30
15	**Purple**	-15	15	-25	-25	**-25**	**Brown**	-35	-15	-15	-5	20
16	**Purple**	-20	10	-30	-20	**-30**	**Brown**	-30	-10	-20	-10	20
17	**Red**	-15	5	-25	-25	**-25**	**Brown**	-25	-5	-25	-15	20
18	**Red**	-10	0	-20	-30	**-30**	**Purple**	-30	-10	-30	-10	20
19	**Red**	-5	-5	-15	-35	**-35**	**Purple**	-35	-15	-35	-5	30
20	**Purple**	-10	-10	-20	-30	**-30**	**Purple**	-40	-20	-40	0	30
21	**Purple**	-15	-15	-25	-25	**-25**	**Brown**	-35	-15	-45	-5	20
22	**Purple**	-20	-20	-30	-20	**-30**	**Brown**	-30	-10	-50	-10	20
23	**Red**	-15	-25	-25	-25	**-25**	**Red**	-25	-15	-45	-15	10
24	**Red**	-10	-30	-20	-30	**-30**	**Red**	-30	-20	-50	-10	20
25	**Purple**	-15	-35	-25	-25	**-35**	**Red**	-25	-25	-45	-15	20
26	**Purple**	-20	-40	-30	-20	**-40**	**Red**	-20	-30	-40	-20	20
27	**Green**	-25	-35	-25	-25	**-35**	**Red**	-15	-35	-35	-25	20
28	**Green**	-30	-30	-20	-30	**-30**	**Green**	-20	-30	-30	-30	10

APPENDIX C1-*Continued*

29	Green	-35	-25	-15	-35	-35	[redacted]	Green	-25	-25	-25	-35	10
30	Green	-40	-20	-10	-40	-40		Green	-30	-20	-20	-40	20
31	Red	-35	-25	-5	-45	-45		Purple	-35	-25	-25	-35	20
32	Red	-30	-30	0	-50	-50		Purple	-40	-30	-30	-30	20
33	Red	-25	-35	5	-55	-55		Purple	-45	-35	-35	-25	30
34	Purple	-30	-40	0	-50	-50		Purple	-50	-40	-40	-20	30
35	Purple	-35	-45	-5	-45	-45		Red	-45	-45	-35	-25	20
36	Purple	-40	-50	-10	-40	-50		Red	-40	-50	-30	-30	20
37	Brown	-35	-45	-15	-45	-45		Red	-35	-55	-25	-35	20
38	Brown	-30	-40	-20	-50	-50		Purple	-40	-60	-30	-30	20
39	Brown	-25	-35	-25	-55	-55		Purple	-45	-65	-35	-25	30
40	Purple	-30	-40	-30	-50	-50		Purple	-50	-70	-40	-20	30
41	Purple	-35	-45	-35	-45	-45		Red	-45	-75	-35	-25	20
42	Purple	-40	-50	-40	-40	-40		Red	-50	-70	-30	-30	10
43	Brown	-35	-45	-45	-45	-45		Red	-45	-65	-25	-35	20
44	Brown	-30	-40	-50	-50	-50		Brown	-40	-60	-30	-40	20
45	Brown	-25	-35	-55	-55	-55		Brown	-35	55	-35	-45	20
46	Green	-30	-20	-50	-60	-60		Purple	-40	-60	-40	-40	20
47	Green	-35	-25	-45	-65	-65		Purple	-45	-65	-45	-35	30
48	Purple	-40	-30	-50	-60	-60		Purple	-50	-70	-50	-30	30
49	Purple	-45	-35	-55	-55	-55		Brown	-45	-65	-55	-35	20
50	Purple	-50	-40	-60	-50	-60		Brown	-40	-60	-60	-40	20
51	Green	-55	-35	-55	-55	-55		Green	-45	-55	-55	-45	10
52	Green	-60	-30	-50	-60	-60		Green	-50	-50	-50	-50	10
53	Green	-65	-25	-45	-65	-65		Green	-55	-45	-45	-55	20
54	Red	-60	-30	-40	-70	-70		Purple	-60	-50	-50	-50	20
55	Red	-55	-35	-35	-75	-75		Purple	-65	-55	-55	-45	30
56	Purple	-60	-40	-40	-70	-70		Purple	-70	-60	-60	-40	30
57	Purple	-65	-45	-40	-65	-65		Green	-75	-55	-55	-45	20
58	Purple	-70	-50	-45	-60	-70		Green	-80	-50	-50	-50	20
59	Red	-65	-55	-40	-65	-65		Green	-85	-45	-45	-55	20
60	Red	-60	-60	-35	-70	-70		Purple	-90	-50	-50	-50	20

REFERENCES

Akerlof, G. (1970). The market of lemons: Quality-Uncertainty and the Market Mechanism. *Quarterly Journal of Economics*, 84, 488-500.

