Essays in Behavioral Game Theory

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ABSTRACT

Abstract of thesis entitled Essays in Behavioral Game Theory submitted by LAU, Ka William for the degree of Doctor of Philosophy at The Chinese University of Hong Kong in July 2010.

Stiglitz (2009) reviewed the cause of the recent financial tsunami, and claimed that Adam Smith's invisible hand is invisible because it is not actually there: market equilibrium is not constrained Pareto efficient whenever there are information imperfection or asymmetric information, which is always the case in reality. People have conflicts of interests and incentives to provide distorted information, which could be difficult to verify by the other parties, so even if individuals are acting in a perfectly rational way, the outcome is not systemically rational. He concluded that "we need to do a better job of managing our economy, but this will require better research that is less framed by the flawed models of the past, less driven by simplistic ideas, and more attuned to the realities of today."

In this dissertation, we relaxed the perfect information assumption in the marketplace, and studied the reality with asymmetric information from a market scope, and then drill down to decision making model at individual level.

At market level, we studied how people evaluate the value of information, and what kind of information revelation mechanism would collectively maximize market efficiency. We examined the prevailing market mechanism and found that there are unavoidable deadweight losses, so we proposed a new model that could eliminate deadweight losses under many market conditions, and designed and conducted experiments to testify our claims.

At individual level, we adopted the well-known ultimatum game experiment with asymmetric information. By allowing individuals to view historical market information, we study how individuals utilize the market transaction information to help them make decisions under the asymmetric information condition. We testified the History-Consistent Rationality Model, and illustrated that the model is sufficient to yield accurate point predictions that are on average within 5% absolute deviation of the total pie size for every subject behavior in 20 rounds.

摘要

斯蒂格利茨（2009）回顧了導致近期的金融海嘯的原因，並聲稱亞當史密斯的無形之手是真的無形的，因爲它實際上並不存在：在現實中，每當有資料缺失或信息不對稱時，市場的均衡都不能達至帕累托效率。生活中的利益衝突和激勵機制經常會誘使人們提供難以被他人核實的歪曲的信息，所以即使每個人都是用理性的行事方式，結果都不會是系統地理性。他總結說：“我們需要做得更好地去管理我們的經濟，但是這將需要更好的研究，而這些研究應該減少使用不合理的框架，擁有較少的模型缺陷或過於簡單的想法以更切合實際。”

在本論文中，我們不再假設市場信息是完整的，並先從市場層面研究不對稱信息的現實是怎樣運作的，然後深入探討在個人層面的決策模型。

在市場層面，我們研究了人們如何評價信息的價值，以及怎麼樣的信息披露機制才能最大限度地發揮市場效率。我們首先研究當下的市場機制，並指出該機制有不可避免的市場效率損失；接著我們提出了一個新的市場模式，並證明該模式在許多種的市場條件下都可以消除無謂損失，以達至最高的市場效率。我們設計並邀請人們進行實驗，以測試我們的理論。

在個人層面上，我們採用了著名的在信息不對稱條件下的最後通牒博弈實驗，並允許所有人都能看到過往的市場信息，以便研究人們如何在信息不對稱的條件下，利用市場的交易信息去幫助他們作出決定。我們亦測試了“歷史相一致的理性模型”，並說明了該模型是可以作出準確的預測，而預測出來的數值在 20 個回合中的平均絕對偏差值都在總體大小的 5%之內。

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Chapter 1

Introduction

If science is defined by its ability to forecast the future, the failure of many of the economists to foresee the recent global economic crisis in 2008 should be a cause of great concern.

1.1 Problem Context

Stiglitz (2002) argued that the traditional economic theory fails to explain the real world because the model assumes perfect information condition, but perfect information seldom exists in our economy. Economists have long been studying the value of information, and have proposed different models to evaluate information, such as Expected Value of Information, Expected Value of Perfect Information, Expected Value of Imperfect Information, etc. In this dissertation, we adopt the behavioral economic approach to study how people evaluate perfect information and imperfect information.

Looking at the market level, we simulated the marketplace in our daily live – sellers know more about the quality of their commodities than the buyers, and buyers have the option to buy perfect information about the quality of the commodity. We used the game theoretic approach to analyze the problems, proposed a behavioral game theoretical model to explain the reality, and ran experiments to verify our models.

Drilling down to the individual level, we simulated the property market in our daily life. Consider a person who wants to purchase a house, he would certainly collect market information to bargain for a better deal, because the real value of the property (or the reservation price of the house owner) is usually unknown to the buyer. In our experiment, we ran ultimatum games under asymmetric information condition with historical market information available to all parties to simulate the above house-searching situation. To better understand how subjects make decisions, we adopt the History-Consistent Rationality Model to track the subject behaviors. The History-Consistent Rationality Model predicts the subject optimal behaviors based on the information of the previous market transaction prices (accepted and rejected offers), and successfully yield an accurate point prediction that is on average within 5% absolute deviation of the total pie size for each subject behavior in 20 rounds.

To sum up, we address the following questions in this dissertation:

1. How do individuals evaluate value of perfect information?
2. What kind of information revelation mechanism can achieve maximum market efficiency under asymmetric information condition?
3. Is there any model that can yield accurate point prediction for subject behaviors in repeated ultimatum game under asymmetric information condition?

1.2 Contribution

Scholars have been exploring, evaluating and modeling value of information. In this dissertation, we designed and ran experiments aiming to elicit how people evaluate the value of perfect information, and to study how different information revelation mechanisms could correct the market failure due to asymmetric information. In Chapter 3, we attempted to explore the optimal strategies of buyers who possess no information about the quality of the commodity in the market, and investigated how much buyers are willing to pay for prefect information about the quality of the commodity. We also examined the efficiency of the prevailing market mechanism, and proposed a more effective information revelation mechanism that can maximize market efficiency and minimize deadweight lost. The experimental results are qualitatively in line with the theoretical prediction.

Besides, within the existing ultimatum game literature it is widely held by economists that game theory cannot predict the subject behaviors accurately. Implicit in this evidence is the conjecture of altruistic concerns and the matter of fairness (see, for example, Bolton, et. al. 1998; Fehr and Schmidt 1999). While it is commonly known that the decision of accepting or rejecting an offer in an ultimatum game depends on Respondent's tolerance of unfairness, none of the models in the literature has been constructed to estimate the optimal offer that Proposer should propose. In Chapter 4, we demonstrated that the History-Consistent Rationality Model can yield point estimation about the optimal offer that a Proposer should propose in each round. This kind of quantitative prediction is different from the past literature which focuses on qualitative prediction. In particular, in an incomplete information environment, there are no traditional economic theories can yield point prediction, but HCR model can.

1.3 Organization of Dissertation

The organization of this dissertation is as follows. Chapter 2 presents a comprehensive literature review of the value of information and ultimatum game. Chapter 3 discusses different market mechanisms to enhance market efficiency under asymmetric information, and studies how buyers evaluate the value of perfect information. In Chapter 4, a History-Consistent Rationality Model is adopted to predict and explain the subject behaviors in repeated ultimatum games. Finally, Chapter 5 summarizes the major contributions of this dissertation, and discusses possible future research direction.

Chapter 2

Literature Review

Literature related to this dissertation comes from two major areas – the value of information and the ultimatum game.

2.1 Value of Information

Modern information economics has shown that even if markets are competitive, they are almost never efficient when information is imperfect or asymmetric, which is always the case in reality. Stiglitz (2000) affirmed that it is now widely recognized that information is imperfect, obtaining information can be costly, and the extent of information asymmetries is determined by actions of firms and individuals. For instance, Zhao et al. (2006) pointed out that guanxi remains one of the critical China-based research topics. We can imagine that guanxi in China could possibly create significant asymmetric information for those that are not able to establish proper guanxi. Arnott et. al. (2003) summarized the problems and solutions to markets with imperfect information as follows:

> A key feature of that real world is asymmetric information. In most situations, the two sides of the market have vastly different information about the good or service being transacted. In particular, sellers typically know more about what they are selling than buyers do. This can lead to adverse selection where low-quality products drive out good-quality products unless other actions are taken. What sorts of actions? Agent may choose to signal information that they have and that other parties do not. For those with

high-quality products, it may be worthwhile doing this rather than be shut out from the market as bad quality drives out good. Or one side of the market may offer a menu of transaction terms, relying on the choices by the other side to screen transactors of one type from another. Offering such a menu may be better than continuing with imperfect information, but for it to play its role as a screening device, the menu has to have a structure that will separate out different types into preferring different parts of the menu. The theory then predicts that the types of transactions that one sees will be different from those that would emerge in a world of perfect information. Combining signaling and screening further enriches the scope of the analysis.

Scholars have been studying value of information from many facets. In this section, we will explore the following issues: 1) problem of asymmetric information; 2) evaluating value of information; 3) modeling value of information.

2.1.1 Problems of Asymmetric Information

Alkerlof's (1970) famous paper on "lemons" was among the first to study the effect of asymmetric information. His emphasis on the possibility that there might in fact be little or no trade in equilibrium under asymmetric information has aroused the interests of many scholars to dive into this area.

Stiglitz (2002) asserted that much of the traditional competitive equilibrium analysis, which conjectures that market would be cleared, is simply invalid if information is imperfect. Over the years, there are plenty of researches examining the problems of asymmetric information to the economy. Of which, it is important to mention three fundamental concepts, which are so fundamental that we are not even able to tell who were the first to propose these ideas, as some of which could be dated back to 1600s. They are 1) moral hazard; 2) adverse selection; and 3) principal-agent problem.

1) **Moral hazard** occurs when a party insulated from risk may behave differently than it would behave if it were fully exposed to the risk. Moral hazard is a special case of information asymmetry, a situation in which one party in a transaction has more information than another. The party that is insulated from risk generally has more information about its actions and intentions than the party paying for the negative consequences of the risk. More broadly, moral hazard occurs when the party with more information about its actions or intentions has a tendency or incentive to behave inappropriately from the perspective of the party with less information.

2) **Adverse selection** refers to a market process in which bad quality drives out good quality. This occurs when buyers and sellers have asymmetric information, and the party that lacks of information would result in picking the bad products, services or customers as they cannot distinguish between good and bad quality.

3) **Principal-agent problem** arises when a principal compensates an agent for performing certain acts that are useful to the principal and costly to the agent, and where there are elements of the performance that are difficult to observe. The problem arises under condition of incomplete and asymmetric information, as principals do not usually know enough about whether (or to what extent) a contract has been satisfied.

In fact, some of the actors in the market actually attempt to create information problems, such as distorting information, or exaggerate asymmetric information, which further complicate the analysis. For instance, Edlin and Stiglitz (1995) documented the case that managers of firms would actually take actions to increase information asymmetry in order to entrench themselves and to reduce competition in the market for managers.

2.1.2 Evaluating Value of Information

There are a variety of methods to evaluate value of information. One of the most commonly used calculations is the expected value of information, which is basically the difference between one's expected payoff with a particular piece of information and one's expected payoff without that piece of information. When we research into the literature, it is interesting to find that an enormous effort has been focused on the potentially negative values of information (i.e. curse of knowledge), which is on the contrary to the conventional economics that assumes information always carries non-negative values. For instances, Camerer et. al. (1989) showed that both financial incentives and learning from feedback cannot help subjects to avoid curse of knowledge, and even though market forces can mitigate its negative effect, curse of knowledge still exists. They also conjectured that the existence of curse of knowledge suggests that the outcome information could be overused – people tend to think that ex ante optimal decisions that turn out to have unfavorable outcomes are not good decisions, while ex ante non-optimal decisions with favorable outcomes are good choices. Loewenstein et. al. (2006) also confirmed that increased experiences cannot overcome the curse of knowledge, and further illustrated that a portion of subjects actually choose to receive (and even willing to pay for) information that is harmful to their decisions and payoffs. Subjects are not aware of the harmful effects of more information, but instead place a positive value on such information.

2.1.3 Modeling Value of Information

Chatterjee and Harrison (1988) incorporated value of information in competitive bidding and solved the equilibrium stage accordingly. They also found that the amount of information the players would collect depends on the sampling cost per unit. If sampling cost is high, the player would not choose to be well-informed. It is shown that the benefits of being informed would diminish if there is a reasonable chance that other players are as well-informed. Pflug (2006) justified the use of the model of expected value of perfect information to optimize a portfolio investment choice. Chernew et. al. (2008) adopted a Bayesian learning model to assess how non-union employees at General Motor Corporation utilize the information provided by the health plan report cards to assist them in choosing among different health plans.

Yet, there have been no experiments aiming to elicit how people evaluate the value of information, or to study how different information revelation mechanisms could correct the market failure due to asymmetric information. We will address this issue in Chapter 3.

2.2 The Ultimatum Game

The ultimatum game has been an area of extensive studies. The first ultimatum experiment was conducted by Guth et al. (1982), who defines ultimatum game as follows:

> A game has perfect information if all its information sets are singletons, i.e. there are no simultaneous decisions and every player is always completely informed about all the previous decisions. Consider a bargaining game with perfect information whose plays are all finite. Such a game is called an ultimatum bargaining game if the last decision of every play is to choose between two predetermined results. Often a game itself does not satisfy this definition, but contains subgames for which this is true In a 2-person bargaining one usually speaks of an ultimatum if one party can restrict the set of possible agreements to one single proposal which the other party can either accept of reject.

In ultimatum game, strategic interaction occurs only in the form of anticipating future decisions. There is no mutual interdependence resulting from simultaneous moves or infinite plays. In fact, bargaining processes are often modeled as ultimatum games (Stahl, 1972), because only when knowing what drives the individual decisions in simple games, one can be sure how to interpret the results of more complex situations. It is well-known in the economic literature that subjects do not anticipate future decisions in the way which characterizes the individually rational decision behavior in ultimatum games (Selten, 1978). Hence, Guth et al. (1982) ran the first ultimatum game experiment in the economic literature, which contains two different versions to investigate subject behaviors – the easy game and the complicated game. The easy game is the traditional ultimatum game, i.e. two subjects are randomly chosen to be Player 1 and Player 2. Player 1 declares an amount he claims for himself, and the difference between the total pie size and the amount Player 1 claims is offered to Player 2. If Player 2 accepts, then both get the proposed amount. If Player 2 rejects, then both gets nothing. In the complicated game, the process is similar to the easy game, except that Player 1 has to divide a bundle of 5 black and 9 white chips. Each chip (either black or white) is worth DM2 to Player 1, and each black chip is also worth DM2 to Player 2, while each white chip is only worth DM1 to Player 2.

The result of the first ultimatum game in the literature (i.e. the easy game) is summarized in Table 2.1. We can see that Player 1, rather than proposing a minimal amount to Player 2 as suggested by game theory, have made a modal proposal as a 50:50 split, and a mean demand as 65% of the total pie, leaving 35% to Player 2. Similar results were obtained from the ultimatum game experiments conducted in later years (see Guth and Tietz [1990], and Camerer and Thaler [1995]).

Table 2.1 Decision Behavior of the First Ultimatum Game

Game	Amount to be Distributed	Demand of Player 1	Decision of Player 2
A	10	6.00	Accepted
B	9	8.00	Accepted
C	8	4.00	Accepted
D	4	2.00	Accepted
E	5	3.50	Accepted
F	6	3.00	Accepted
G	7	3.50	Accepted
H	10	5.00	Accepted
We	10	5.00	Accepted
J	9	5.00	Accepted
K	9	5.55	Accepted
L	8	4.35	Accepted
M	8	5.00	Accepted

N	7	5.00	Accepted
O	7	5.85	Accepted
P	6	4.00	Accepted
Q	6	4.80	Rejected
R	5	2.50	Accepted
S	5	3.00	Accepted
T	4	4.00	Rejected
U	4	4.00	Accepted

Thaler (1988) summarizes the anomalies found in the ultimatum games, such as the experiments conducted by Kahneman et al. (1986), who recruited psychology students and found that even if the offers made by Proposers could not be rejected by Respondents, most of the Proposers (76%) are still very generous to divide the pie evenly. The author also found that subjects are willing to pay some costs to split money with a stranger who has been generous rather than with the one who has been greedy. Another experiment conducted by Binmore et al. (1985) showed that in a two-stage game with discount factor and where subjects could switch role, subjects behaved more in accordance with game theory when strategic advantage can be easily calculated. Neelin et al. (1988) designed a five-round game and suggested that subjects often choose myopic strategy, which leads to a conclusion that subjects either only think one step ahead, or are just conservative, wishing to minimize the risk that their partner would reject their offer. Ochs and Roth (1989) introduced a 10-period game with discount rates varied among different subjects, and proved that the results of the ultimatum game provide nearly no support for the descriptive value of game theory, as the theoretical mean offer always lies outside two standard deviations of the actual mean offer in all trails.

In fact, many anomalies have been found in the ultimatum games. For another comprehensive review, see Camerer and Thaler (1995). Throughout the years, many scholars have attributed the anomalies in ultimatum game to a variety of reasons, which, in my opinion, could be classified into five categories, namely i) cultural difference; ii) gender difference; iii) other-regarding behavior; iv) stake size; and v) experiment setting.

2.2.1 Cultural Difference

Roth et al. (1991) compared the bargaining behaviors using the multi-person market environment and a two-person single-period ultimatum game among four different countries, and found that subjects in all four countries behave similarly in market setting[1] – the transaction price converges to the equilibrium price after a few periods. In contrast, subjects in two-person ultimatum games behave differently among the four countries. Respondents in United States and Yugoslavia tend to reject unequal offers more often than Japan and Israel. The offer that maximizes subject's expected earning is to propose 50:50 in United States and Yugoslavia, 55:45 in Japan, and 60:40 in Israel. This finding reveals that the concept of "fairness" is different among different cultural settings, thus Proposers in different countries may behave differently in the experiments.