Alchian, A.A., and Demsetz. H. (1972). Production, Information Costs, and Economic Organization. *American Economic Review*, 62, 777.

Allsopp. J.H., Eysenck, J., and Eysenck. S.B. (1991). Machiavellianism as a component in psychoticism and extraversion. *Personality and Individual Differences*, 12, 29-41.

Al-Najjar. N.I. (1997). Incentive contracts in two-sided moral hazards with multiple agents. *Journal of Economic Theory*, 74, 174-175.

Andreoni, J. (1987). Why Free Ride? Strategies and Learning in Public Goods Experiments. Discussion Paper University of Wisconsin, Department of Economics.

Arthur, B.W. (1991). Designing Economic Agents that Act Like Human Agents: A Behavioral Approach to Bounded Rationality. *American Economic Review*, Papers and Proceedings, 81, 353-59.

Aumann, R.J. (1974). Subjectivity and Correlation in Randomized Strategies. *Journal of Mathematical Economics*, 1, 67-96.

Axelrod, R. (1984). The Evolution of Cooperation. New York, Basic Books.

Axelrod, R., and Hamilton, W.D. (1981). The Evolution of Cooperation in Biological Systems. *Science*, 211, 1390-1396.

Baddeley, A. (1996). Exploring the Central Executive. *The Quarterly Journal of Experimental Psychology*, 49A, 5-28.

Baddeley, A., Emslie, H., Kolodny, J., and Ducan, J. (1998). Random Generation and The Executive Control of Working Memory. *The Quarterly Journal of Experimental Psychology*, 51A. 819-852.

Bar-Hillel, M., and Wagenaar, W.A. (1993). The perception of randomness. *Advances in Applied Mathematics*, 12, 428-454.

Baron-Cohen, S. (1995). Mindblindness. An Essay on Autism and Theory of Mind. Brandford Books, MIT Press.

Baron-Cohen, S., and Swettenham, J. (1996). The Relationship between SAM and ToMM. In Carruthers, P., and Smith, P.K. (Eds.). Theories of theories of mind. Cambridge University Press.

Bechara, A., Damasio, H., Tranel, D., and Anderson, S.W. (1998). Dissociation of working memory from decision making within the human prefrontal cortex. *The Journal of Neuroscience*, 18, 428-437.

Berg, J., Dickhaut, J., and McCabe, K.A. (1995). Trust, Reciprocity, and Social History. *Games and Economic Behavior*, 10, 122-142.

Berkowitz, M.K., and Kotowitz, Y. (1993). Promotions as Work Incentives. *Economic Inquiry*, 31, 342-53.

Bhattacharyya, S., and Lafontaine, F. (1995). Double-sided moral hazard and the nature of share contracts. *Rand Journal of Economics*, 26, 761-781.

Binmore, K., Swierzbinki, J., and Proulx, C. (2001). Does Minimax Work? An Experimental Study. *The Economic Journal*, 111, 445-464.

Blair, B.F. (1994). Optimal Retail Contracts with Asymmetric Information and Moral Hazard. *Rand Journal of Economics*, 25, 284-296.

Bohm, P. (1972). Estimating demand for public goods: An experiment. *European Economic Review*, 3, 111-130.

Bolton, D. (1995). Self-knowledge, Error and Disorder. In Davies, M., and Stone, T. (Eds.) Mental Simulation, Blackwell Publishers.

Bolton, G. (1997). The rationality of splitting equally. *Journal of Economic Behavior and Organization*, 32, 365-381.

Bolton, G., Brandt, J., and Ockenfels, A. (1998). Measuring Motivation for the Reciprocal Responses Observed in a Simple Dilemma Game. *Experimental Economics*, 1, 207-219.

Bolton, G.E., and Ockenfels, A. (2000). ERC-A Theory of Equity, Reciprocity, and Competition. *American Economic Review*, 90, 166-93.

Borel, E. (1921). La theorie du jeu et les equations integrals a noyan symetrique gauche. Comtes Rendus de l'Academie des Sciences, 173, 1304-1308. English translation by Savage, L.J., 1953, *Econometrica*, 21, 97-100.

Bowles, S., and Gintis, H. (1999). The Evolution of Strong Reciprocity. Mimeo, University of Michigan.

Brandenburger, A. (1992). Knowledge and Equilibrium in Games. *Journal of Economic Perspectives*, 6, 83-101.

Brandts, J., and Holt, C.A. (1992). An experimental test of Nash refinements in signaling games. *American Economic Review*, 82, 1350-1365

Brandts, J., and Holt, C.A. (1995). Limitations of dominance and forward induction: experimental evidence. *Economics Letters*, 49, 391-395.

Brothers, L., and Ring, B. (1992). A neuroethological framework for the representation of minds. *Journal of Cognitive Neuroscience*, 4, 107-18.

Brown, G.W. (1951). Iterative solutions of games by fictitious play. In Koopmans, T.C. (Eds.), Activity analysis of production and allocation. New York: John Wiley.

Brown, J., and Rosenthal, R. (1990). Testing the minimax hypothesis: A rexamination of O'Neill's game experiment. *Econometrica*, 58, 1065-1081.

Brugger, P. (1997). Variables that influence the generation of random sequences: an update. *Perceptual and Motor Skills*, 84, 627-661.

Budescu, D.V., and Rapoport, A. (1994). Subjective Randomization in One-and-Two-Person Games. *Journal of Behavioral Decision Making*, 7, 261-278.

Camerer, C. F. (1997). Progress in Behavioral Game Theory. *Journal of Economic Perspectives*, 11, 167-188.

Camerer, C.F., and Thaler, R.H. (1995). Anomalies: Ultimatums, Dictators and Manners. *Journal of Economic Perspectives*, 9, 209-219.

Camerer, C.F., and Weigelt, K. (1988). Experimental Tests of a Sequential Equilibrium Reputation Model. *Econometrica*, 1, 1-36.

Chamberlin, E. (1948). An Experimental Imperfect Market. *Journal of Political Economy*, 56, 95-108.

Cho, In-Koo, and Kreps, D.M. (1987). Signaling Games and Stable Equilibria. *The Quarterly Journal of Economics*, 179-221.

Coleman, J. (1990). Foundation of Social Choice Theory. Cambridge, MA: Harvard University Press.

Cooper, R., and Ross, T.W. (1985). Product warranties and double moral hazard. *Rand Journal of Economics*, 103-113.

Cooper, R., and Ross, T.W. (1988). An intentemporal model of warranties. *Canadian Journal of Economics*, 21, 72-86.

Cooper, R.W., DeJong, D.V., Forsythe, R., Ross, T.W. (1990). Selection criteria in coordination games: Some experimental results. *American Economic Review*, 80, 218-33.

Coricelli, G., McCabe, K.A., and Smith, V.L. (2000). Theory-of-mind mechanism in personal exchange. In Hatano, et al. (Eds.), Affective Mind. Elsevier Science Publisher, 250-259.

Cosmides, L. (1989). The Logic of Social Exchange: Has Natural Selection Shaped How Humans Reason? Studies with the Wason Selection Task. *Cognition*, 31, 187-276.

Cosmides, L., and Tooby, J. (1992). Cognitive Adaptations for Social Exchange. In: Barkow J., Cosmides L., and Tooby, J. (Eds.), The Adapted Mind. New York: Oxford University Press.

Cox, J.C. (2001). On the Economics of Reciprocity. Discussion paper. University of Arizona.

Cox, J.C., and Deck, C.A. (2002). On the Nature of Reciprocal Motives. Discussion paper, University of Arizona.

Cox, J.C., Sadiraj, K., and Sadiraj V. (2001). Trust, Fear, Reciprocity, and Altruism. Discussion paper. University of Arizona.

Damasio, A.R. (1995). Descartes'Error. Emotion, Reason and the Human Brain. London : Picador. First pub. 1994, New York: G.P. Putnam's Sons.

Darwin, C. (1859). The origin of the Species. Cambridge, MA: Harvard University Press (published in 1964).

Davis, D., and Holt, C. (1990). Equilibrium Cooperation in Three-Person Choice-of-Partner Games. Working Paper. Virginia Commonwealth University.

Davis, D., and Holt, C. (1993). Experimental Economics. Princeton University Press: Princeton, New Jersey.

Dawes, R.M., and Thaler, R. (1988). Anomalies Cooperation. *Journal of Economic Perspectives*, 2, 187-197.

Demski, J.S. and Sappington, D.E.M. (1991). Resolving Double Moral Hazard Problems with Buyout Agreements. *Rand Journal of Economics*, 22, 232-240.

Dennet, D.C. (1978). Brainstorms. A Brandford Book. Cambridge, MA: MIT Press.

Dennet, D. C. (1987). The Intentional Stance. Cambridge, MA: MIT Press.

Dennet, D.C. (1995). Darwin's Dangerous Idea. New York: Simon and Schuster.

Dennet, D.C. (1996). Kinds of Minds, Toward an Understanding of Consciousness. Basic Books.

Dosi, G., and Egidi, M. (1991). Substantive and Procedural Uncertainty. *Journal of Evolutionary Economics*, 1, 145-68.