The claim was supported by Henrich (2000), who suggested that notions about what is fair and/or what deserves punishment are a cultural variable, because economic decisions and economic reasoning could be heavily influenced by cultural differences as a consequence of different cultural evolutionary trajectories. To verify this statement, the author conducted several ultimatum games in Machiguenga of the Peruvian Amazon, where people are economically independent at the family level, possess little social hierarchy or political complexity. The result was surprisingly different from the many ultimatum games reported in the literature – the mean offer

[1] In each market, there is only one seller but multiple buyers. After buyers' proposed prices for a given round are collected, the highest proposed price in each market is posted on the blackboard, then the seller decides whether accept or reject this highest offer.

is only 26% of the pie (mode is 15%, and standard deviation is 0.14), but the rejection rate is less than 5%! Only 10% of the offers that are less than 20% of the pie size are being rejected, and this outcome is very different from the results of the other ultimatum games conducted elsewhere. In particular, the Respondents in the postgame interviews told Henrich that rather than viewing themselves as being screwed by the Proposers, they feel that it is just bad luck that they are the Respondents, but not the Proposers. For the few Proposers who offered 50%, they stated firmly that their fellow would definitely accept less, but it seems fairer to offer 50%. In essence, these few exceptions who offered 50% are those having greater exposure and dealings with Westerners, especially with the North American evangelical missionaries.

Henrich et al. (2001) also conducted a large scale cross-cultural study to investigate subject behaviors in ultimatum game. Twelve experienced field researchers, working in twelve countries on five continents, recruited subjects from fifteen small-scale societies exhibiting a wide variety of economic and cultural conditions. Their sample consists of three foraging societies, six that practice slash-and-burn horticulture, four nomadic herding groups, and three sedentary, small-scale agriculturalist societies. The experimental results show that while the ultimatum game mean offers in industrial societies are typically close to 44%, the mean offers in the sample range from 26% to 58%. Similarly, while modal offers are usually 50% in industrialized societies, it ranges from 15% to 50% in the sample countries. Because of this wide variety across countries, the authors proposed two factors to account for the difference in ultimatum offers – the Payoffs to Cooperation and the Market Integration. The first dimension measures how important and how large a group's payoff from cooperation in economic production is, while the second dimension measures how much do people rely on market exchange in their daily lives. A regression analysis showed that both factors are highly significant – the normalized regression coefficients are large in positive magnitude (about 0.3), and the two factors jointly explain 68% of the variance of the ultimatum offers. The authors then concluded that subject preferences and expectations in the experiment are affected by group-specific condition, such as social institutions or cultural fairness norms. A plausible interpretation of this phenomenon is that when subjects face a novel situation, they look for analogues in their daily experience, finding the similar situation, and then act in a way appropriate for the analogous situation.

Oosterbeek et al. (2004) performed a meta-analysis of the culture differences in ultimatum game experiment by collecting 37 papers around the globe with 75 results of standard ultimatum game experiments. This study successfully identifies regional differences in Respondents' behavior – conditional on other study characteristics, Asian Respondents have significantly higher rejection rates than Respondents in the U.S.[2]; and Respondents in the western part of the U.S. have lower rejection rates than Respondents in the eastern part of the U.S. The authors also conducted several statistical analyses, and concluded that the countries with more respect for authority have a negative impact on Proposers' offers. Apparently, in countries in which authority is respected more, the Proposers anticipate this and offer less.

In fact, not only the country-wide culture differences affect subject behaviors in ultimatum game, but also the sub-culture among different groups. For instances, although Kagel et al. (1996) found no differences between subjects with different

[2] The finding here is inconsistent with Roth et al. (1991). The possible explanation is that Oosterbeek et al. (2004) includes four countries in Asia in their study, and the country Papua New Guinea in the Asia group has much higher rejection rate (33.5%) than in Japan (19.27%).

academic backgrounds, Kahneman et al. (1986), Carter and Irons (1991), and Hoffman et al. (1996a) all observed that economics and business students make smaller offers to the Respondents than the students in psychology and other disciplines. Murnighan and Saxon (1994) also found that kindergartens are more tolerate to accept minimal offers at about 70% of the time, compared to 40% for third- and sixth-graders students, and even less in college students.

As culture differences do influence economic behavior, the implicit assumption that all human beings share the same economic decision-making processes must be brought into question.

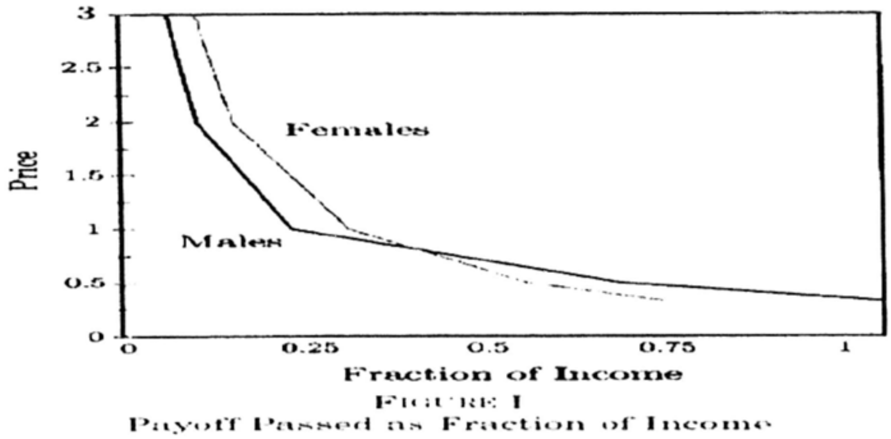
2.2.2 Gender Difference

Darwin (1874) stated that "woman seems to differ from man in mental disposition, chiefly in her greater tenderness and less selfishness Man delights in competition, and this leads to ambition which passes too easily into selfishness." The research in social sciences other than economics has shown that women are more socially oriented – selfless; while men are more individually oriented – selfish (Eckel and Grossman, 1998). The view is now also shared by economists, as the ultimatum game experiments conducted by Eckel and Grossman (2001) reported evidence that women's proposals were on average more generous than men's, regardless of the gender of their partners. Women also display solidarity with female partners – female dyads rarely fail to reach an agreement, in sharp contrast to what happens in male or mixed dyads.

In fact, there were a lot more behavioral differences between male and female found in ultimatum games. Eckel and Grossman (1992) revealed that the demand for fairness by males is highly inelastic with respect to the price of fairness, while the demand by females is relatively elastic. Solnick and Schweitzer (1999) designed a simple ultimatum game with players being informed of their bargainer's gender, and found that men are usually offered more, but less is demanded of them. Solnick (2001) conducted a very comprehensive ultimatum experiment to test for the gender difference, and identified that the average offer to male is significantly higher than the average offer to female. In particular, female offers to males are significantly higher than female offers to females, which is different from the findings of Eckel and Grossman (2001). Solnick (2001) also found that Respondents of both genders choose a higher minimum acceptable offer when facing a female Proposer. As a result, men achieve the highest average earning when paired with women.

Apparently, some of the results of gender difference in ultimatum game are inconsistent. This may potentially be explained by the findings from Andreona and Verterlund (2001), who adopted a variation of the number of tokens and multiplication factors to different subjects in a dictator game (e.g. one token may be worth one dollar, two dollars, five dollars, etc. to the subject and to his/her partner differently). The results disclosed that men are more sensitive to price change – when the relative price of giving was lower, men gave more, as shown in Figure 2.1. The authors pointed out that giving from men has the maximum variance when the price of altruism was unity (i.e. one token is worth one point to both parties), and this might be the potential explanation of the contradicting results found in the gender difference of the ultimatum games.

Figure 2.1 Payoff Passed as Fraction of Income between Male / Female Dictators



2.2.3 Other-regarding Behavior

Smith (1969) stated that "how selfish soever man may be supposed, there are evidently some principles in his nature, which interest him in the fortunes of others, and render their happiness necessary to him, though he derives nothing from it except the pleasure of seeing it." Throughout the years, subjects in economic experiments regularly reveal their concern for the payoffs of others. Other-regarding behavior is undoubtedly one of the factors that have driven the Proposers and Respondents in ultimatum games to deviate their behaviors from purely payoff maximization. It is widely documented in dictator game that altruism is an important element in the dictator giving, though altruism requires a context – an increased in the "deservingness" of the Respondents in the dictator game increases the quantity of dictator giving made by the experimental subjects (Eckel and Grossman, 1996).

However, a number of researchers have conjectured that many subjects are not altruistic in nature but only afraid of punishment in ultimatum game. Bolton and Zwick (1995) designed three different experiments – classical ultimatum game, ultimatum game without experimenter's observation (double blind), and impunity game[3], and found that the percentage of subjects playing perfect equilibrium in these games were 30%, 46% and 100% respectively, which reveals that subjects rejecting offers in ultimatum games aimed at punishing the Proposers. Bolton et al. (1998) further developed and testified the "I'm no-saint hypothesis", claiming that if the dictator was restricted to two division choices, one being the equal split and other being unequal split favoring the dictator, then the percentage choosing the equal split would be equal to the percentage that would choose the equal split in the unrestricted game. Hence, when facing a choice between erring in favor of the other person's welfare and erring in favor of his/her own, the dictator would always choose an unequal split in favors of his/her own. Camerer and Thaler (1995) also revealed that Proposers usually aim to "seem fair" rather than "be fair". The authors designed an ultimatum game that give private information to Proposers that a token is worth 30 cents to them but only 10 cents to the Respondents, and found that most subjects proposed a 50:50 distribution of tokens. A similar finding was disclosed by Kagel et al. (1996), who designed an ultimatum game with subjects bargaining over chips with different exchange rates and with different information regarding these exchange rates. The results showed that offers generally reflected a self-serving definition of fairness, and provided evidence that relative income shares enter player utility function.

[3] The impunity game played differs from the classical ultimatum game treatment by just one feature: if the second mover rejects a first mover's offer, the first mover still receives what he/she suggests to himself/herself, i.e. the second mover's punishment strategy is removed.

2.2.4 Stake Size

The effect of stake size in ultimatum game has been debated among scholars for many years. One of the logical arguments is: if we consider fairness as a commodity such that consumption is maximized when the split is equal in ultimatum game, then it is reasonable to assume that the value of fairness varies inversely with its price. In other words, if we raise the stakes, the price of fairness increases. Hence, if the stake size is large enough, then it is plausible that a small proportion of the stake offered to the Respondents in ultimatum game will be accepted.

In the existing literatures, numerous experiments have been conducted to verify the above argument. On one hand, Roth et al. (1991) examined games played for $10 and for $30, and noticed no important differences. Straub and Murnighan (1995) also found little difference in Proposer or Respondent behaviors in ultimatum games between the stake sizes of $5 and $100. Likewise, Cameron (1999) could not discover any difference in either Proposer or Respondent behaviors when stakes changed from 5,000 to 200,000 Indonesian Rupiahs[4].

On the other hand, Eckel and Grossman (1992) reported that the demand for fairness by female is relatively elastic with respect to the price of fairness. Forsythe et al. (1994) identified a pronounced decline in rejection rates as the stake size increased from no pay to $5 to $10. The claim is supported by a qualitative look at the result of the experiment conducted by Hoffman et al. (1996a), who ran the

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4 The exchange rate when the experiment was conducted is approximately US$1 = 2160 Rupiahs. In terms of purchasing power, the World Bank [1994] estimates that US$1 in Indonesia buys as much as $4.4 in the U.S. Hence, 5000 Rupiahs has approximately the same purchasing power as $10 to $15 in the U.S., and this is a much larger share of average earnings in Indonesia.

ultimatum game with $100 stake size at University of Arizona, and found a few first movers assume they can offer less. Slonim and Roth (1998) ran repeated ultimatum games with 60 Sk, 300 Sk and 1500 Sk[5] in the Slovak Republic, and demonstrated that both the middle and high stakes conditions decrease the likelihood that an offer will be rejected relative to the low stake condition, and there is an interaction effect between stakes and experience: in the higher stake condition the offers decrease with experience. Munier and Zaharia (2002) also revealed that the lowest acceptable offers stated by the responders are proportionally lower in the high-stake condition than in the low-stake condition. Finally, Oosterbeek et al. (2004) conducted a meta-analysis of 37 papers around the globe with 75 results of standard ultimatum game experiments, and indicated that the mean offer is significantly lower for larger pie size, and the size of the pie has a negative effect on the average rejection rate.

The above summary shows that increasing stake size usually affects the Respondent behavior but not (or only mildly) the Proposer behavior. To explain this discrepancy, Slonim and Roth (1998) conducted a rigorous statistical power test by generating 500 simulated data sets (p.583-585), and showed that the lack of significant difference in Proposer offer between low stake and high stake games is due to the low power of the statistical test. Munier and Zaharia (2002) suggested that Proposer's tendency to propose equal split in the high-stake condition is risk-averse. By raising the ultimatum bargaining stakes, on one hand, the Respondents adopt a behavior more consistent with the perfect equilibrium model – non-monetary aspects of Respondent's behavior (e.g. fairness, punishment, etc.) seem to play a less important role in his/her decision-making process. On the other hand, the simple

[5] 60 Sk, 300 Sk and 1500 Sk are approximately 2.5, 12.5 and 62.5 hours of wages respectively in the Slovak Republic, where the average monthly wage rate is 5500 Sk at the time when the experiment was conducted.

linear income-maximization hypothesis is no more a satisfactory explanation of Proposer's behavior – the Proposer seems to prefer a rejection risk reduction rather than an average earning maximization.

2.2.5 Experiment Setting

In the economic literature, scholars have long noticed that even subtle difference in experimental settings will affect subject behaviors. According to Guth and Tietz (1990), the strategy method in ultimatum game would strengthen fairness consideration, leading to some systematic differences between the ultimatum game adopting the strategy method and the direct method[6] of preference elicitation. The argument was supported by Oosterbeek et al. (2004), who reported in their meta-analysis of 37 ultimatum experiment papers that the mean offer is significantly larger for studies employing the strategy method. The authors also found that there is a large difference in average rejection rate between studies that use the strategy method and studies that ask the Respondents to accept or reject a given offer (the direct method). A statistical test shows that for strategy method, the average rejection rate is about 13% higher.

On the other hand, Hoffman et al. (1996a) revealed that Proposers offer substantially less to the Respondents in ultimatum games when they feel their role as the Proposer is justified and legitimate, and this is independent of the stake size. For example, if the role of Proposer is determined by a contest, they usually expected a

[6] With strategy method, subjects have to specify complete strategies for the game before it is played. With direct method, subjects make decisions in sequential order. In other words, with strategy method, Respondents have to declare their minimum acceptable offer before Proposers make the offer; while with direct method, Respondents decide whether to accept or reject the offers after they observe the actual offers made by the Proposers.

more unequal offer. In another paper, Hoffman et al. (1996b) proposed that people have unconscious, programmed rules of social exchange behavior that suit them well in the repeated game of life's interaction with other people. These patterns are imported into the laboratory, so the only way to weaken such behavior is to modify the game settings and instructions by lengthening the distance between the individuals, and finally imposing completely isolation in a double blind treatment. Bolton and Zwick (1995) have run an experiment to testify the anonymity and punishment hypotheses in ultimatum game, and found statistically significant supportive evidences for the anonymity hypothesis, i.e. a double blind design do shift subjects towards the perfect equilibrium prediction. However, the magnitude is rather small, and the effect of experimenter observation only has little effect to the subject behaviors in ultimatum game.

2.2.6 Descriptive Models for Ultimatum Game

With so many anomalies found in ultimatum games, Thaler (1988) conjectured that consumers may be unwilling to participate in an exchange in which the other party gets too large a share of the surplus, and cites a relevant example (p.203). He then suggested scholars to develop prescriptive game theory to explain the phenomenon observed in the ultimatum game. The term "prescriptive theory" was first introduced by Bell et al. (1988), who claimed that three kinds of theories of decision making under uncertainly should be distinguished – normative theories tell how a rational agent should behave; descriptive theories tell how agents do behave; and prescriptive theories advise how to behave when faced with one's own cognitive or other limitations. The economists have put a huge amount of efforts in developing normative theories (e.g. game theory) and descriptive theories, but not much on prescriptive theories. In this section, we study the descriptive theories for ultimatum game found in the literature. Then, in Chapter 4, we will describe and adopt a prescriptive theory to rationalize subject behaviors in ultimatum game.

Scholars continuously found evidences that subjects are not perfectly rational in ultimatum games, as they do not make decision purely based on monetary incentives – Respondents always reject positive offers when the offers are notably less than what Proposers kept for themselves. To explain why Respondents reject non-zero offers, Bolton (1991), Fehr and Schmidt (1999) and Trautmann (2006) have proposed different descriptive models.

Bolton (1991) considered bargainers behave as if they are negotiating both absolute and relative money, and proposed a model suggesting that players have a utility function $u(x_r, x_r/x_p)$, where x_r is the absolute amount Respondents got, and x_r/x_p is the ratio of Respondent's share to Proposer's share. Fehr and Schmidt (1999) shared similar ideas and built a more comprehensive mathematical model to calculate player *i*'s utility with consideration on others' payoff as follows:

$$U_i(x) = x_i - \alpha_i \frac{1}{n-1}\sum_{j \neq i} \max\{x_j - x_i, 0\} - \beta_i \frac{1}{n-1}\sum_{j \neq i} \max\{x_i - x_j, 0\}$$

where x_i is the payoff to player *i*

n is the number of players

$\beta_i \leq \alpha_i$ and $0 \leq \beta_i \leq 1$

coefficients α and β represent the weight of envy and guilt

When coefficients α and β are zero, players are purely self-interested, so the standard perfect rationality assumption of players is a special case of this model. The model suggests that Respondents in ultimatum games may reject low offers to enforce equality, and it is a dominant strategy for Respondents to accept any offers $x \geq 0.5$, and to reject x if

$$x < \frac{\alpha_2}{1 + 2\alpha_2}$$

where α_2 is the weight of envy of Respondent, and the pie size is normalize to 1

Proposers, believing α_2 is distributed with a cumulative distribution function $F(\alpha_2)$, where $F(\alpha_2)$ has support $[\underline{\alpha}, \overline{\alpha}]$ with $0 \leq \underline{\alpha} < \overline{\alpha} < \infty$, has the optimal strategy of proposing the following:

$$x^* \begin{cases} = 0.5 & \text{if} \quad \beta_1 > 0.5 \\ \in \left[\dfrac{\overline{\alpha}}{1 + 2\overline{\alpha}}, 0.5\right] & \text{if} \quad \beta_1 = 0.5 \\ \in \left[\dfrac{\underline{\alpha}}{1 + 2\underline{\alpha}}, \dfrac{\overline{\alpha}}{1 + 2\overline{\alpha}}\right] & \text{if} \quad \beta_1 < 0.5 \end{cases}$$

where β_1 is the weight of guilt of Proposer

Though Fehr-Schmidt model successfully explains subject behaviors in a qualitative way, it could not address the issue that Respondents aim at "punishing unfairness, not rejecting inequality" in ultimatum games, i.e. they could accept a computer generated low offer more readily than a human decided low offer. Hence, Trautmann (2006) modified their model to incorporate process fairness, and successfully testified the new model by a random ultimatum game, which uses a random device to propose an allocation of the pie to the Proposer and Respondent.