Dufwenberg, M., and Gneezy, U. (2000). Measuring Beliefs in an Experimental Lost Wallet Game. *Games and Economic Behavior*, 30, 163-182.

Dybvig, P.H., and Lutz, N.A. (1993). Warranties, Durability, and Maintenance: Two-sided Moral Hazard in a Continuous-Time Model. *Review of Economic Studies*, 60, 575-597.

Edgeworth, F.Y. (1881). Mathematical Psychics. Kelley, A.M., New York (published in 1967).

Emons, W. (1989, a). Warranties, Moral Hazard and the Lemons Problem. *Journal of Economic Theory*, 46, 16-33.

Emons, W. (1989, b). On the Limitation of Warranty Duration. *Journal of Industrial Economics*, 37, 287-301.

Falk, A., Fehr, E., and Fischbacher, U. (2000). Testing Theories of Fairness – Intentions Matter. Working Paper, University of Zurich.

Fehr, E., and Gächter, S. (2000). Fairness and Retaliation: The Economics of Reciprocity. *Journal of Economic Perspectives*, 14, 159-181.

Fehr, E., and Schmidt, K. (1999). A Theory of Fairness, Competition, and Cooperation. *Quarterly Journal of Economics*, 114, 817-68.

Fink, G.R., Marshall, J.C., Halligan, P.W., Frith, C.D., Driver, J., Frackowiak, R.S.J., and Dolan, R.J. (1999). The neural consequences of conflict between intention and the senses. *Brain*, 122, 497-512.

Fletcher, P.C., Happe, F., Frith, U., Baker, S.C., Dolan, R.J., Frackowiak, R.S.J. and Frith, C.C. (1995). Other Minds in the Brain: a Functional Imaging Study of "Theory of Mind" in Story Comprehension. *Cognition*, 57, 109-28.

Fodor, J.A. (1983). The Modularity of Mind: an Essay on Faculty Psychology, Cambridge, MA: MIT Press.

Fodor, J.A. (1992). A theory of the child's theory of mind. *Cognition*, 44, 283-296.

Fouraker, L., and Siegel, S. (1963). Bargaining Behavior. New York: McGraw-Hill.

Fouraker, L., Shubik, M., and Siegel. S. (1961). Oligopoly Bargaining. The Quantity Adjuster Models. Research Bulletin 20, Department of Psychology, Pennsylvania State University.

Fudenberg, D., and Levine, D.K. (1998) The theory of learning in games. Cambridge, MA: MIT Press.

Gale, J. and Rotenthal, R.W. (1994). Price and Quality Cycles for Experience Goods. *Rand Journal of Economics*, 25, 590-607.

Gale, J., Binmore, K.G., and Samuelson, L. (1995). Learning to be imperfect: The ultimatum game. *Games and Economic Behavior*, 8, 56-90.

Gallese, V., and Goldman, A. (1998). Mirror neurons and the simulation theory of min-reading. *Trends in Cognitive Sciences*, 2, 493-501.

Gallese, V., Fadiga, L., Fogassi, L. And Rizzolatti G. (1996). Action recognition in the premotor cortex. *Brain*, 119, 593-609.

Gallup, G. G., Jr ((1970). Chimpanzees: Self-recognition. *Science*, 167, 86-87.

Gazzaniga, M.S. (1997). Conversation in the cognitive neurosciences. A Brandford Book. Cambridge, MA: MIT Press.

Geanakoplos, J., Pearce, D., and Stacchetti, E. (1989). Psychological Games and Sequential Rationality. *Games and Economic Behavior*, 1, 60-79.

Goldman, A.I. (1995). Interpretation Psychologized. ? In Davies, M., and Stone, T. (Eds.) Folk Psychology: The Theory of Mind Debate, Blackwell Publishers.

Goldman, A. (2001). Using your mind to read others. University of Arizona Working Paper.

Golosinski, D., and West, D.S. (1995). Double Moral Hazard and Shopping Center Similarity in Canada. *Journal of Law, Economics, and Organization*; 11, 456-78.

Gordon, R.M. (1995). Folk Psychology as Simulation. ? In Davies, M., and Stone, T. (Eds.) Folk Psychology: The Theory of Mind Debate, Blackwell Publishers.

Grossman, S. (1981). The informational Role of Warranties and Private Disclosure about Product Quality. *Journal of Law and Economics*, 24, 173-190.

Gunnthorsdottir, A., McCabe, K.A., and Smith L.V. (2002). Using the Machiavellianism instrument to predict trustworthiness in a bargaining game. *Journal of Economic Psychology*, 23, 49-66.

Gupta, M.R. (1989). Credit and Share-cropping: Comments. *Journal of Development Economics*, 31, 403-11.