The modified model for the two-person ultimatum game is:

$$U_i(x_i, X, Y) = x_i - \alpha_i \max\{E[Y] - E[X], 0\} - \beta_i \max\{E[X] - E[Y], 0\}$$

where x_i is the payoff to the player i

$\beta_i \le \alpha_i$ and $0 \le \beta_i \le 1$

E[X] is the expected payoff to the player i

E[Y] is the expected payoff to the other player

Trautmann's model captures the expected values rather than the actual outcomes in the game, and focus on the process fairness rather than the outcome fairness. However, since it is technically impossible to measure each subject's α and β, all these proposed models are essentially qualitative in nature – they cannot yield a numerical prediction of what Proposers should offer to responders.

Guth (1995), after actively involved in ultimatum bargaining experiments for many years, concluded that human decision making is a dynamic reasoning process guided by past experiences and limited strategic considerations. Thinking along the same line, we conjectured that subjects tend to choose the previously successful mode of behavior, and formulate their strategies accordingly. In Chapter 4, we investigate the optimal subject behaviors with the History-Consistent Rationality model, which assumes players respond to each other "rationally", but their rationality is bounded by their knowledge about the game and how others play, and their knowledge is derived from historical data. We will show how this model could explain the actual human behaviors, supported by experimental data.

Chapter 3

A Game Theoretical Approach to Study Efficient Market Mechanism

3.1 Introduction

Stiglitz (2000) claimed in his millennium review that "in the field of economics, perhaps the most important break with the past – one that leaves open huge areas for future work – lies in the economics of information." Stiglitz (2000, 2002) elaborated how information economics has made a fundamental change to the prevailing paradigm within traditional economics, which conjectures invisible hands would efficiently lead market to an equilibrium stage under perfect competition. He argued that the traditional economic theory fails to explain the real world because the model assumes perfect information condition, but perfect information seldom exists in our economy. In contrast, the real world is filled with imperfect and asymmetric information.

Scholars have been exploring, evaluating and modeling value of information. In our experiments, we attempted to elicit how people evaluate the value of perfect information, and study how different information revelation mechanisms could correct market failure due to asymmetric information. We examined the efficiency of the prevailing market mechanism, and proposed a more effective information revelation mechanism that could maximize market efficiency and minimize deadweight loss. We designed and conducted experiments to verify our arguments.

In this chapter, we prove that in the basic model where the buyers have no information, there exist pooling equilibrium or multiple equilibria, depending on the market conditions. Unfortunately, all market equilibria in the basic model are not sustainable in the long run, because the bad quality will drive out the good quality as a result of adverse selection.

With an improved prevailing market mechanism where the buyers have the opportunity to buy perfect information before they decide to accept or reject the offers from the sellers, there exists a pooling equilibrium, but only under a very restricted market condition. The more possible outcome is a semi-pooling equilibrium with mixed strategies. This model improves the long-term sustainability and solves the adverse selection problem; however, there is always a possibility that the offers from the sellers with low quality commodity would be rejected by the buyers, resulting in deadweight loss.

Au and Chung (2007) demonstrated that the order of contribution in a sequential public goods dilemma could affect cooperation. Following the same logic, we proposed a new model with different sequential order, which also has the option of buying perfect information as in the prevailing market mechanism, but this time the offers are made from the buyers instead of from the sellers. This is not a common practice in today's marketplace, but surprisingly the model significantly improves total welfare and minimizes deadweight loss. The argument is supported by the significant increment in the volume of transactions found in the experiments between the two market mechanisms.

The next section briefly describes the models. Section 3.3 documents the experimental design, followed by a discussion of the experimental results in Section 3.4. Section 3.5 summarizes the findings and concludes.

3.2 The Model

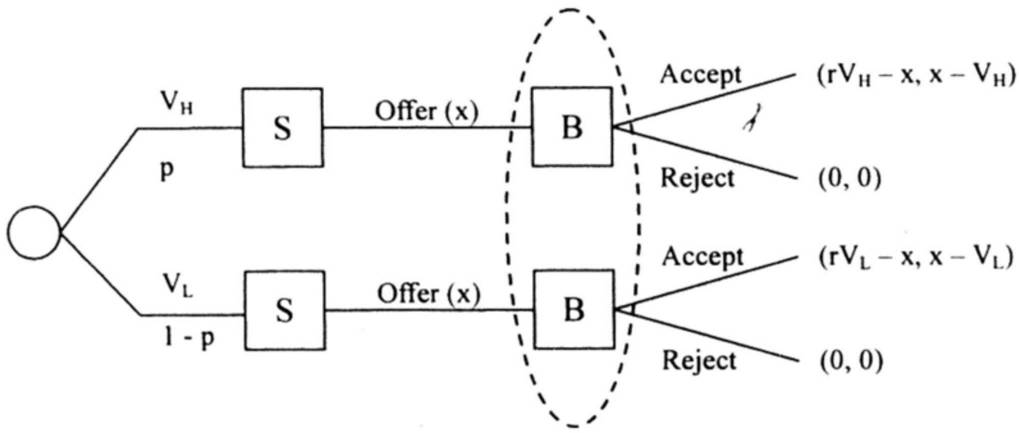
Akerlof (1970) claimed that due to asymmetric information, the market for lemons will collapse, and no trade will take place at all in equilibrium. We doubted the validity of this conclusion in reality, as the analysis has ignored the desire of both buyers and sellers to acquire more information – they do not necessarily sit passively and make inferences about quality from price. In this section, we study how the option of buying information could correct this market failure, and in particular, how much buyers are willing to pay for acquiring perfect information. We also examine market efficiency under different market mechanisms.

To simplify the analysis, the model assumes there are only one seller and one buyer, and we assume all subjects are risk neutral. The value of a commodity is either V_L or V_H, depending on its quality. The seller (S) knows its quality but the buyer (B) does not. There are p of sellers selling the V_H commodities and $(1-p)$ of sellers selling the V_L commodities in the market, which is common information to both buyers and sellers. Furthermore, the commodity is worth more to the buyers than to the sellers, at a ratio r ($r > 1$).

For convenience, the buyer will sometimes be referred as "she" and the seller as "he" in the later discussion.

3.2.1 Basic Model

The following diagram summarizes the basic model:



In the basic model, there is a seller and a buyer – both are risk-neutral. The seller is trying to sell a commodity to the buyer. The value of the commodity is only known to the seller. However, the buyer knows that it is either V_H or V_L ($V_H > V_L$) with probabilities p and $1 - p$, respectively. We shall denote the V_H seller as S_H and V_L seller as S_L. Whatever the value of the commodity is, it is worth more to the buyer than to the seller by a factor of r (> 1). The seller first makes an offer x and the buyer then decides whether to accept or reject the offer. If the seller's offer is rejected, both players get nothing; otherwise, if the offer is accepted, the seller's payoff is $x - V_i$ and the buyer's is $rV_i - x$ ($i = H$ or L), depending on the actual value of the commodity.

Before analyzing the complete model with option of buying information, we describe briefly the market equilibrium of this simplest model, where the buyers have no information about the quality of the commodity.

Apparently, there exists no pure strategy separating equilibrium in the game described above. The reason is as follows. In such an equilibrium, S_H and S_L are supposed to make different offers. So, upon seeing the seller's offer, the buyer will be able to infer correctly the value of the commodity and will accept the offer as long as he gets positive payoff. But then, S_L will always have an incentive to mimic S_H by offering the same price that S_H makes (which is supposed to be accepted) and, hence, the equilibrium collapses.

So, the equilibrium must be either pooling or semi-pooling. The following theorem describes the condition under which the pooling equilibrium arises:

Theorem 3.1

If $prV_H + (1-p)rV_L \geq V_H$, there exists a pooling equilibrium in which both S_L and S_H offer $x^* = prV_H + (1-p)rV_L$. The buyer accepts all seller offers less than or equal to x^* and rejects otherwise.

Proof:

Given that the buyer accepts all $x \leq prV_H + (1-p)rV_L$ and rejects otherwise, both S_H and S_L will offer $x^* = prV_H + (1-p)rV_L$ (which is greater than V_H) to maximize their payoffs. Since the buyer cannot distinguish S_H from S_L, he will hence accept the offer. ***Q.E.D.***

If $prV_H + (1-p)rV_L < V_H$, since S_H will never offer anything less than V_H, the pooling equilibrium described above cannot arise. In this case, there will be semi-pooling equilibria as described in the following Theorem 3.2:

Theorem 3.2

If $prV_H + (1-p)rV_L < V_H$, there exist multiple semi-pooling equilibria in which the players' strategies are given below:

- S_H offers x' with probability 1, where $x' = p'rV_H + (1 - p')rV_L$, $x' \in [\text{Max}(rV_L, V_H), rV_H]$, and p' is the posterior probability of S_H given x', defined as $p' = P(S_H \mid x') = \dfrac{P(x' \mid S_H)P(S_H)}{P(x' \mid S_H)P(S_H) + P(x' \mid S_L)P(S_L)} = \dfrac{p}{p + \beta(1-p)}$
- S_L offers x' with probability β and rV_L with probability $1 - \beta$, where $\beta = \dfrac{p(rV_H - x')}{(1-p)(x' - rV_L)}$
- The buyer accepts all offers less than or equal to rV_L with probability one. For offers greater than rV_L, he accepts x' with probability γ and rejects all other offers based on the belief that it is made by the V_L seller, where $\gamma = \dfrac{rV_L - V_L}{x' - V_L}$

Proof

$prV_H + (1-p)rV_L < V_H$ implies that $V_L < rV_L < prV_H + (1-p)rV_L < V_H < rV_H$.

The buyer only accepts $x \le prV_H + (1-p)rV_L$, but S_H only offers $x \ge V_H > prV_H + (1-p)rV_L$, thus there exists no pooling equilibrium. The semi-pooling equilibrium is as follows:

S_H offers x' with probability 1, where $x' \in [V_H, rV_H]$.

S_L offers x' with probability β, and offer rV_L with probability $(1-\beta)$.

The buyer accepts offer x' with probability γ, and reject with probability $(1-\gamma)$.

$$P(H \mid x') = \frac{P(x' \mid H)P(H)}{P(x' \mid H)P(H) + P(x' \mid L)P(L)}$$

$$= \frac{p}{p + \beta(1-p)}$$

$$P(L \mid x') = 1 - P(H \mid x') = \frac{\beta(1-p)}{p + \beta(1-p)}$$

where $P(H \mid x')$ is the posterior probability that the commodity is of high quality given x'

$P(L \mid x')$ is the posterior probability that the commodity is of low quality given x'

For buyer, the expected value of accepting x' must be equal to rejecting it in order for buyer to randomize her acceptance. Hence:

$$P(H \mid x')(rV_H - x') + P(L \mid x')(rV_L - x') = 0$$

$$\frac{p}{p + \beta(1-p)}(rV_H - x') + \frac{\beta(1-p)}{p + \beta(1-p)}(rV_L - x') = 0$$

$$\beta = \frac{p(rV_H - x')}{(1-p)(x' - rV_L)}$$

The value of β is apparently a positive number, but for β to be less than 1, we have:

$$\frac{p(rV_H - x')}{(1-p)(x' - rV_L)} \leq 1$$

$$x' \geq prV_H + (1-p)rV_L$$

Since x' must be greater than V_H, and $V_H > prV_H + (1-p)rV_L$, $0 \leq \beta \leq 1$.

For the V_L seller, the expected value of offering x' must be equal to offering rV_L in order for V_L seller to randomize their offers, hence:

$$\gamma(x' - V_L) = rV_L - V_L$$

$$\gamma = \frac{rV_L - V_L}{x' - V_L}$$

The value of γ is apparently greater than 0 but less than 1, because $x' \geq V_H > rV_L$.

There exist multiple semi-pooling equilibria because any $x' \in [V_H, rV_H]$ satisfying the above is in equilibrium. For any values of x' that are off equilibrium, buyer would accept only if it is smaller than rV_L, and reject otherwise.

In equilibrium, the expected payoff is 0 for the buyer, $(rV_L - V_L)$ for the V_L seller, and $(x' - V_H)\frac{rV_L - V_L}{x' - V_L}$ for the V_H seller.

Insights

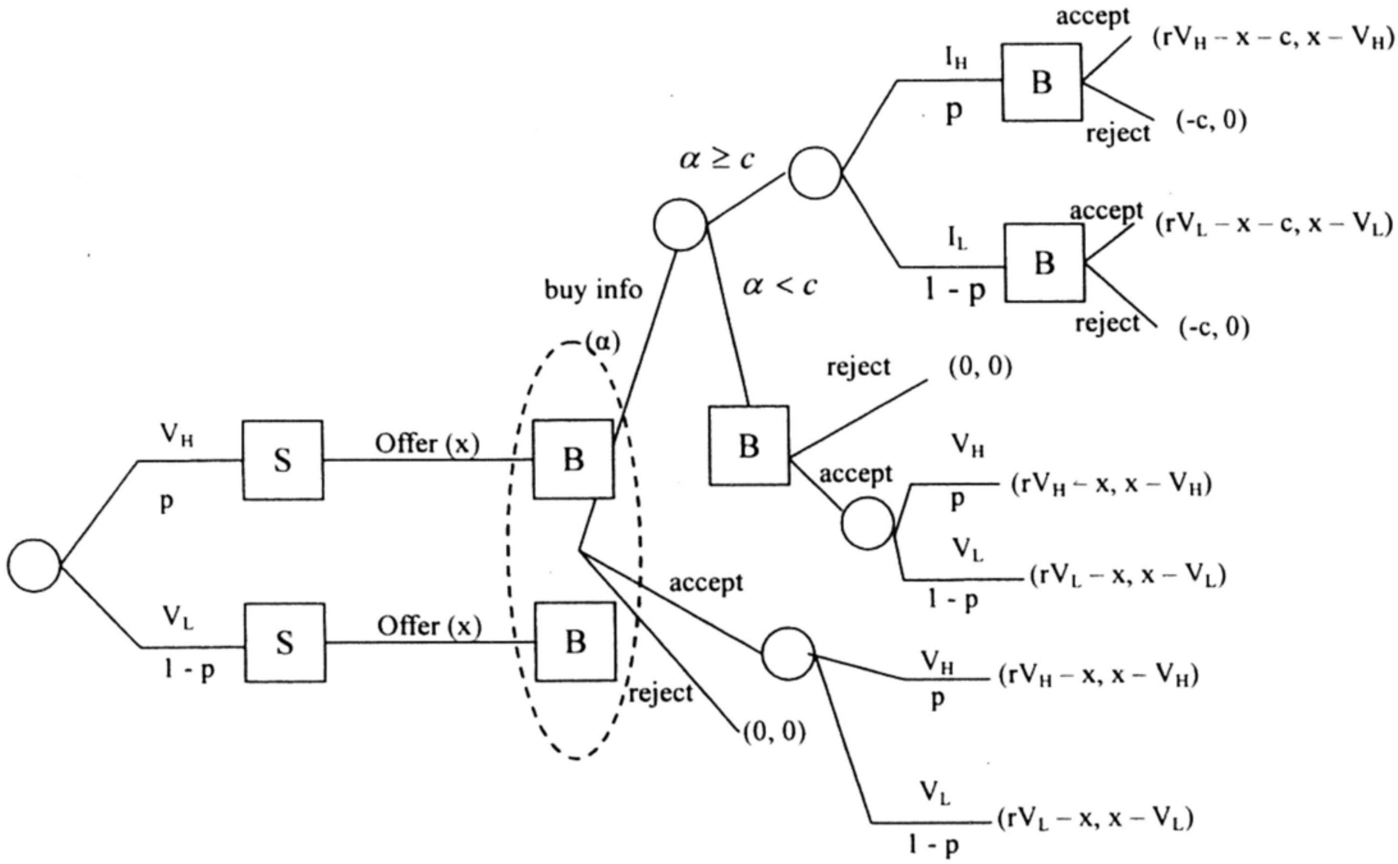
Note that for both pooling and semi-pooling equilibria, they are short-termed and not sustainable in the long run, as the V_H seller will eventually choose to produce V_L commodities because the expected payoff of the V_L seller is always strictly greater than the expected payoff of the V_H seller.

In the next section, we analyze our extended model. We first study whether a market with the option of buying information can solve the adverse selection problem that results in the bad quality driving out the good quality.

3.2.2 Model under Prevailing Market Mechanism

The market is under asymmetric information where only the sellers know the quality of the commodities, although all parties know that there is a probability p that the seller possesses a high quality commodity valued at V_H, and a probability $1\ \ p$ that the seller possesses a low quality commodity valued at V_L. Both V_L and V_H commodities are worth more to the buyers than to the sellers at a ratio r ($r > 1$), which is common information. At the beginning, the seller proposes a price x to sell the commodity to the buyer. The buyer then can choose to immediately accept or reject, or he can bid a price α to buy perfect information about the quality of the commodity from a third party before deciding whether to accept or reject the seller's offer. The cost of information c is uniformly distributed between 0 and 1. If the buyer's offer α is greater than c, then the buyer gets the information by paying c. Otherwise, the buyer will not get any information, nor does he pay any costs.

The following diagram summarizes the model with the option of buying information under the prevailing market mechanism:



We first argue that there exists no pure strategy separating equilibrium. The reason is as follows. If the S_L and S_H make separate offers, the buyer would have no incentive to buy information but to response directly based on the seller's type that is signaled by the offered amount. But then, if the buyer does not buy information, S_L will always have the incentive to mimic S_H, because the buyer cannot distinguish S_L from the S_H without perfect information.