Güth, W., and Yaari, M. (1992). An evolutionary approach to explain reciprocal behavior in a simple strategic game. In Witt, U. (Eds.), Explaining Process and Change-Approaches to Evolutionary Economics, Ann Arbor, MI: University of Michigan Press, 23-34.

Güth, W., Huck, S., and Muller, W. (2001). The relevance of Equal Split in Ultimatum Games. *Games and Economic Behavior*, 37, 161-169.

Hart, O.D., and Moore, J. (1988). Incomplete contracts and renegotiations. *Econometrica*, 56, 755-785.

Harsanyi, J.C. (1973). Games with Randomly Disturbed Payoffs: A New Rationale for Mixed-Strategy Equilibria. *International Journal of Game Theory*, 1-23.

Heal, G.M (1976). Do bad products drive out good? *Quarterly Journal of Economics*, 90, 499-502

Heal, G.M. (1977). Guarantees and Risk Sharing. *Review of Economic Studies*, 44, 549-560.

Hertwig, R., and Ortmann, A. (2001). Experimental Practices in Economics: A Methodological Challenge for Psychologist? *Behavioral and Brain Sciences*, 24, 383-451.

Hoffman, E., McCabe, K.A., and Smith, V.L. (1998). Behavioral foundations of reciprocity: experimental economics and evolutionary psychology. *Economic Inquiry*, 36, 335-352.

Hoffman, E., McCabe, K.A., and Smith, V.L. (1996). Trust, Punishment and Assurance: Experiments on the Evolution of Cooperation. *Paper presented at the Economic Science Association Annual Meeting*.

Hogarth, R.M., and. Reder, M.W. (Eds.) (1986). Rational Choice. The Contrast between Economics and Psychology. Chicago: The University of Chicago Press.

Holland, J.H., Holyoak, K.J., Nisbett, R.E., and Thagard, P.R (1986). Induction: Processes of Inference, Learning and Discovery. Cambridge, MA: MIT Press.

Holmstrom, B. (1979). Moral Hazard and Observability. *Bell Journal of Economics*, 10, 74-91.

Holmstrom, B. (1982). Moral hazard in Teams. *The Bell Journal of Economics*, 13, 324-340.

Holmstrom, B. (1987). The theory of contracts. In Truman F. Bewley (Eds.), *Advances in Economic Theory*. Cambridge: University Press.

Holt, C.A., and Sherman, R. (1990). Advertising and Product Quality in Posted-Offer Experiments. *Economic Inquiry*, 28, 39-56.

Iacoboni, M., Woods, R.P., Brass, M., Bekkering, H., Mazziotta, J.C., and Rizzolatti, G. (1999). Cortical Mechanisms of Human Imitation. *Science*, 286, 2526-2528.

Isaac, R.M., and Walker, J.M. (1988). Group Size Effects in Public Goods Provision: The Voluntary Contribution Mechanism. *Quarterly Journal of Economics*, 103, 179-99.

Jensen, M.C., and Meckling, W.H. (1976). Theory of the Firm: Managerial Behavior, Agency costs and Ownership Structure. *Journal of Financial Economics*, 3, 305-360.

Johnson-Laird, P.N. (1983). Mental Models: Towards a Cognitive Science of Language, Inference, and Consciousness. Cambridge, MA: Harvard University Press.

Johnson-Laird, P.N., and Oatley, K. (1992). Basic Emotions, Rationality, and Folk Theory. *Cognition and Emotion*, 6, 201-23.

Johnson-Laird, P.N., and Wason, P.C. (1977). Thinking: Readings in Cognitive Science. New York: Cambridge University Press.

Kagel, J.H., Kim, C., and Moser, D. (1996). Fairness in Ultimatum Games with Asymmetric Information and Asymmetric Payoffs. *Games and Economic Behavior*, 13, 100-110.

Kahneman, D., and Tversky, A. (1979). Prospect Theory: An Analysis of Decision under Risk. *Econometrica*, 47, 263-91.

Kakutani, S. (1941). A Generalization of Brouwer's Fixed Point Theorem. *Duke Mathematical Journal*, 457-459.

Kambhu, J. (1982). Optimal Product Quality Under Asymmetric Information and Moral Hazard. *Bell Journal of Economics*, 13, 483-492.

Keynes, J.M. (1936). The General Theory of Interest, Employment, and Money. London: Macmillan.

Kim, S.K., and Wang, S. (1998). Linear Contracts and the Double Moral-Hazard. *Journal of Economic Theory*, 82, 342-78.

Kreps, D.M., and Wilson, R. (1982). Sequential equilibria. *Econometrica*, 50, 863-894.

Ku Kim, S., and Wang, S. (1998). Linear Contracts and the Double Moral-Hazard. *Journal of Economic Theory*, 82, 342-378.