So, we end up with only two possible equilibria – the pooling equilibrium or the semi-pooling equilibrium. Before describing the equilibria, we will first show that if the seller's offer is higher than $Max(V_H, rV_L)$, the buyer will always bid for the information.

Lemma 3.1

For all seller offers $x \in [Max(V_H, rV_L), rV_H]$, the buyer will always bid for information. In addition, the buyer's optimal bidding price α^* is as follows:

$$\alpha^* = \begin{cases} Min[\hat{p}(rV_H - x), I] & \text{if } x > \hat{p}rV_H + (1-\hat{p})rV_L \\ Min[(1-\hat{p})(x - rV_L), I] & \text{if } x \le \hat{p}rV_H + (1-\hat{p})rV_L \end{cases}$$

Proof:

Define $EV(A) = \hat{p}(rV_H - x) + (1-\hat{p})(rV_L - x)$, where $\hat{p}$ is the probability (possibly the posterior probability) that the commodity is of high-quality.

We need to consider two cases: (1) $EV(A) < 0$ and (2) $EV(A) \ge 0$.

When $EV(A) < 0$, the offer x will be rejected by the buyer in case he fails to get the information. If the buyer successfully gets the information, he will only accept the offer when the information shows that the commodity is of the high-quality one. Suppose that the buyer bids an amount α, then the expected cost of the information is $\alpha/2$ (if buyer successfully gets information), and the probability he will get the information is α/I, as the cost of information is uniformly distributed between 0 and I. Hence, the expected value of bidding for information to buyer is:

$$EVBI(\alpha) = \frac{\alpha}{I}[\hat{p}(rV_H - x) - \frac{\alpha}{2}]$$

The optimal bidding price for the information (α) is the solution to the following problem.

$$\underset{\alpha}{Max}\ EVBI(\alpha)$$
$$\text{Subject To} \quad 0 \le \alpha \le I$$

Given that $EVBI(\alpha)$ is concave in α and $EVBI(\alpha) = 0$ when $a = 0$, it is easy to see that the optimal bidding price for information must be either $\alpha = \hat{p}(rV_H - x)$ or $\alpha = I$, depending on which is smaller.

Note that in both cases, the expected payoffs for the buyer are always higher than those of immediate acceptance or rejection. In the first case when $\alpha = \hat{p}(rV_H - x)$, the buyer expects to get $\frac{\hat{p}^2(rV_H - x)^2}{2I}$, which is obviously non-negative. In the second case when $\alpha = I$ (which implies that $\hat{p}(rV_H - x) \geq I$); the buyer's expected payoff is $\hat{p}(rV_H - x) - \frac{I}{2} > 0$. Therefore, the optimal strategy for the buyer is to bid for the information because accepting the offer immediately results in a negative expected payoff while rejecting the offers immediately means getting nothing.

When $EV(A) \geq 0$, the offer x will be accepted by the buyer in case he fails to get the information. If the buyer successfully gets the information, he will only accept the offer when the information shows that the commodity is of the high-quality one. Hence, the buyer's expected value of bidding for information is:

$$EVBI(\alpha)$$

$$= \frac{\alpha}{I}[\hat{p}(rV_H - x) - \frac{\alpha}{2}] + (1 - \frac{\alpha}{I})[\hat{p}(rV_H - x) + (1 - \hat{p})(rV_L - x)]$$

$$= \hat{p}(rV_H - x) + (1 - \frac{\alpha}{I})(1 - \hat{p})(rV_L - x) - \frac{\alpha^2}{2I}$$

Again, the optimal bidding price for the information (α) is the solution to the following problem:

$$\underset{\alpha}{Max}\, EVBI(\alpha)$$

$$\text{Subject To} \quad 0 \leq \alpha \leq I$$

Given that $EVBI(\alpha)$ is concave in α and $EVBI(0) = \hat{p}(rV_H - x) + (1-\hat{p})(rV_L - x)$, it is easy to see that the optimal bidding price for information must be either $\alpha = (1-\hat{p})(x - rV_L)$ or $\alpha = I$.

Note that in both cases, the expected payoff for buyer is always higher than immediate acceptance, i.e. $\hat{p}(rV_H - x) + (1-\hat{p})(rV_L - x)$, or immediate rejection, i.e., 0. In the first case when $\alpha = (1-\hat{p})(x - rV_L)$, the buyer's expected payoff is $\hat{p}(rV_H - x) + (1-\hat{p})(rV_L - x) + \frac{(1-\hat{p})^2 (x - rV_L)^2}{2I}$, which is obviously no less than $\hat{p}(rV_H - x) + (1-\hat{p})(rV_L - x)$. In the second case when $\alpha = I$, which implies that $(1-\hat{p})(x - rV_L) \geq I$ or equivalently $(1-\hat{p})(rV_L - x) \leq -I < -\frac{I}{2}$, the buyer's expected payoff is $p(rV_H - x) - \frac{I}{2}$, which must be greater than $\hat{p}(rV_H - x) + (1-\hat{p})(rV_L - x)$. Therefore, it is optimal for the buyer to bid for information. ***Q.E.D.***

We have shown in the above lemma that the buyer will always bid for information if an offer $x \geq Max(V_H, rV_L)$ is observed. However, since the equilibrium must be either pooling or semi-pooling, it is necessarily the case that the buyer never bids up to the maximum price (i.e., I) so that there is always the possibility that the buyer will not get the information, allowing S_L to mimic S_H. If the buyer bids up to the maximum price for the information, he is guaranteed to get the information and will then be able to distinguish perfectly S_L from S_H. In such case, it is impossible for S_L to mimic S_H and neither pooling nor semi-pooling equilibrium can arise.

We will first characterize the conditions for the pooling equilibrium. Note that, in order for the pooling equilibrium to arise, it is necessary that the following three conditions be met:

(1) $x^* = prV_H + (1 - p)rV_L \geq V_H$, where x^* is the common offer made by both types of sellers,

(2) $\alpha^* = (1 - p)(x^* - rV_L) < I$, and

(3) $(1 - \alpha^*/I)(x^* - V_L) \geq rV_L - V_L$.

The first condition ensures that S_H will have the incentive to make such an offer. It also ensures that the buyer will accept the offer if he fails to get the information. (In fact, in this case, the buyer is indifferent between acceptance and rejection. We assume that the buyer will accept when he is indifferent.) If the pooling equilibrium offer x will be rejected after the buyer fails to get the information, S_L will have no incentive to offer x and will simply offer rV_L. The second condition ensures that there is always some probability that the buyer will not get the information. Finally, the third condition makes sure that S_L will have the incentive to mimic S_H. Note that condition (3) actually implies condition (2) because, if $\alpha \geq I$, the left-hand side of (3) will be non-positive which cannot be greater the right-hand side. We thus have the following theorem:

Theorem 3.3

When the following conditions are satisfied, there exists a pooling equilibrium.

1. $x^* = prV_H + (1 - p)rV_L \geq V_H$
2. $(1 - \frac{(1 - p)(x^* - rV_L)}{I})(x^* - V_L) \geq rV_L - \mathrm{V_L}$

In equilibrium, both S_L and S_H offer x^*. The buyer always bids $\alpha^* = (1-p)(x^* - rV_L)$ for information. If he successfully gets the information, the buyer will only accept x^* if the information shows that the commodity is of high-quality type; otherwise he rejects. If the buyer fails to get the information, he accepts x^*.

The expected payoff is $\frac{p^2(1-p)^2(rV_H - rV_L)^2}{2I}$ for the buyer, $[prV_H + (1-p)rV_L - V_L] \times \frac{I - p(1-p)(rV_H - rV_L)}{I}$ for the V_L seller, and $prV_H + (1-p)rV_L - V_H$ for the V_H seller. The proof is as follows.

As shown earlier in the Lemma 3.1, the expected payoff for buyers is:

$$
\begin{aligned}
& p(rV_H - x) + (1-p)(rV_L - x) + \frac{(1-p)^2(x - rV_L)^2}{2I} \\
& = 0 + \frac{(1-p)^2[prV_H + (1-p)rV_L - rV_L]^2}{2I} \\
& = \frac{p^2(1-p)^2(rV_H - rV_L)^2}{2I}
\end{aligned}
$$

The expected payoff for S_L is the probability of being accepted multiply by the payoff when the offer is accepted, as shown below:

$$
\begin{aligned}
& (1 - \frac{(1-p)(x - rV_L)}{I})(x - V_L) \\
& = \frac{I - (1-p)[prV_H + (1-p)rV_L - rV_L]}{I} \times [prV_H + (1-p)rV_L - V_L] \\
& = [prV_H + (1-p)rV_L - V_L] \times \frac{I - p(1-p)(rV_H - rV_L)}{I}
\end{aligned}
$$

The offer from S_H is always accepted by the buyer no matter the buyer gets the perfect information or not, so his expected payoff is $prV_H + (1-p)rV_L - V_H$.

On the other hand, if the conditions for pooling equilibrium are not met, there exists semi-pooling equilibria in which S_H offers x' with probability 1 and the S_L randomizes between offering x' and rV_L. In a semi-pooling equilibrium, it is necessary that the following conditions be met:

(1) $x' = P(S_H|x')rV_H + P(S_L|x')rV_L \geq V_H$, where $P(S_H|x')$ *and* $P(S_L|x')$ are the posterior probabilities of S_H and S_L given x',

(2) $\alpha' = P(S_L|x')(x' - rV_L) < I$

(3) $\gamma[1 - P(S_L|x')(x' - rV_L)/I](x' - V_L) = rV_L - V_L$, where $1 - P(S_L|x')(x' - rV_L)/I$ is the probability that the buyer will not get the information and γ is the probability that he will accept x' if he fails to get information.

The first condition ensures that S_H will have the incentive to offer x'. It also makes the buyer indifferent between acceptance and rejection in case he fails to get the information and will thus randomize between acceptance and rejection. The second condition ensures that there is always some probability that the buyer will not get the information. Finally, the third condition makes sure that S_L is indifferent between offering x' and rV_L and thus will randomize his offer. Again, it should be easy to see that condition (3) implies condition (2). We thus have the following theorem:

Theorem 3.4:

If there exists x', β, and γ such that the following conditions are met, then there exists semi-pooling equilibria.

(1) $x' = P(S_H|x')rV_H + P(S_L|x')rV_L \geq V_H$

(2) $\gamma\,[1 - P(S_H|x')(x' - rV_L)/I](x' - V_L) = rV_L - V_L$

$$(3)\ \ P(H\mid x') = \frac{P(x'\mid H)P(H)}{P(x'\mid H)P(H)+P(x'\mid L)P(L)} = \frac{p}{p+\beta(1-p)} \text{ and } P(S_L|x') = 1 - P(S_H|x')$$

In equilibrium, S_H offers x' with probability one and S_L offers x' with probability β and rV_L with probability $1-\beta$. The buyer will accept the seller offer immediately (without bidding for information) if it is less than or equal to rV_L. If the seller offer is greater than rV_L, the buyer always bids $\alpha^* = P(S_L|x')(x' - rV_L)$ for information. If he successfully gets the information, the buyer will only accept x' if the information shows that the commodity is of high-quality type; otherwise he rejects. If the buyer fails to get the information, he accepts x' with probability γ.

The expected payoff is $\frac{P(L\mid x')^2(x'-rV_L)^2}{2I}$ for the buyer, $rV_L - V_L$ for the V_L seller, and $P(H\mid x')rV_H + P(L\mid x')rV_L - V_H$ for the V_H seller. The proof is as follows.

As shown earlier in the Lemma 3.1, the expected payoff for buyers is:

$$P(H\mid x')(rV_H - x') + P(L\mid x')(rV_L - x') + \frac{P(L\mid x')^2(x'-rV_L)^2}{2I}$$

$$= \frac{P(L\mid x')^2(x'-rV_L)^2}{2I}$$

S_L is indifferent between offering rV_L and x', and buyer will accept rV_L with probability 1, so the expected payoff for S_L is $rV_L - V_L$.

The offer from S_H is always accepted by the buyer no matter the buyer get the perfect information or not, so the expected payoff for S_H is:

$P(H\mid x')rV_H + P(L\mid x')rV_L - V_H$.

Insights

We showed that buyers always prefer to buy information if there are uncertainties, and the optimal offer is always greater than 0 but less than the maximum potential cost. This is in line with many uncertain situations in real life. Consider the customs, the government will never pay up to the maximum possible cost to check every traveler to get perfect information, because in this case all travelers know they must be checked, so no one would smuggle. However, if there are no smugglings, the government would have no incentives to make use of the public resources to set up the customs. Our model provides a logical explanation of this kind of phenomenon by showing that buyers would never bid up to the maximum possible cost to buy information in the equilibrium.

Moreover, it can be derived from Theorem 3.3 that only if $(1-p)[p(rV_H - rV_L)+(rV_L - V_L)] \leq I$, there exists pooling equilibrium. However, in pooling equilibrium, the problem of adverse selection exists, and the bad quality would drive out the good quality in the long run, because the expected payoff of S_L is strictly greater than the expected payoff of S_H, so S_H will eventually opt to produce the low-quality commodities to maximize his profit. We note that if I is sufficiently large, then the pooling equilibrium exists. This is intuitive – if the potential cost of information is too high to know the seller type, then it does not make any good senses to produce anything that is of high-quality, because the cost of finding out the quality level is too high.

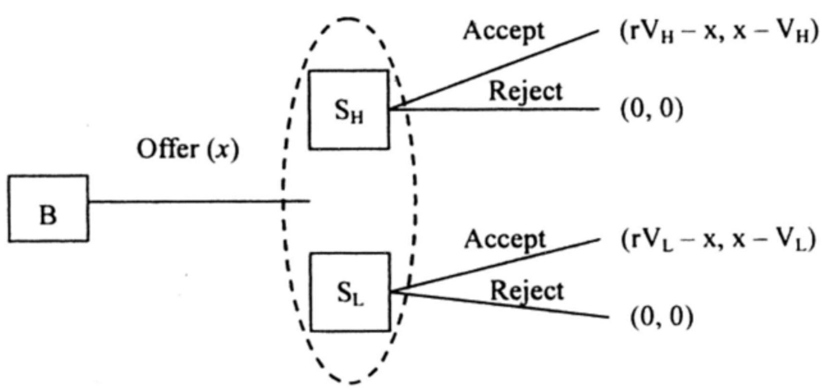
Finally, we notice that in all equilibria, buyer always has a positive expected payoff, compared to 0 in the simplest model without the option of buying information. This enhances the equity in the market. Furthermore, S_L and S_H have different expected payoffs in semi-pooling equilibrium, which solves the problem of adverse selection and enhance the sustainability of the market. Nevertheless, in all equilibria, there is always a chance for buyer to reject the proposed offers from S_L, which leads to deadweight loss and market inefficiency.

Next, we propose a different model with option of buying information, though it is not a common market mechanism in our daily marketplace.

3.2.3 Model under Proposed Market Mechanism

Again, this market mechanism gives buyer an option to buy information, but this time it is the buyer to make offers to the seller, then the seller decides to accept or reject. This is not a common practice in our daily marketplace, where customers are usually the price-takers. However, we are interested to investigate if this unusual market mechanism can enhance the total welfare in the society.

We first analyze the simplest model without the option of buying information in our proposed market mechanism.



Under asymmetric information where only the seller knows the quality of the commodities, buyer cannot distinguish between S_L and S_H, so buyer will either offer V_L, which will only be accepted by S_L; or offer V_H, which will be accepted by both S_L and S_H.

If buyer offers V_L, she expects to get:

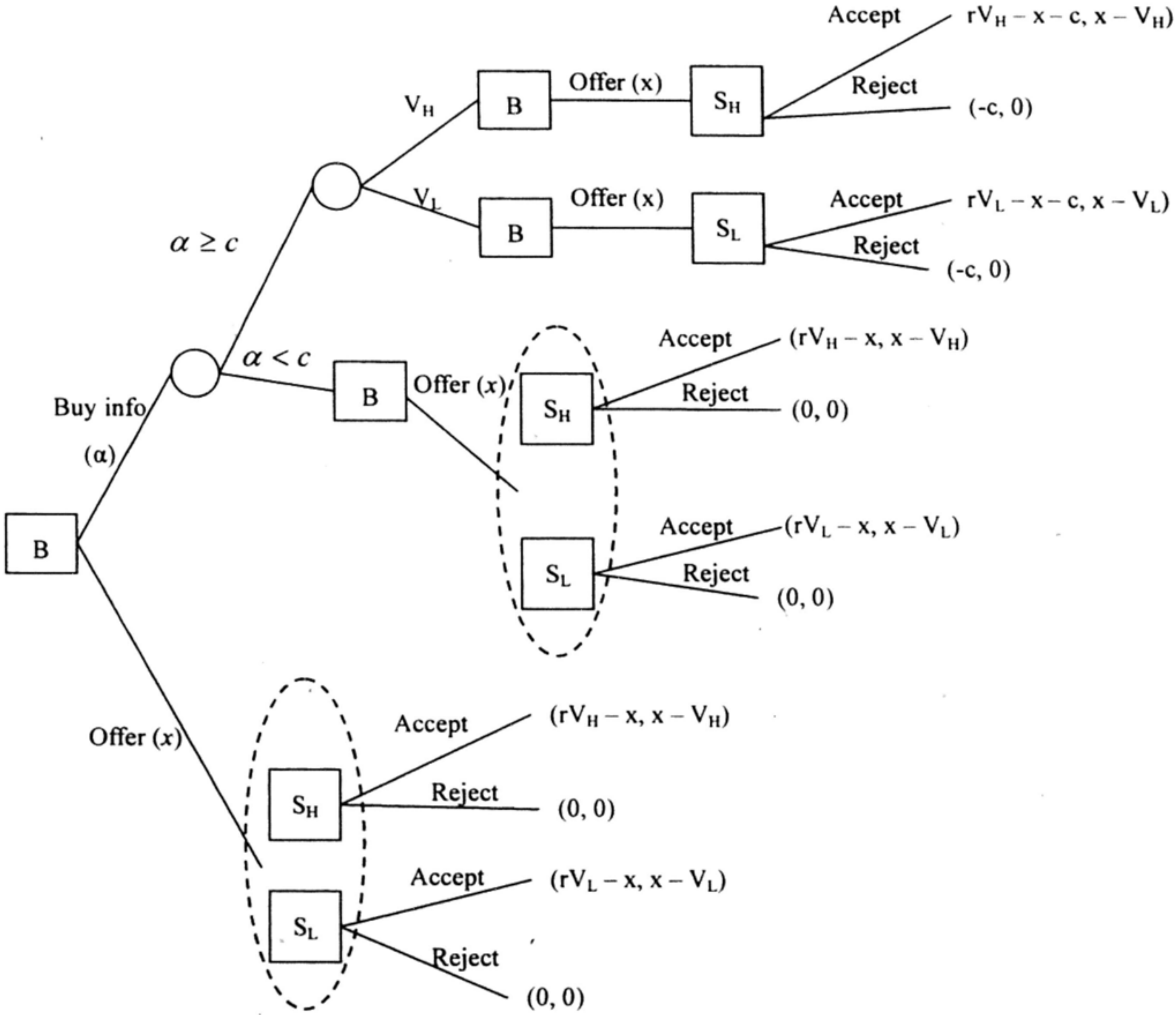
$$(1-p)(rV_L - V_L)$$

If buyer offers V_H, she expects to get:

$$(1-p)(rV_L - V_H) + p(rV_H - V_H)$$

Hence, buyer will compare the expected values of both offers and choose the higher one. Basically, if $V_H - V_L \geq p(rV_H - V_L)$, then buyer will offer V_L, else buyer will offer V_H. In the first case, the bad quality drives out the good quality; in the latter case, S_H will also be driven out from the market in the long run, as the cost of producing V_L is cheaper, but both S_H and S_L get the same offered amount from buyer, so S_H seller will eventually produce V_L commodities to maximize his profit.

In either case, the problem of adverse selection exists, and the bad quality drives out the good quality. Next, we study whether having an option of buying information will mitigate the problem. The following decision tree summarizes the complete model.



At the beginning, the buyer starts with bidding a price (α) for the information about the value of the commodity owned by the seller (i.e., V_H or V_L). The cost of information c is uniformly distributed between 0 and I. If the buyer's offer α is greater than c, then the buyer gets the information by paying c. Otherwise, the buyer will not get any information, nor does he pay any costs. After the outcome of bidding is revealed, the buyer makes an offer to the seller and the seller then can accept or reject the buyer's offer.

Without bidding for information, the buyer can offer either V_L, expecting to get $(1-p)(rV_L - V_L)$, or V_H, expecting to get $p(rV_H - V_H) + (1-p)(rV_L - V_H)$. Hence, we need to separate our discussions into two cases:

Cases 1: $(1-p)(rV_L - V_L) \geq p(rV_H - V_H) + (1-p)(rV_L - V_H)$ (which is equivalent to $V_H - V_L \geq p(rV_H - V_L)$)

In this case, the buyer will offer V_L if he fails to get the information. So, his expected payoff of bidding for information is:

$$EVBI(\alpha) = \frac{\alpha}{I}[p(rV_H - V_H) + (1-p)(rV_L - V_L) - \frac{\alpha}{2}] + (1 - \frac{\alpha}{I})(1-p)(rV_L - V_L)$$
$$= \frac{\alpha}{I} p(rV_H - V_H) + (1-p)(rV_L - V_L) - \frac{\alpha^2}{2I}$$

Since $EVBI(\alpha)$ is concave in α, it is easy to see that the optimal value of α must be either $p(rV_H - V_H)$ or I, depending on which is smaller.

If $\alpha = p(rV_H - V_H)$, $EVBI(\alpha)$ becomes $\frac{p^2(rV_H - V_H)^2}{2I} + (1-p)(rV_L - V_L)$, which is greater than $(1-p)(rV_L - V_L)$. If $\alpha = I$, $EVBI(\alpha)$ becomes $p(rV_H - V_H) + (1-p)(rV_L - V_L) - I/2$, which is also greater than $(1-p)(rV_L - V_L)$ since $p(rV_H - V_H) \geq I$ (implied by $\alpha = I$). So, in either case, the buyer should bid for information.

Cases 2: $(1-p)(rV_L - V_L) < p(rV_H - V_H) + (1-p)(rV_L - V_H)$ (which is equivalent to $V_H - V_L < p(rV_H - V_L)$)

In this case, the buyer will offer V_H if he fails to get the information. So, his expected payoff of bidding for information is:

$$EVBI(\alpha)$$

$$= \frac{\alpha}{I}[p(rV_H - V_H) + (1-p)(rV_L - V_L) - \frac{\alpha}{2}] + (1 - \frac{\alpha}{I})[(1-p)(rV_L - V_H) + p(rV_H - V_H)]$$

$$= p(rV_H - V_H) + (1-p)(rV_L - V_H) + \frac{\alpha}{I}(1-p)(V_H - V_L) - \frac{\alpha^2}{2I}$$

Since $EVBI(\alpha)$ is concave in α, it is easy to see that the optimal value of α must be either $(1-p)(V_H - V_L)$ or I, depending on which is smaller.

If $\alpha = (1-p)(V_H - V_L)$, $EVBI(\alpha)$ is $\frac{(1-p)^2(V_H - V_L)^2}{2I} + (1-p)(rV_L - V_H) + p(rV_H - V_H)$, which is greater than $p(rV_H - V_H) + (1-p)(rV_L - V_H)$, the expected value without bidding for information. If $\alpha = I$, $EVBI(\alpha)$ becomes $p(rV_H - V_H) + (1-p)(rV_L - V_L) - I/2$, which is also greater than $p(rV_H - V_H) + (1-p)(rV_L - V_H)$ since $\{p(rV_H - V_H) + (1-p)(rV_L - V_L) - I/2\} - \{p(rV_H - V_H) + (1-p)(rV_L - V_H)\} = (1-p)(V_H - V_L) - I/2 > 0$ as $(1-p)(V_H - V_L) \geq I$ (implied by $\alpha = I$). So, in either case, the buyer should bid for information.

We thus have the following theorem.

Theorem 3.5

If $V_H - V_L \geq p(rV_H - V_L)$, the buyer bids $\alpha = Min[p(rV_H - V_H), I]$ for the information. If she successfully gets the information, she will offer V_L to S_L, and V_H to S_H. If she fails to get the information, she will offer V_L.

If $V_H - V_L < p(rV_H - V_L)$, the buyer bids $\alpha = Min[(1-p)(V_H - V_L), I]$ for the information. If she successfully gets the information, she will offer V_L to S_L, and V_H to S_H. If she fails to get the information, she will offer V_H.

In both cases, S_L accepts all $x \geq V_L$ and rejects otherwise. S_H accepts all $x \geq V_H$ and rejects otherwise.

Insights

In all equilibria, buyers should always buy information, and the problem of adverse selection is mitigated under this market mechanism. In particular, under the condition $V_H - V_L < p(rV_H - V_L)$, or $(1-p)(V_H - V_L) \geq I$, we have 100% market transaction rates, so the deadweight loss is eliminated and the total welfare is maximized.

3.2.4 Model Comparison

The following table summarizes the models we discussed so far.

	Basic	Option of Buying Information (Prevailing)	Option of Buying Information (Proposed)
Solve Adverse Selection	Not in the long run	Yes under semi-pooling equilibria	Yes
Enhance Equity	No, buyers always get 0.	Yes	No, V_H sellers always get 0.
Enhance Efficiency	Yes if $prV_H + (1-p)rV_L > V_H$	No, there is always a chance that buyers reject offers from the V_L sellers.	Yes if $V_H - V_L < p(rV_H - V_L)$, or $(1-p)(V_H - V_L) \geq I$.

Remarks: 1) Here we define "equity" weakly as having positive expected payoffs for all parties, so it does not necessarily mean all parties are getting exactly the same expected payoffs.

2) We also define "efficiency" weakly as 100% transactions, which means all commodities are traded in the market, but the efficient market can incur costs paid to third party for buying information.

3.3 Hypothesis and Experimental Design

Our experiment aims to elicit how subjects place value on perfect information, and what kind of information revelation mechanism could have the most efficient market with minimum deadweight loss.

As shown in our previous analysis, the prevailing market mechanism is unable to clear market under all kinds of market conditions, but three out of four market conditions of our proposed market mechanism can have the market clear, as summarized below:

Can market be cleared in our proposed model under this market condition?		Buyer's offer if with no information	
		V_L	V_H
Optimal offer to buy information	$\alpha \leq I$	No	Yes
	$\alpha > I$	Yes	Yes

where α is the optimal offer for buyer to buy information.
I is the highest possible cost of information

We are interested to compare the prevailing and our proposed market mechanisms under these three conditions to investigate whether the reality follows our theoretical analysis that illustrates our proposed model dominates the prevailing model in term of market efficiency.

From the ultimatum game literature, we understand that transaction rate would seldom achieve 100% in practice even though the theoretical prediction says market would be cleared, as subjects would often reject positive payoffs if they are too small compared to their counter parties' payoffs. Moreover, subjects are usually not perfectly rational and would not do the game theoretical calculations to reconcile their behaviors to the equilibrium as suggested by the game theory. Therefore, we have the following minimal rationality hypothesis:

Hypothesis 1:

Transaction rate is higher in the proposed market mechanism than in the prevailing market mechanism, if same set of parameter values are used in both markets.

Theoretically, the transaction rate would achieve 100% so market is efficient in certain market conditions under our proposed market mechanism; however, we expect that similar to ultimatum games, some positive offers in both market mechanisms would be rejected if they are relatively too low. Hence, we hypothesize a higher transaction rate in our proposed market mechanism to test if it is a better model in term of market efficiency.

Hypothesis 2:

If seller with low-quality commodities chooses to mimic what seller with high-quality commodities would offer in the prevailing market mechanism, then he should offer exactly what seller with high-quality commodities would offer.

As shown in our analysis, seller with low-quality commodity would randomize between offering rV_L and x' (i.e. offer from the V_H seller), so he should not have any psychological barriers to mimic the V_H seller that lead him to offer some in-between prices.

Hypothesis 3:

All players could expect positive payoffs in both market mechanisms, thus enhancing equity in the market.

The theoretical analysis suggests that only the prevailing market mechanism but not the proposed market mechanism can enhance equity to all parties, as the V_H seller always gets zero profit in our proposed market mechanism. However, we learnt from ultimatum game that the first player would not necessarily take the whole pie size, as this would easily be rejected by their counter parties. Hence, we hypothesize that all parties in both market mechanisms can anticipate positive payoffs, thus equity is enhanced in both market mechanisms.

We selected the following sets of parameters to test all of the three conditions in our proposed model which suggest market would be cleared.

	Parameters and Theoretical Predictions for Our Proposed Model		
	Set 1: Buyer offers V_L if she fails to buy information, but as $\alpha > I$, buyer always successfully buys information.	**Set 2:** $\alpha \leq I$, and buyer offers V_H if she fails to buy information.	**Set 3:** Buyer offers V_H if she fails to buy information, but as $\alpha > I$, buyer always successfully buys information.
p	30%	50%	30%
r	1.5	2	2
I	\$20	\$55	\$33
V_H	\$200	\$150	\$130
V_L	\$100	\$60	\$80

where p is the proportion of V_H sellers in the market

r is the ratio that the commodity is worth more to the buyers than to the sellers

I is the upper bound of the information cost

V_H is the value of the high-quality commodity to the sellers

V_L is the value of the low-quality commodity to the sellers

Experimental Procedures:

For the prevailing market mechanism, at the start of the experiment, the computer will randomly assign the role of buyers and sellers (possessing low- or high-quality commodity) to each participant. Then, each seller would offer a price to sell the commodity, and randomly matches with a buyer. The buyer, who knows there are p and $1 \; p$ of the sellers with V_H and V_L commodities respectively in the market, can choose to immediately accept or reject the price, or she can choose to state the maximum price to buy perfect information about the quality of the commodity before she decides to accept or reject. If the buyer accepts the price, then she pays the price, and the commodity is worth r times the value of the commodity, and the seller receives the price minus the value of the commodity. Else, if buyer rejects, then both parties get \$0. In case the buyer chooses to state a maximum price to buy information, the computer will draw a random number, which is between 0 and I. If the maximum price stated by the buyer is larger than the random number, then buyer pays the random number and get the perfect information; else buyer gets nothing nor does she need to pay any costs.

For the proposed market mechanism, at the start of the experiment, the computer will randomly assign the role of buyers and sellers (possessing low or high quality commodity) to each participant. Then, each buyer would offer a price to buy the commodity, or she can choose to state the maximum price to buy perfect information about the quality of the commodity before she makes any offers to buy the commodity. If the buyer chooses to state a maximum price to buy information, the computer will draw a random number, which is between 0 and I. If the maximum price stated by the buyer is larger than the random number, then buyer pays the random number and get the perfect information; else buyer gets nothing but also does not need to pay anything. Then, the seller will be informed about the price that buyer proposed to buy his commodity, and he can choose to accept or reject. If seller accepts, then he receives the price minus the value of the commodity, while the buyer would get the commodity that is worth *r* times the value of the commodity, minus the price she paid. Else, if seller rejects, then both parties get $0.

Subjects were randomly assigned to the role of buyers or sellers at the beginning of all experiments, and played the same role for the entire experiment. In each period, however, they were matched with different, anonymous partners. The entire session consisted of 15 – 20 rounds, but the number of rounds was unknown to the subjects. To provide subjects sufficient incentives to play the game seriously, they were informed that they would be paid the weighted average of the profits they earned in 4 randomly selected games with a weighting of 10%, 20%, 30% and 40% in sequential order. The sequential weighted average is to encourage subjects who may get bored in the later rounds to perform consistently well throughout the entire experimental session, as later games are relatively more important in determining their final payoffs.

Prior to the start of the play, self-paced instructions were presented via individual PowerPoint presentation that includes interactive questions to assess their understanding of the experiment [the instructions are shown in Appendix 1 & 2]. Before the session starts, subjects were told that they would be paid HK$40 - HK$70 seed money to motivate them to read the instructions very carefully.

In each session, we have 34 – 38 participants, who are undergraduates or postgraduates at The Chinese University of Hong Kong. Participants earned HK$82 on average in an approximately one hour experiment, which is very attractive compared to the standard hourly rate of HK$50 for an on-campus job.

3.4 Experimental Results and Analysis

In this section, we will summarize the experimental results and conduct the hypothesis tests with the three sets of experimental parameters separately, and then conduct an aggregate analysis of all experimental data at the end of the section.

3.4.1 Parameter Set 1

In the first set of experiments, we have 30% of the sellers with high-quality commodities, and 70% of the sellers with low-quality commodities. The low-quality commodity and the high-quality commodity are worth $100 and $200 respectively to the sellers, and the values of the commodities are worth 1.5 times more to the buyers than to the sellers. The buyer's cost of buying perfect information is uniformly distributed between $0 and $20.

3.4.1.1 Theoretical Prediction

Prevailing Model

Based on the game theoretical analysis in Section 3.2, we would have a semi-pooling equilibrium with mixed strategies. Analysis is as follows:

Buyers always reject offers that are between $150 and $200, as any offers from sellers with high-quality commodities would not be less than $200, but the low-quality commodity is only worth \$150 to the buyers.

V_H sellers always offer x', and V_L sellers mix their strategies between offering x' and rV_L with probability β and 1 β respectively.

$$P(H \mid x') = \frac{P(x' \mid H)P(H)}{P(x' \mid H)P(H) + P(x' \mid L)P(L)} = \frac{p}{p + \beta(1-p)}$$

$$P(L \mid x') = 1 - P(H \mid x') = \frac{\beta(1-p)}{p + \beta(1-p)}$$

$$x' = P(H \mid x')rV_H + P(L \mid x')rV_L$$

$$x' = \frac{I}{P(L \mid x')} + V_L$$

Solving the equations, we have:

$x' = \$284$

$P(H \mid x') = 89\%$; $P(L \mid x') = 11\%$

$\alpha = \$15$

Hence, the rejection rate in the market is $\frac{15}{20} \times 11\% = 8\%$[7]. In other words, there should be 8% of the commodities in the market left with no transactions.

In equilibrium, buyers expect to get \$5, V_L sellers expect to get \$50, and V_H

[7] In the experiment, the random numbers are integers, so buyers have 16 (0, 1, , 14, 15) out of 21 (0, 1, , 19, 20) chances to successfully buy information rather than 15/20; however, the difference is minimal, so we would use the theoretical calculation, which is more intuitive. The same approach will be used when calculating the rejection rate for parameter set 2 and set 3.

sellers expect to get $84.

Proposed Model

Buyers will offer V_L if they fail to buy information, as offering V_L they expect to get $(1-p)(rV_L - V_L) = 0.7 \times (\$100 \times 1.5 - \$100) = \$35$, but offering V_H they get $(1-p)(rV_L - V_H) + p(rV_H - V_H) = 0.7 \times (\$150 - \$200) + 0.3 \times (\$300 - \$200) = -\$5$.

However, they would prefer to buy information rather than immediately proposing an offer to buy the commodity, The optimal offer to buy perfect information is $p(rV_H - V_H) = 0.3(1.5 \times \$200 - \$200) = \$30$. Since this is greater than the possible highest information cost ($20), so buyers would simply offer $20 to ensure they are able to buy perfect information, and then offer V_L if the commodity is of low quality, V_H if the commodity is of high quality, and sellers always accept. Hence, the transaction rate is 100% for all commodities.

In equilibrium, buyers expect to get $55, and both high-quality and low-quality sellers expect to get $0.

3.4.1.2 Experimental Results

The following tables summarize the major findings for the two market mechanisms.