Kurzban, R. (2001). The social psychophysics of cooperation: Nonverbal communication in a public goods game. *Journal of Nonverbal Behavior*, 25, 241-259.

Kurzban, R., McCabe, K.A., Smith, V.L., and Wilson, B. (2001). Incremental Commitment and Reciprocity in a Real Time Public Goods Game. *Personality and Social Psychology Bulletin*, 27, 1662-1673.

Laffont, J.J., and J. Maskin (1987). Monopoly with asymmetric information about quality: behavior and regulation. *European Economic Review*, 31, 483-489

Lafontaine, F., and Slade, M.E. (1998). Incentive Contracting and the Franchise Decision. *National Bureau of Economic Research Working Paper*, 6544-98.

Lakoff, G. (1987). Women, Fire, and Dangerous Things. What Categories Reveal about the Mind. Chicago: The University of Chicago Press.

Ledyard, J.O. (1995). Public Goods: A Survey of Experimental Research. In Kagel, J.H., and Roth, A.E. (Eds.), Handbook of Experimental Economics, Princeton University Press.

Levine, D. (1998). Modeling Altruism and Spitefulness in Experiments. *Review of Economic Dynamics*, 1, 593-622.

Lutz, N.A. (1989). Warranties as Signals Under Asymmetric Information and Moral Hazard. *Rand Journal of Economics*, 20, 239-255.

Lynch, M., Miller, M.R., Plott, C.R., and Porter, R. (1986). Product Quality, Consumer Information and 'Lemons' in Experimental Markets. In Ippolito, P.M., and Scheffman, D.T. (Eds.), Empirical Approaches to Consumer Protection Economics. Washington, D.C.: Federal Trade Commission, Bureau of Economics, 251-306.

Macho-Stadler, I., and Pèrez-Castrillo, J. (1991). Double risque moral et délegation. *Recherches Economiques de Louvain*, 53.

Mann, D.P., and Wissink, J.P. (1988). Money-back Contracts with Double Moral Hazard. *Rand Journal of Economics*, 19, 285-292.

Mansoob, M. (1994). Risk and uncertainty in economics. Essays in honor of James L. Ford Dickinson, David G., Driscoll, Michael J., Sen, Somnath, (Eds.) Aldershot, U.K.: Elgar;

Mathewson, G.F., and Winter, R.A. (1985). The Economics of Franchise Contracts. *Journal of Law and Economics*, 8, 503-26.

Myerson, R.B. (1999). Nash Equilibrium and the History of Economic Theory. *Journal of Economic Literature*, 1067-1082.

McCabe, K.A., Coricelli, G., Houser, D., Ryan, L., Trouard, T., and Smith, V.L. (2000). Other Minds in the Brain: A Functional Imaging Study of "Theory of Mind" in Two-person Exchange. Paper presented at the ESA meeting 2000, NY.

McCabe, K.A., and Smith, V.L. (2000). A comparison of naïve and sophisticated subject behavior with game theoretic predictions. *Proceedings National Academy of Sciences*, 97, 3777-3781.

McCabe, K.A., Rassenti, S., and Smith V.L. (1996). Game Theory and Reciprocity in Some Extensive Form Bargaining Games. *Proceedings National Academy of Science*, 13421-28.

McCabe, K.A., Smith, V.L., and Lepore, M. (1997). Intentionality Signalling: Why Game Form Matters? *Manuscripts Economic Science Laboratory*, University of Arizona.

McKelvey, R.D., and Palfrey, T.R. (1992). An experimental study of the centipede game. *Econometrica*, 60, 803-836.

Messick, D.M. (1967). Interdependent decision strategies in zero-sum games. Behavioral Science, 12, 33-48.

Metcalfe, J., and Mischel, W. (1999). A hot/cool-system analysis of delay of gratification: dynamics of willpower. *Psychological Review*, 106, 3-19.

Miller, R.M., and Plott, C.R. (1985). Product Quality Signaling in Experimental Markets. *Econometrica*, 53, 837-872.

Mirlerlees, J. (1974). Notes on Welfare Economics, Information, and Uncertainty. In Balch, McFadden, and Wu, (Eds.), *Essay on Economic Behavior under Uncertainty*, Amsterdam: North Holland Publishing Co.

Mookherhee, D., and Sopher, B. (1994). Learning Behavior in an Experimental Matching Pennies Game. *Game and Economic Behavior*, 7, 62-91.

Morasch, K. (1995). Moral Hazard and Optimal Contract Form for R&D Cooperation. *Journal of Economic Behavior and Organization*, 28, 63-68.