	Prevailing Market Mechanism		Proposed Market Mechanism	
	Theoretical Predication	Experiment Result	Theoretical Predication	Experiment Result
Average payoff for Buyers	\$5.3	\$12.3	\$55.0	\$28.7
Average payoff for V_L Sellers	\$50.0	\$29.5	\$0.0	\$10.8
Average payoff for V_H Sellers	\$83.7	\$41.7	\$0.0	\$16.2
Proportion of buyers who buy information*	100%	76.3%	100%	98.5%
Average offer to buy information	\$14.6	\$13.6	\$20.0	\$15.8
Average offer from V_H Sellers	\$283.7	\$260.9	N.A.	N.A.
Average offer from V_L Sellers who mimic V_H Sellers	\$283.7	\$252.0	N.A.	N.A.
Percentage of V_L Sellers to mimic V_H Sellers	5.2%	15.6%	N.A.	N.A.
Proportion of $>V_H$ offers that are from V_L Sellers	10.9%	23.7%	N.A.	N.A.
Proportion of $>V_H$ offers that are from V_H Sellers	89.1%	76.3%	N.A.	N.A.
Rejection rate in the market	7.9%	28.1%	0%	24.4%

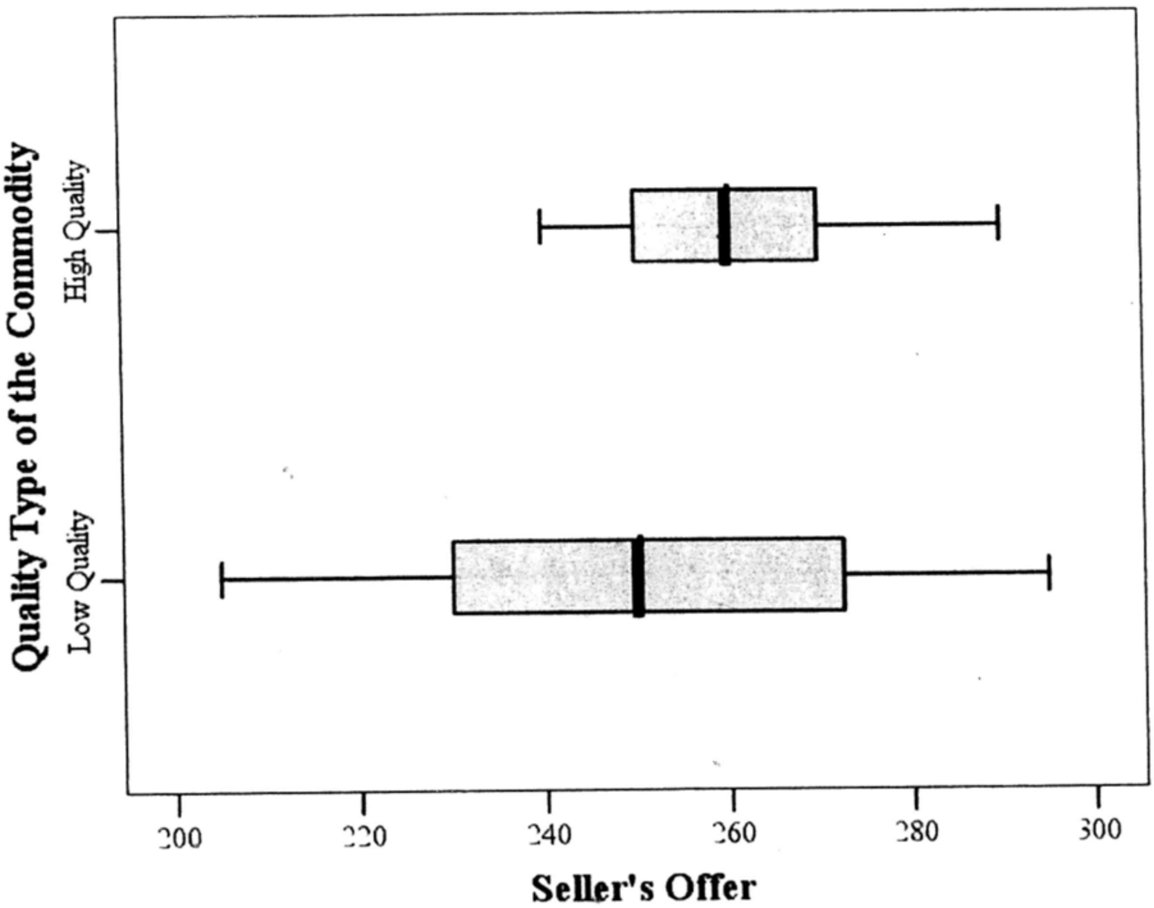
* In the prevailing market mechanism, we only count those buyers when seller's offer is larger than V_H; while in the proposed market, we count all buyers.

Testing Hypothesis 1:

The one-tail test for the difference between two proportions obtained from independent sample shows a p-value of 0.164, so we are unable to reject the hypothesis to show that the transaction rate in the proposed market mechanism is higher than in the prevailing market mechanism.

We then conducted a two-tail test to examine whether the difference of rejection rates between the prevailing market mechanism and proposed market mechanism in the experiments is significantly different from the theoretical prediction of 7.9%. The p-value is 0.265, so we cannot reject the hypothesis that there is 7.9% difference in rejection rates.

Testing Hypothesis 2:



The above box-and-whisker plots[8] summarize the distributions of offers from sellers with high-quality commodities and sellers with low-quality commodities who mimic the V_H sellers. Apparently, the V_H sellers are less likely to make mistakes, and their offers are more concentrated at around $\$200 + \$100 \times 60\% = \$260$, which is 60% of the pie size (the pie size is $100 because the high-quality commodity is

[8] There were four offers greater than $150 but less than $200, which were apparently careless mistakes, so we took them out from the box-and-whisker plots.

worth \$200 to sellers and \$300 to buyers, so there is essentially \$100 for sellers and buyers to divide among themselves). The two-tail separate-variance t test for the difference between the two means shows a p-value of 0.069, so we are unable to reject the hypothesis that the V_L sellers offer the same mean amount as V_H sellers when they are trying to mimic the V_H sellers at 5% significance level.

Testing Hypothesis 3:

The one-tail t tests showed that the mean payoffs for buyers, V_L sellers and V_H sellers in both market mechanisms are all significantly greater than \$0 (p-value is 0.000 in all cases), which provided a strong evidence that equity is enhanced in both market mechanisms, as all parties expect positive payoffs.

3.4.2 Parameter Set 2

In the second set of experiments, we have 50% of the sellers with high-quality commodities, and 50% of the sellers with low-quality commodities. The low-quality commodity and high-quality commodity are worth \$60 and \$150 respectively to the sellers, and the values of the commodities are worth 2 times more to the buyers than to the sellers. The buyer's cost of buying perfect information is uniformly distributed between \$0 and \$55.

3.4.2.1 Theoretical Prediction

<u>Prevailing Model</u>

Based on the game theoretical analysis in Section 3.2, we would have a semi-pooling equilibrium with mixed strategies. Analysis is as follows:

Buyers always reject offers that are between \$120 and \$150, as any offers from sellers with high-quality commodities would not be less than \$150, but the low-quality commodity is only worth \$120 to the buyers.

V_H sellers always offer x', and V_L sellers mix their strategies between offering x' and rV_L with probability β and $1-\beta$ respectively.

$$P(H \mid x') = \frac{P(x' \mid H)P(H)}{P(x' \mid H)P(H) + P(x' \mid L)P(L)} = \frac{p}{p + \beta(1-p)}$$

$$P(L \mid x') = 1 - P(H \mid x') = \frac{\beta(1-p)}{p + \beta(1-p)}$$

$$x' = P(H \mid x')rV_H + P(L \mid x')rV_L$$

$$x' = \frac{I}{P(L \mid x')} + V_L$$

Solving the equations, we have:

$x' = \$247$

$P(H \mid x') = 71\%;\ \ P(L \mid x') = 29\%$

$\alpha = \$37$

Hence, the rejection rate in the market is $\frac{37}{55} \times 29\% = 20\%$. In other words, there would be 20% of the commodities in the market left with no transactions.

In equilibrium, buyers expect to get \$13, V_L sellers expect to get \$60, and V_H sellers expect to get \$97.

Proposed Model

Buyers will offer V_H if they fail to buy information, as offering V_H they expect to get $(1-p)(rV_L - V_H) + p(rV_H - V_H) = 0.5 \times (\$120 - \$150) + 0.5 \times (\$300 - \$150) = \$60$, but offering V_L they expect to get $(1-p)(rV_L - V_L) = 0.5 \times (\$120 - \$60) = \$30$. However, they would prefer to buy information rather than immediately proposing an offer to buy the commodity, The optimal offer to buy perfect information is $(1-p)(V_H - V_L) = 0.5(\$150 - \$60) = \$45$. If buyers successfully buy perfect information, they will offer V_L for the low-quality commodity, and V_H for the high-quality commodity. Else, if buyers fail to buy information, they will offer V_H. In either case, sellers would always accept. Hence, the transaction rate is 100% for all commodities in the market.

In equilibrium, buyers expect to get \$78, low-quality sellers expect to get \$16, and high-quality sellers expect to get \$0.

3.4.2.2 Experimental Results

The following tables summarize the major findings for the two market mechanisms.

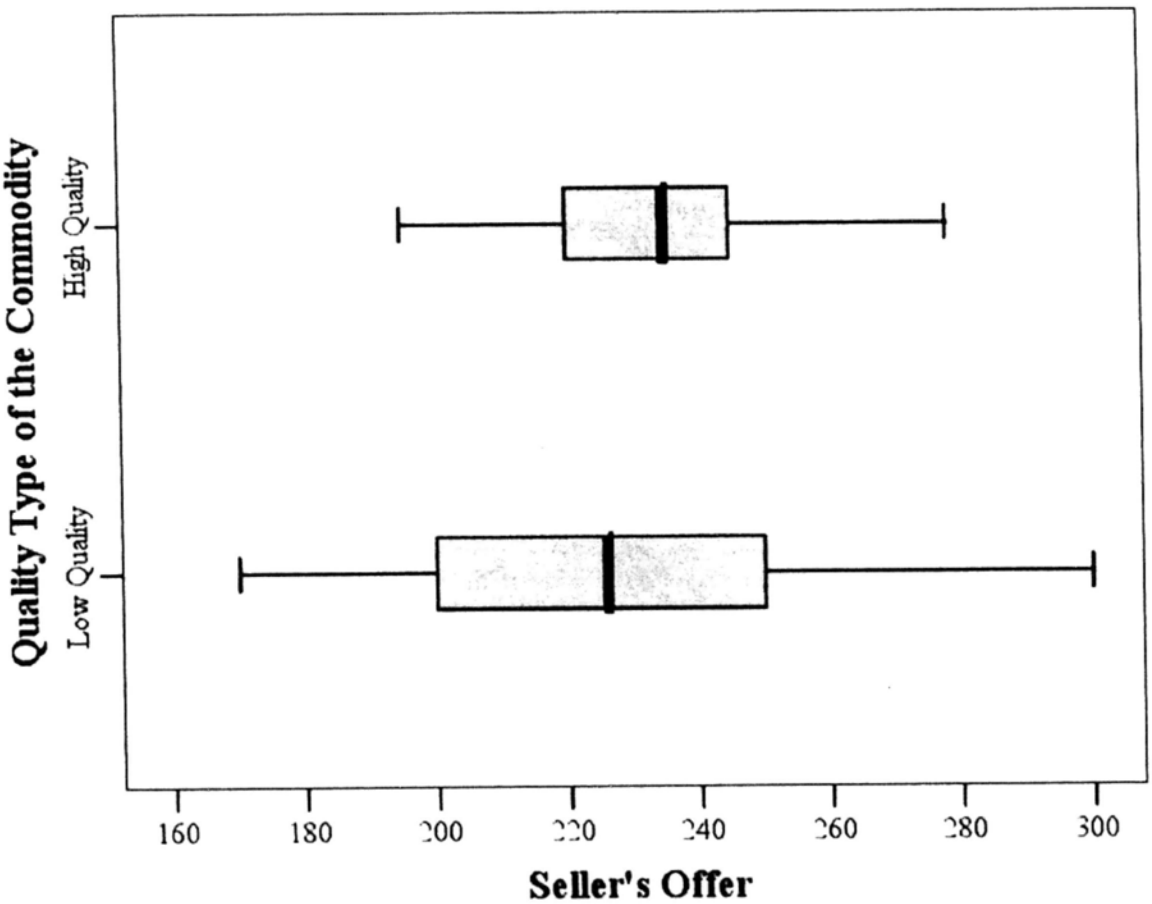
	Prevailing Market Mechanism		Proposed Market Mechanism	
	Theoretical Predication	Experiment Result	Theoretical Predication	Experiment Result
Average payoff for Buyers	\$12.7	\$17.0	\$78	\$34.5
Average payoff for V_L Sellers	\$60.0	\$39.5	\$16	\$28.7
Average payoff for V_H Sellers	\$97.1	\$65.0	\$0	\$16.5
Proportion of buyers who buy information*	100%	80.2%	100%	90.6%
Average offer to buy information	\$37.4	\$30.9	\$45	\$36.4
Average offer from V_H Sellers	\$247.1	\$235.1	N.A.	N.A.
Average offer from V_L Sellers who mimic V_H Sellers	\$247.1	\$233.3	N.A.	N.A.
Percentage of V_L Sellers to mimic V_H Sellers	41.6%	34.4%	N.A.	N.A.
Proportion of >V_H offers that are from V_L Sellers	29.4%	25.6%	N.A.	N.A.
Proportion of >V_H offers that are from V_H Sellers	70.6%	74.4%	N.A.	N.A.
Rejection rate in the market	20.0%	32.8%	0%	24.7%

* In the prevailing market mechanism, we only count those buyers when seller's offer is larger than V_H; while in the proposed market, we count all buyers.

Testing Hypothesis 1:

The one-tail test for the difference between two proportions obtained from independent sample shows a p-value of 0.009, so we can reject the hypothesis and conclude that the transaction rate in the proposed market mechanism is significantly higher than in the prevailing market mechanism.

Testing Hypothesis 2:



The above box-and-whisker plots[9] summarize the distributions of offers from sellers with high-quality commodities and sellers with low-quality commodities who mimic the V_H sellers. Apparently, the V_H sellers are less likely to make mistakes, and their offers are more concentrated at around $\$150 + \$150 \times 60\% = \$240$, which is 60% of the pie size (the pie size is \$150 because the high-quality commodity is worth \$150 to sellers and \$300 to buyers, so there is essentially \$150 for sellers and buyers to divide among themselves). The two-tail separate-variance t test for the difference between the two means shows a p-value of 0.775, so the hypothesis that the V_L sellers offer the same mean amount as V_H sellers when mimicking the V_H sellers cannot be rejected.

[9] There were two offers at \$130, two offers at \$150 and one offer at \$500, which are apparently careless mistakes, so we took them out from the box-and-whisker plot.

Testing Hypothesis 3:

The one-tail t tests showed that the mean payoffs for buyers, V_L sellers and V_H sellers in both market mechanisms are significantly greater than \$0 (p-value is 0.000 in all cases), which provided a strong evidence that equity is enhanced in both market mechanisms, as all parties expect positive payoffs.

3.4.3 Parameter Set 3

In the third set of experiments, we have 30% of the sellers with high-quality commodities, and 70% of the sellers with low-quality commodities. The low-quality commodity and high-quality commodity are worth \$80 and \$130 respectively to the sellers, and the values of the commodities are worth 2 times more to the buyers than to the sellers. The buyer's cost of buying perfect information is uniformly distributed between \$0 and \$33.

3.4.3.1 Theoretical Prediction

Prevailing Model

Based on the game theoretical analysis in Section 3.2, we would have a semi-pooling equilibrium with mixed strategies. Analysis is as follows:

V_H sellers always offer x', and V_L sellers mix their strategies between offering x' and rV_L with probability β and 1 β respectively.

$$P(H \mid x') = \frac{P(x' \mid H)P(H)}{P(x' \mid H)P(H) + P(x' \mid L)P(L)} = \frac{p}{p + \beta(1-p)}$$

$$P(L \mid x') = 1 - P(H \mid x') = \frac{\beta(1-p)}{p + \beta(1-p)}$$

$$x' = P(H \mid x')rV_H + P(L \mid x')rV_L$$

$$x' = \frac{I}{P(L \mid x')} + V_L$$

Solving the equations, we have:

$x' = \$239$

$P(H \mid x') = 79\%$; $P(L \mid x') = 21\%$

$\alpha = \$16$

Hence, the rejection rate in the market is $\frac{16}{33} \times 21\% = 10\%$. In other words, there would be 10% of the commodities in the market left with no transactions.

In equilibrium, buyers expect to get \$4, V_L sellers expect to get \$80, and V_H sellers expect to get \$109.

Proposed Model

Buyers will offer V_H if they fail to buy information, as offering V_H they expect to get $(1-p)(rV_L - V_H) + p(rV_H - V_H) = 0.7 \times (\$160 - \$130) + 0.3 \times (\$260 - \$130)$ =\$60, but offering V_L they expect to get $(1-p)(rV_L - V_L) = 0.7 \times (\$160 - \$80)$ = \$56.

However, they would prefer to buy information rather than immediately proposing an offer to buy the commodity, The optimal offer to buy perfect information is $(1-p)(V_H - V_L) = 0.7(\$130 - \$80) = \$35$. Since this is greater than the possible highest information cost (\$33), so buyers would simply offer \$33 to ensure they are able to buy perfect information, and then offer V_L if the commodity is of low quality, V_H if the commodity is of high quality, and sellers always accept. Hence, the transaction rate is 100% transactions for all commodities in the market.

In equilibrium, buyers expect to get \$78.5, and both low-quality and high-quality sellers expect to get \$0.

3.4.3.2 Experimental Results

The following tables summarize the major findings for the two market mechanisms.

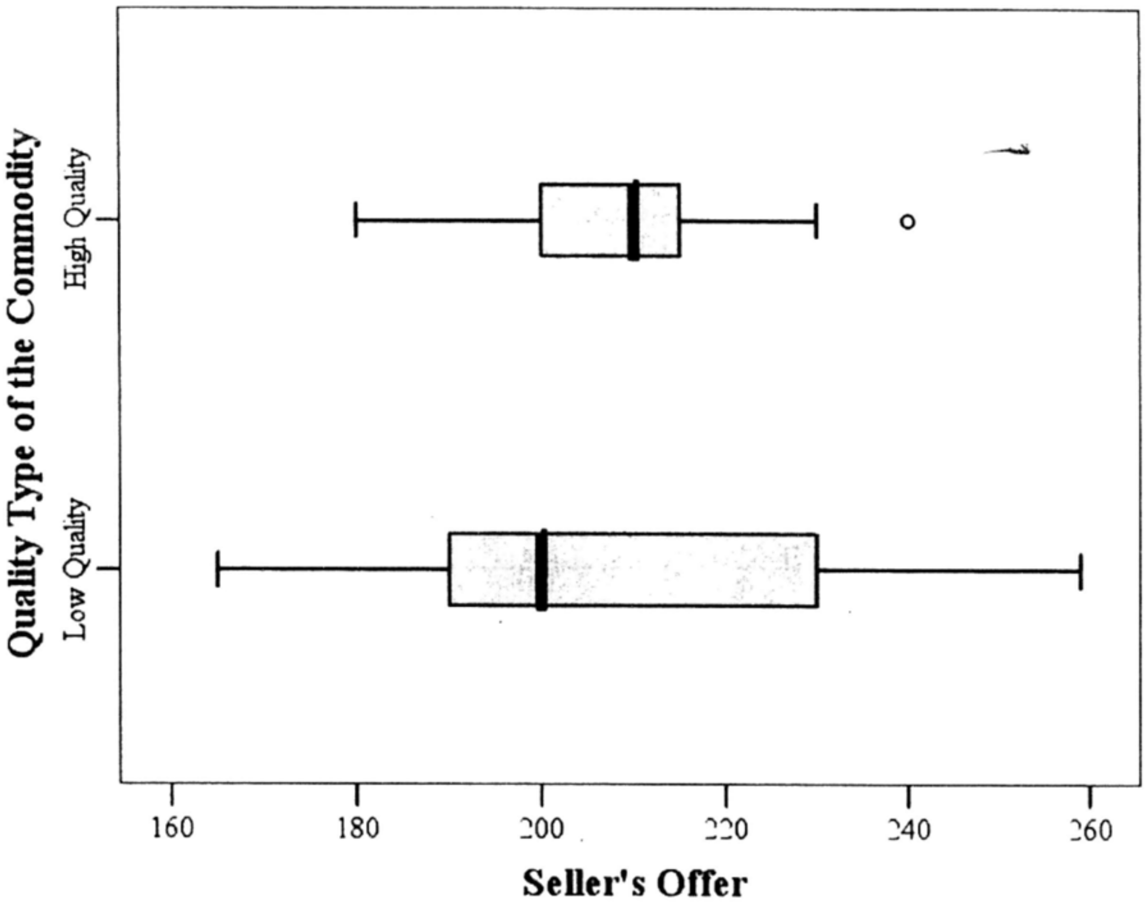
	Prevailing Market Mechanism		Proposed Market Mechanism	
	Theoretical Predication	Experiment Result	Theoretical Predication	Experiment Result
Average payoff for Buyers	\$4.1	\$11.2	\$78.5	\$38.6
Average payoff for V_L Sellers	\$80.0	\$49.4	\$0	\$27.7
Average payoff for V_H Sellers	\$109.3	\$51.9	\$0	\$18.3
Proportion of buyers who buy information*	100%	68.2%	100%	88.2%
Average offer to buy information	\$16.4	\$17.0	\$33	\$17.2
Average offer from V_H Sellers	\$239.3	\$206.6	N.A.	N.A.
Average offer from V_L Sellers who mimic V_H Sellers	\$239.3	\$205.9	N.A.	N.A.
Percentage of V_L Sellers to mimic V_H Sellers	11.2%	29.6%	N.A.	N.A.
Proportion of $>V_H$ offers that are from V_L Sellers	20.7%	39.5%	N.A.	N.A.
Proportion of $>V_H$ offers that are from V_H Sellers	79.3%	60.5%	N.A.	N.A.
Rejection rate in the market	10.3%	33.9%	0%	28.2%

* In the prevailing market mechanism, we only count those buyers when seller's offer is larger than V_H; while in the proposed market, we count all buyers.

Testing Hypothesis 1:

The one-tail test for the difference between two proportions obtained from independent sample shows a p-value of 0.049, so we can reject the hypothesis at 5% significance level and conclude that the transaction rate in the proposed market mechanism is higher than in the prevailing market mechanism.

Testing Hypothesis 2:



The above box-and-whisker plots summarize the distributions of offers from sellers with high-quality commodities and sellers with low-quality commodities who mimic the V_H sellers. Apparently, the V_H sellers are less likely to make mistakes, and their offers are more concentrated at around $\$130 + \$130 \times 60\% = \$208$, which is 60% of the pie size (the pie size is \$130 because the high-quality commodity is worth \$130 to sellers and \$260 to buyers, so there is essentially \$130 for sellers and buyers to divide among themselves). The two-tail separate-variance t test for the difference between the two means shows a p-value of 0.821, so the hypothesis that the V_L sellers offer the same mean amount as V_H sellers when they are trying to mimic the V_H sellers cannot be rejected.

Testing Hypothesis 3:

The one-tail t tests showed that the mean payoffs for buyers, V_L sellers and V_H sellers in both market mechanisms are significantly greater than \$0 (p-value is 0.000 in all cases), which provided a strong evidence that equity is enhanced in both market mechanisms, as all parties expect positive payoffs.

1.4.4 Aggregate Analysis of Experimental Results

It appears that the experimental results do not follow the game theoretical prediction. Then, what kinds of strategies are subjects playing in these games?

From the ultimatum literature, we learnt that people cannot claim 100% of the pie size, as it would be easily rejected by their counter parties. A commonly acceptable spilt would be some amounts between 50:50 and 60:40.

<u>Prevailing Market Mechanism</u>

From Section, 3.2.2, we analyzed the prevailing market mechanism using a game theoretical approach, and conclude that for the equilibrium to hold, we need the following conditions:

1. $P(H \mid x')(rV_H - x') + P(L \mid x')(rV_L - x') \geq 0$
2. $P(H \mid x')(rV_H - x') + P(L \mid x')(rV_L - x') \leq 0$
3. $(1 - \frac{P(L \mid x')(x' - rV_L)}{I})(x' - V_L) \geq rV_L - \mathrm{V_L}$
4. $V_H \leq x' \leq rV_H$
5. $0 \leq \beta \leq 1$

Condition 1, 3 & 5 form the necessary conditions for the V_L sellers to follow the equilibrium, while Conditions 2 & 4 are for the V_H sellers. However, in reality, V_H sellers cannot really optimize the offer x' to maximize their expected payoffs, as buyers would simply reject if the offers are relatively too low, even if the offers give buyers positive expected payoffs. Therefore, the value of x' is not purely determined by "rational" strategies, but it is rather constrained to be less than certain percentage, say π_1 (usually 60% based on the ultimatum game literature), of the pie size. This argument is supported by our experimental data, which show that the mean demands of the pie size from the V_H sellers in Parameter Set 1, 2 & 3 are 59%, 56% and 59% respectively. Similarly, for V_L sellers, they cannot really offer rV_L and expect buyers to accept; instead they would have to offer some amount less than rV_L. From the experimental data, we found that the mean demands of the pie size from the V_L sellers in Parameter Set 1, 2 & 3 are 81%, 81% and 87% respectively. Therefore, we would assume that the V_L sellers would claim π_2 of the pie size in equilibrium[10]. For our experimental analysis, we would assume π_2 equal to 80%, because for all $\pi_2 \leq 80\%$, the acceptance rate is over 90% in all experimental sessions. To sum up, for the equilibria to hold, we have the following conditions:

1. $P(H \mid x')(rV_H - x') + P(L \mid x')(rV_L - x') \geq 0$
2. $x' \leq \pi_1(rV_H - V_H) + V_H$
3. $(1 - \dfrac{P(L \mid x')(x' - rV_L)}{I})(x' - V_L) \geq \pi_2(rV_L - V_L)$
4. $V_H \leq x' \leq rV_H$
5. $0 \leq \beta \leq 1$

[10] The difference in the claimed percentage of the pie size between V_H sellers and V_L sellers is justified given the fact that buyers would likely to have to pay a cost to buy information to accept any commodities with high quality. Similar behaviors about the changes of fairness concept under different strategic positions were found in the literature, which we have discussed in Section 2.2.5.

In Parameter Set 1, the mean of all offers that are larger than V_H (\$200) is \$259, so by solving Condition 3, we have:

$$[1-\frac{P(L\mid x')(\$259-\$150)}{\$20}](\$259-\$100)\geq 0.8(\$150-\$100)$$

$$P(L\mid x')\leq 13.7\%$$

Since for all $0\%\leq P(L\mid x')<13.7\%$, the expected values for offering x' are greater than offering $0.8(rV_L-V_L)+V_L$ for V_L sellers, so there is a high incentive for V_L sellers to mimic V_H sellers. However, to maintain the equilibrium, the maximum proportion of V_L sellers to mimic V_H sellers is:

$$P(L\mid x')=\frac{\beta(1-p)}{p+\beta(1-p)}$$

$$\beta=\frac{p\times P(L\mid x')}{(1-p)[1-P(L\mid x')]}$$

$$\beta=\frac{0.3\times 13.7\%}{0.7\times(1-13.7\%)}$$

$$\beta=6.8\%$$

where β is the probability of the V_L sellers to mimic the V_H sellers.

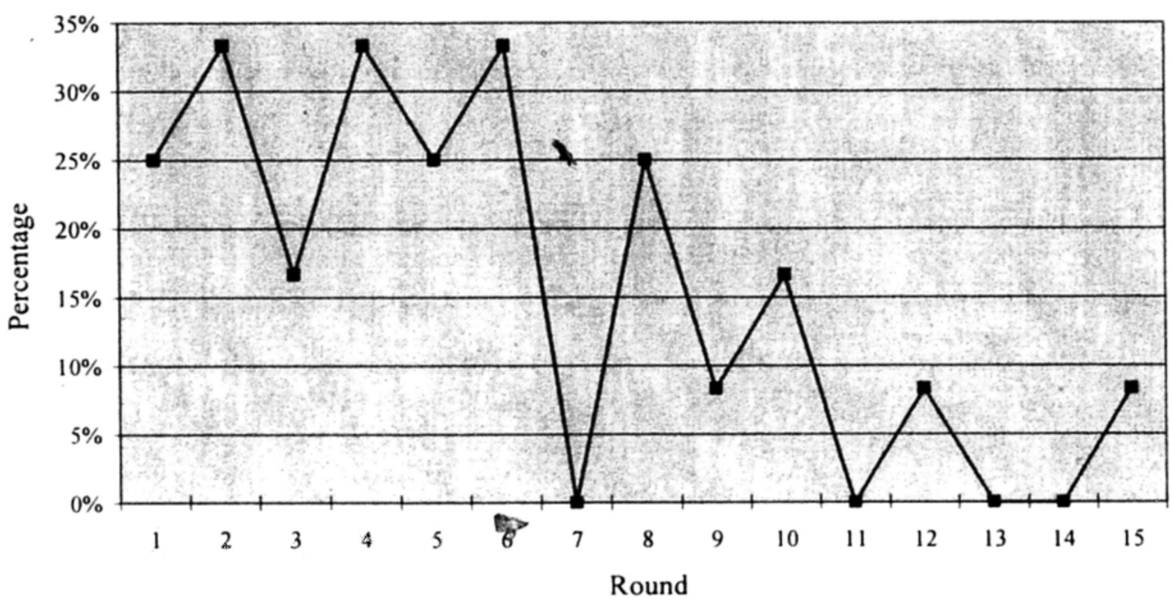
Therefore, V_L sellers should randomize their strategies to offer \$259 with 6.8%, and to offer \$140 with 93.2%.

For buyers, they should pay $P(L\mid x')(x'-rV_L)=0.137\times(\$259-\$150)=\$15$ to buy information, and in case they fail to buy information, they would prefer accepting to rejecting the offers, because acceptance would give them an expected payoff of $P(H\mid x')(rV_H-x')+P(L\mid x')(rV_L-x')=0.863\times\$41+0.137\times(-\$109)$ =\$20; while rejection would give them \$0.

The mean offer to buy information in the experiment was \$13.6, which is quite close to the predicted value of \$15. However, the mean value of β from the experimental data was 15.6%, which is out of the equilibrium range of 0% to 6.8%. Theoretically, if the percentage of V_L sellers who mimic the V_H sellers (i.e. value of β) is larger than 6.8%, then buyers would have incentives to pay a higher offer to buy information, which will lead to a higher chance for buyers to successfully buy information, thus rejecting offers from V_L sellers who mimic the V_H sellers. As a result, the expected payoff for V_L sellers to mimic the V_H sellers would be lower than the expected payoff of offering $0.8(rV_L - V_L) + V_L$. In this case, the equilibrium would collapse. Hence, we are interested to investigate whether subjects learn from experience, and adjust their strategies accordingly.

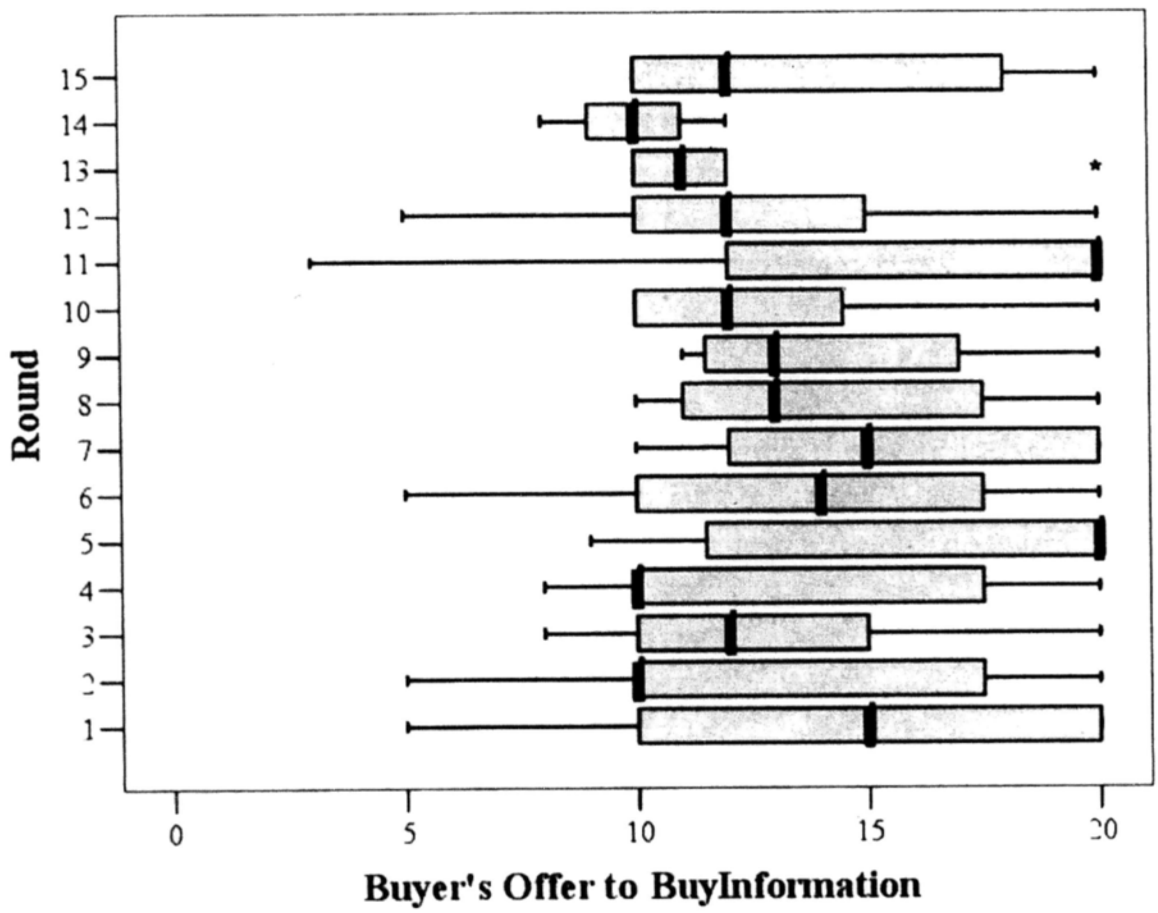
From the percentage of V_L sellers who mimic the V_H sellers across periods as plotted below, we notice that though the aggregate mean value of β is 15.6%, the V_L sellers actually learnt to mimic less and gradually towards an average of 6.8% mimicking proportion after 10 rounds of plays.

Percentage of low-type sellers mimicking high-type sellers (β)



We then study the pattern of buying information across periods. The following table shows the average offers to buy information, and the proportion of buyers who opt to buy information in each round. The box-and-whisker plot shows the actual distribution of the offers to buy information across periods.

Round	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Average Offer to Buy Information	$14	$13	$13	$13	$16	$13	$15	$14	$14	$13	$15	$12	$13	$10	$14
Proportion of Buyers who Buy Information	89%	70%	63%	80%	78%	70%	83%	78%	57%	100%	83%	71%	83%	67%	71%



The data show an adaptation of buyer's decision to buy information based on the proportion of the V_L sellers who mimic the V_H sellers. To verify the trend, we ran a regression analysis of the buyer's offer to buy information against the proportion of V_L sellers who mimic the V_H sellers in the previous three rounds, and the regression results show a p-value of 0.017, R^2 of 0.45, and a positive value of coefficient. Apparently, buyers realized that when there are more V_L sellers to mimic the V_H sellers in the market, they should offer a higher value to buy information. The V_L sellers also realized that if the collective proportion of V_L sellers to mimic what the V_H sellers offer in the market is too high, their mimicking offers are very likely to be rejected. Therefore, both buyers and sellers are adapting their behaviors towards the equilibrium across periods.