Mussa, M., and Rosen, S. (1978). Monopoly and product Quality. *Journal of Economic Theory*, 18, 301-317.

Nash, Jr. J.F. (1950, a). The Bargaining Problem. *Econometrica*, 18, 155-162.

Nash, Jr. J.F. (1950, b). Equilibrium Points in n-Person Games. *Proceedings National Academy of Sciences*, 48-49.

Nash, Jr. J.F. (1953). Two-Person Cooperative Games. *Econometrica*, 21, 128-140.

Nelson, P. (1970). Information and Consumer Behavior. *Journal of Political Economy*, 78, 311-329.

Newcomb, T.M. (1972). Expexctation as a Social Psychological Concept. In: Strumpel - Morgan - Zahan (Eds.), Human Behavior in Economic Affairs. New York: Elsevier.

O'Neill, B. (1987). Nonmetric test of the minimax theory of two-person zerosum games. *Proceedings National Academy of Sciences*, 84, 2106-2109.

Piattelli Palmarini, M. (1996). Inevitable Illusions: How Mistakes of Reason Rule Our Minds. New York: Wiley Publisher.

Povinelli, D. J. (1993). Recostructing the evolution of mind. *American Psychologist*, 48, 493-509.

Prelec, D. (2000). Compound Invariant Weighting Functions in Prospect Theory. In Kahneman, D., and Tversky, A. (Eds.) Choices, Values, and Frames. Cambridge University Press, 67-92.

Priest, G. (1981). A Theory of Consumer Product Warranty. *Yale Law Journal*, 90, 1297-1352.

Prosser, W.L. (1943). The implied warranty of merchantable quality. *Minnesota Law Review* 27, 117-168.

Rabin, M. (1993). Incorporating Fairness into Game Theory and Economics. *American Economic Review*, 83, 1281-1302.

Rabin, M. (1993). Economics and psychology. *Journal of Economic Literature*, 36, 11-46.

Rapoport, A., and Amaldoss, W. (2000). Mixed strategies and iterative elimination of strongly dominated strategies: an experimental investigation of states of knowledge. *Journal of Economic Behavior and Organization*, 42, 483-521.

Rapoport, A., and Boebel, R.B. (1992). Mixed Strategies in Strictly Competitive Games: A Further Test of the Minimax Hypothesis. *Games and Economic Behavior*, 4, 261-283.

Rapoport, A., and Budescu, D.V. (1997). Randomization in individual choice behavior. *Psychological Review*, 104, 603-617.

Rapoport, A., Ido, E., Abraham, E.V., and Olson, D. (1997). Randomization and adaptive learning in a simplified poker game. Organizational Behavior & Human Decision Processes. 69, 31-49.

Reid, J.D. (1977). The Theory of Share Tenancy. *Journal of Political Economy*, 85, 403-407.

Rogerson, W.P. (1985). Repeated Moral Hazard. *Econometrica*, 53, 69-76.

Romano, E.R. (1994). Double Moral Hazard and Resale Price Maintenance. *Rand Journal of Economics*, 25, 455-466.

Ross, S. (1973). The Economic Theory of Agency: the principal's problem. *The American Economic Review*, 63, 134-139.

Roth, A.E., Erev, I. (1995). Learning in extensive-form games: Experimental data and simple dynamic models in the intermediate term. *Games and Economic Behavior*, 8, 164-212.

Rubin, P.H. (1978). The Theory of the Firm and the Structure of the Franchise Contract. *The Journal of Law and Economics*, 223-233.

Sally, D. (2001). On sympathy and games. *Journal of Economic Behavior and Organization*, 44, 1-30.

Sauermann, H., Selten, R. (1960). An Experiment in Oligopoly. In Von Bertalanffy, L., and Rapoport, A. (eds.) *General Systems Yearbook of the Society for General Systems Research*, vol. 5. Ann Arbor: Society for General Systems Research.

Savage, L.J. (1954). The Foundations of Statistics. New York: Wiley.

Schelling, T. (1984). Self-Command in Practice, in Policy, and in a Theory of Rational Choice. *American Economic Review*, 1-11.

Selten, R. (1967). Die Strategiemethode zur Erforschung des eingershrankt rationalen Verhalterns im Rahmen eines Oligopolexperimentes, 136-68.

Selten, R. (1967). A simple model of imperfect competition. Where four are few and six are many. *International Journal of Game Theory*, 2, 141-201.

Selten, R., and Stoecker, R. (1986). End behavior in sequences of finite prisoner's dilemma supergames: A learning theory approach. *Journal of Economic Behavior and Organization*, 7, 47-70.

Shachat, J (1995). Mixed strategy play and the minimax hypothesis. *Journal of Economic Theory*, 104, 189-226.

Shallice, T. (1988). From Neuropsychology to Mental Structure. New York: Cambridge University Press.

Shapiro, C. (1983). Premiums for high quality products as returns to reputation. *Quarterly Journal of Economics*, 97, 659-679.

Shavell, S. (1979). Risk Sharing and Incentives in the Principal and Agent Relationship. *Bell Journal of Economics*, 10, 55-73.

Shubik, M. (1970). Game theory, behavior, and the paradox of prisoner's dilemma: Three solutions. *Journal of Conflict Resolution*, 14, 181-194.

Simon, H.A. (1955). A Behavioral Model of Rational Choice. *Quarterly Journal of Economics*, 69, 99-118.

Simon, H.A. (1959). Theories of decision-making in economics and behavioral science. *American Economic Review*, 49, 253-83.

Simon, H.A. (1972). Theory of bounded rationality. In McGuire and Radner, R. (Eds.), Decision and Organization, North Holland.

Simon, H.A. (1976). From substantive to procedural rationality. In: Latsin, S.J. (Eds.), Method and appraisal in economics, Cambridge Press.

Simon, H.A. (1978). Rational as a process and as a product of thought. *American Economic Review*, 68, 1-16.

Smith, A. (1790). The Theory of Moral Sentiments. Indianapolis, Liberty classics (published in 1982).

Smith, V.L. (1962). An Experimental Study of Competitive Market Behavior. *The Journal of Political Economy*, 70.

Smith, V.L. (1976). Experimental Economics: Induced Value Theory. *The American Economic Review*, 66, 274-79.

Spatt, J. (1996). Evaluation of a simulation of human performance on random-digit generation: Measures of concept and redundancy. *Perceptual and Motor Skills*, 83, 319-322.

Spence, A.M. (1973). Job Market Signaling, *The Quarterly Journal of Economics*, 355-374.

Spence, A.M. (1974). Market Signaling: Informational Transfer in Hiring and Related Screening Processes. Cambridge MA: Harvard University Press.

Spence, M. (1977). Consumer misperception, product failure and product Liability. *Review of Economic Studies*, 44, 561-572.

Spier, K.E. (1992). Incomplete Contracts and Signaling. *Rand Journal of Economics*, 23.

Stahl, D., and Wilson, P.W. (1995). On Players' Model of Other Players: Theory and Experimental Evidence. *Games and Economic Behavior*, 10, 218-254.

Stich, S., and Nichols, S. (1995). Folk Psychology: Simulation or Tacit Theory? In Davies, M., and Stone, T. (Eds.) Folk Psychology: The Theory of Mind Debate, Blackwell Publishers.

Stiglitz, J. (1975). Incentives, Risk, and Information: Notes toward a Theory of Hierarchy. *Bell Journal of Economics*, 6, 552-579.

Suppes, P., and Carlsmith, J.M. (1962). Experimental Analysis of a Duopoly Situation. *International Economic Review*, 3.

Tomasello, M., Kruger, A., and Ratner, H.H. (1993). Cultural learning. *Behavioral and Brain Sciences*, 16, 495-552.

Trivers, R.L. (1971). The evolution of reciprocal altruism. *Quarterly Review of Biology*, 46, 35-57.

Von Neumann, J. (1928). Zur Theories der Gesellschaftsspiele. Mathematische Annalen, 100, 295-320. English translation by Bergmann, S., in Luce, R.D., and Tucker, A.W. (Eds.), Contributions to the Theory of Games IV (1959). Princeton University Press, 13-42.

Von Neumann, J., and Morgenstern, O. (1944). Theory of Games and Economic Behavior. Princeton University Press.

Wagenaar, W.A. (1991). Randomness and randomizers: Maybe the problem is not so big. *Journal of Behavioral Decision Making*, 4, 220-222.

Wagenaar, W.A., and Keren, G.B. (1985). Calibration of probability assessments by professional blackjack dealers, statistical experts, and lay people. *Organizational Behavior & Human Decision Processes*, 36, 406-416.

Wakker, P., and Tversky, A. (1993). An Axiomatization of Cumulative Prospect Theory. *Journal of Risk and Uncertainty*, 7, 147-75.

Walker, M., and Wooders, J. (1999). Minimax Play at Wimbledon. Manuscript.

Watson, J.D.G., Myers, R., Frackowiak, R.S.J., Hajnal, J.V., Woods, R.P., Mazziotta, J.C., Shipp, S., and Zeki, S. (1993). Area-V5 of the human brain –evidence from a combined study using positron emission tomography and magnetic-resonance-imaging. *Cerebral Cortex*, 3, 79-94.

Woodruff, G., and Premack, D. (1979). Intentional communication in the chimpanzee: the development of deception. *Cognition*, 7, 333-362.