Next, we study Parameter Set 2, in which the mean of all offers that are larger than V_H (\$150) is \$235, so we have:

$$[1-\frac{P(L\mid x')(\$235-\$120)}{\$55}](\$235-\$60)\geq 0.8(\$120-\$60)$$
$$P(L\mid x')\leq 34.7\%$$

Since for all $0\%\leq P(L\mid x')<34.7\%$, the expected values for offering x' is greater than offering $0.8(rV_L-V_L)+V_L$ for V_L sellers, so there is a high incentive for V_L sellers to mimic V_H sellers. However, to maintain the equilibrium, the maximum proportion of V_L sellers to mimic V_H sellers is:

$$P(L\mid x')=\frac{\beta(1-p)}{p+\beta(1-p)}$$
$$\beta=\frac{p\times P(L\mid x')}{(1-p)[1-P(L\mid x')]}$$
$$\beta=\frac{0.5\times 34.7\%}{0.5\times(1-34.7\%)}$$

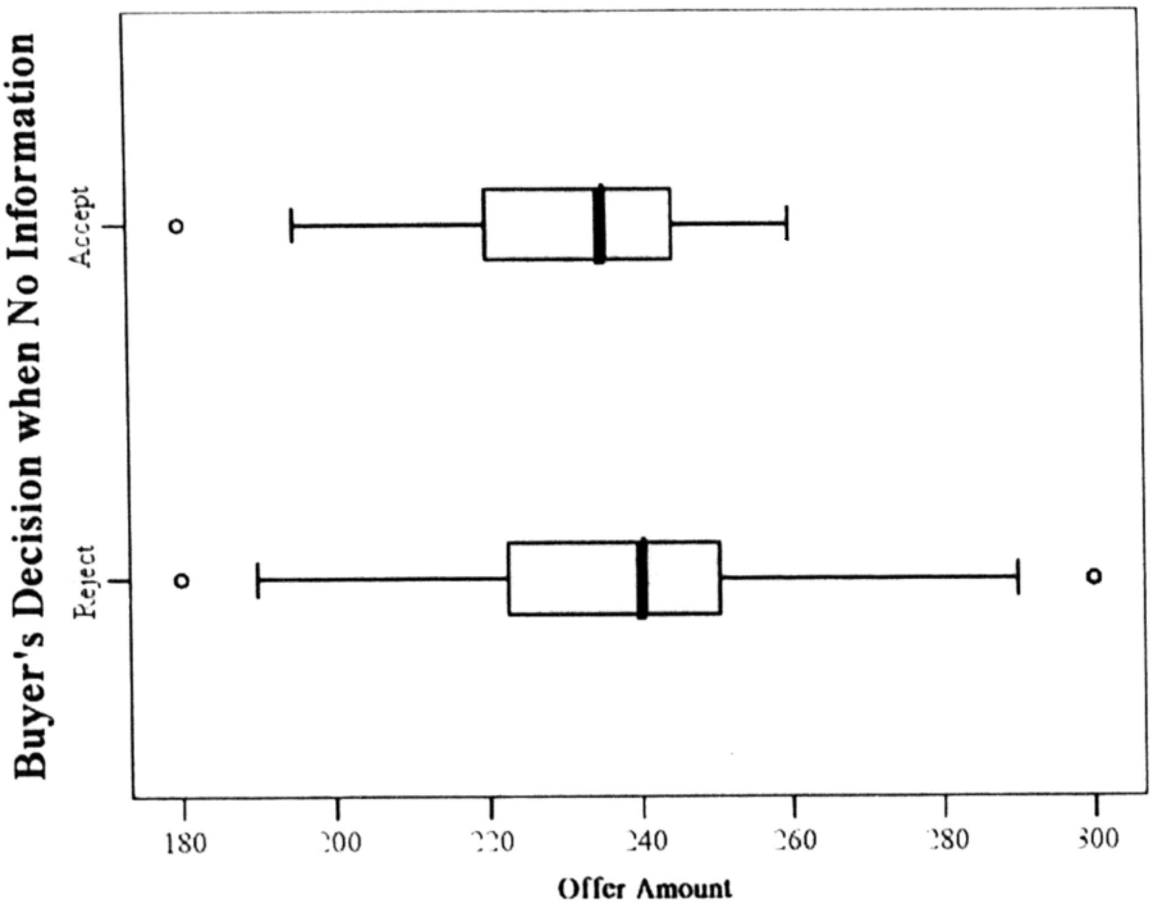
$\beta = 53.1\%$

where β is the probability of the V_L sellers to mimic the V_H sellers.

Therefore, V_L sellers should randomize their strategies to offer \$235 with 53.1%, and to offer \$108 with 46.9%.

For buyers, they should pay $P(L \mid x')(x' - rV_L) = 0.347 \times (\$235 - \$120) = \$40$ to buy information, and in case they fail to buy information, they would prefer accepting to rejecting the offers, because acceptance would give them an expected payoff of $P(H \mid x')(rV_H - x') + P(L \mid x')(rV_L - x') = 0.653 \times \$65 + 0.347 \times (-\$115)$ $= \$3$; while rejection would give them \$0.

However, even though \$3 is greater than \$0, many people are risk averse so they would not always accept the offers when they fail to buy information, because it is possible to loss \$115 with a probability of 34.7% if they accept. The potential loss is relatively large for buyers (more than \$100, compared to less than \$100 in the games with Parameter Set 1 and Set 3). In fact, among those buyers who did not get the perfect information about the quality of the commodity in this experimental setting, only 56% chose to accept the offers. The following box-and-whisker plot shows a similar distribution pattern and overlapping range of the offer amounts between the accepted and rejected offers, so we conjecture that buyers essentially randomize their decisions to accept or reject offers with an equal chance when they fail to buy information.



In this case, the optimal value for buyers to buy information becomes:

$$\frac{P(L \mid x')(x' - rV_L) + (1 - P(L \mid x'))(rV_H - x')}{2}$$

Hence, the value of $P(L \mid x')$ is:

$$\{1 - \frac{[P(L \mid x')(\$235 - \$120) + (1 - P(L \mid x'))(\$300 - \$235)] \div 2}{\$55}\}(\$235 - \$60) \geq 0.8(\$120 - \$60)$$

$$P(L \mid x') \leq 29.7\%$$

The proportion of V_L sellers to mimic V_H sellers is:

$$P(L \mid x') = \frac{\beta(1-p)}{p + \beta(1-p)}$$

$$\beta = \frac{p \times P(L \mid x')}{(1-p)[1-P(L \mid x')]}$$

$$\beta = \frac{0.5 \times 29.7\%}{0.5 \times (1-29.7\%)}$$

$$\beta = 42.2\%$$

where β is the probability of the V_L sellers to mimic the V_H sellers.

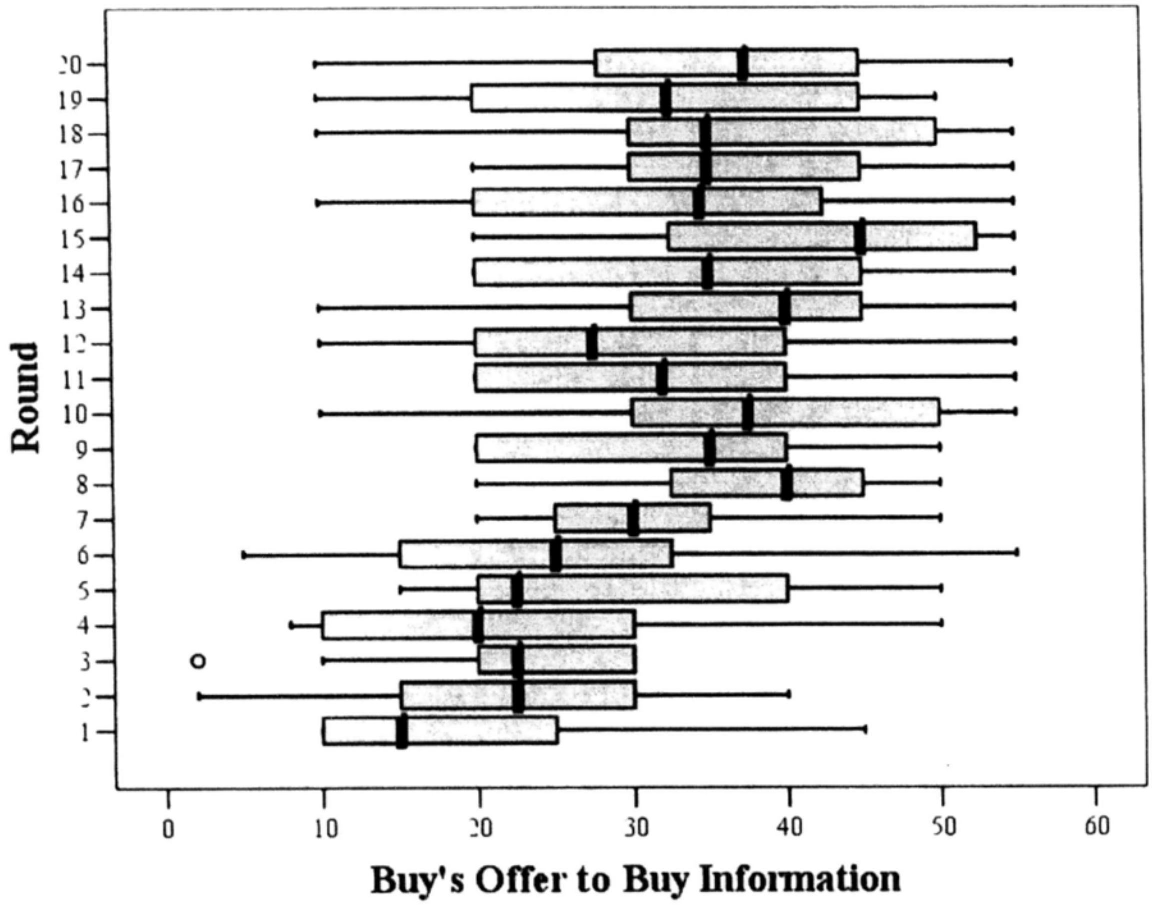
Therefore, V_L sellers should randomize their strategies to offer \$235 with 42.2%, and to offer \$108 with 57.8%.

For buyers, they should pay $\frac{P(L \mid x')(x'-rV_L)+(1-P(L \mid x'))(rV_H - x')}{2}$ =\$39.9 to buy information, and in case they fail to buy information, they would randomize between accepting and rejecting with a 50:50 chance.

The mean offer to buy information in the experiment was \$30.9, compared to the predicted value of \$39.9. The mean value of β from the experimental data was 34.4%, which is within the equilibrium range of 0% to 42.2%.

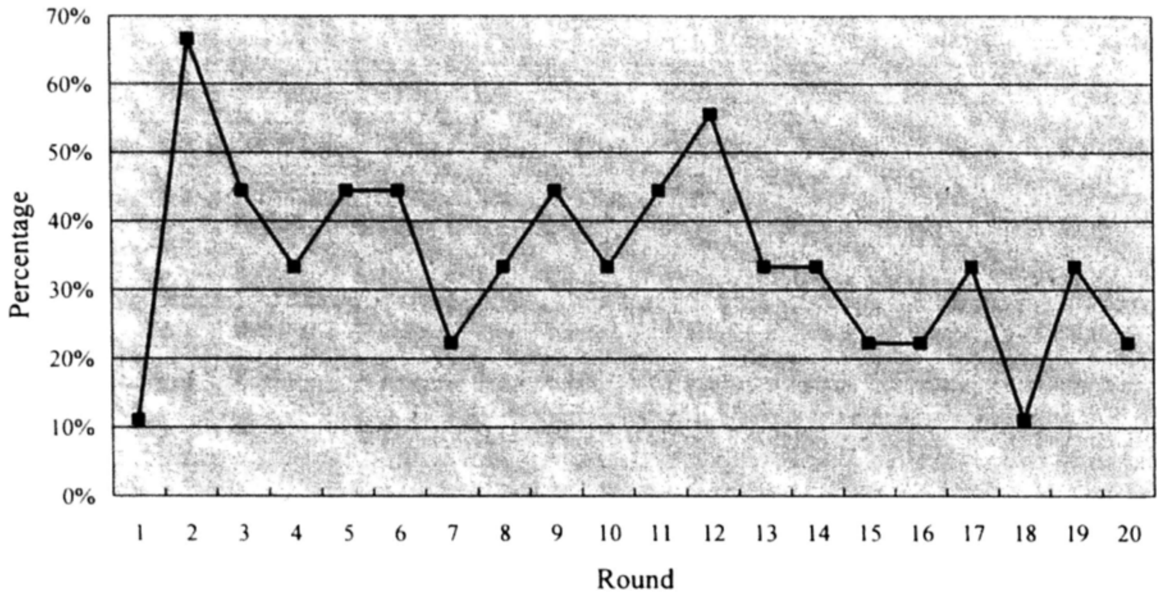
The following table summarizes buyer's average offers and the proportion of buyers who opt to buy information across periods, while the box-and-whisker plot shows the actual distribution of the offers to buy information across periods.

Round	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Average Offer to Buy Information	\$20	\$22	\$22	\$24	\$29	\$25	\$31	\$38	\$33	\$37	\$33	\$30	\$36	\$35	\$41	\$32	\$37	\$37	\$32	\$36
Proportion of Buyers who Buy Information	90%	93%	92%	83%	67%	85%	82%	58%	69%	83%	77%	86%	75%	83%	64%	73%	83%	90%	83%	91%



Though the aggregate mean offer ($30.9) to buy information in the experiment was significantly lower than the theoretical prediction, it could be accounted by the fact that inexperienced subjects offered significantly less amounts in the first few rounds. There was a trend for buyers to increase their offers to buy information, moving steadily towards the equilibrium prediction of $39.9, and then settled at slightly below $39.9. This is consistent with the experimental proportion of V_L sellers who mimic the V_H sellers across periods, which also settled at slightly below the optimal proportion as per the equilibrium prediction. The proportion distribution across periods is summarized in the following graph. We are not surprised to see these results, as people are usually risk averse, so V_L sellers may slightly prefer to have a more certain payoff of $48 by offering $108, rather than offering $235 to earn a potential payoff of $175 but with more than 50% chance of being rejected.

Percentage of low-type sellers mimicking high-type sellers (β)



Finally, we study Parameter Set 3, which the mean of all offers that are larger than rV_L (\$160) is \$206, so we have:

$$[1-\frac{P(L\mid x')(\$206-\$160)}{\$33}](\$206-\$80)\geq 0.8(\$160-\$80)$$

$$P(L\mid x')\leq 35.3\%$$

Since for all $0\%\leq P(L\mid x')<35.3\%$, the expected values for offering x' are greater than offering $0.8(rV_L-V_L)+V_L$ for V_L sellers, so there is a high incentive for V_L sellers to mimic V_H sellers. However, to maintain the equilibrium, the maximum proportion of V_L sellers to mimic V_H sellers is:

$$P(L\mid x')=\frac{\beta(1-p)}{p+\beta(1-p)}$$

$$\beta=\frac{p\times P(L\mid x')}{(1-p)[1-P(L\mid x')]}$$

$$\beta = \frac{0.3 \times 35.3\%}{0.7 \times (1 - 35.3\%)}$$

$$\beta = 23.4\%$$

where β is the probability of the V_L sellers to mimic the V_H sellers.

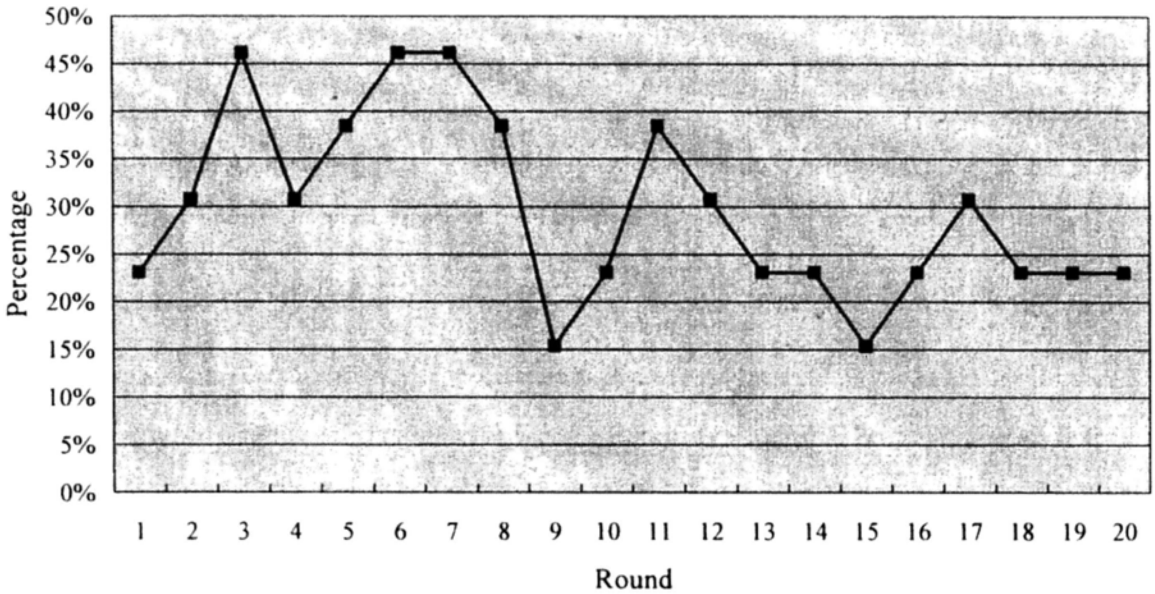
Therefore, V_L sellers should randomize their strategies to offer \$206 with 23.4%, and to offer \$144 with 76.6%.

For buyers, they should pay $P(L \mid x')(x' - rV_L) = 0.353 \times (\$206 - \$160) = \$16$ to buy information, and in case they fail to buy information, they would prefer accepting to rejecting the offers, because acceptance would give them an expected payoff of $P(H \mid x')(rV_H - x') + P(L \mid x')(rV_L - x') = 0.647 \times \$54 + 0.353 \times (-\$46)$ =\$19; while rejection would give them \$0.

The mean offer to buy information in the experiment was \$17, which is quite close to the predicted value of \$16. However, the mean value of β from the experimental data was 29.6%, which is out of the equilibrium range of 0% to 23.4%. Theoretically, if the percentage of V_L sellers who mimic the V_H sellers (i.e. value of β) is larger than 23.4%, then buyers would have incentives to pay a higher offer to buy information, which will lead to a higher chance for buyers to successfully buy information, thus rejecting offers from the V_L sellers who mimic the V_H sellers. As a result, the expected payoff for the V_L sellers to mimic the V_H sellers would be lower than the expected payoff of offering $0.8(rV_L - V_L) + V_L$. In this case, the equilibrium would collapse. Hence, we are interested to investigate whether subjects learn from experience, and adjust their strategies accordingly.

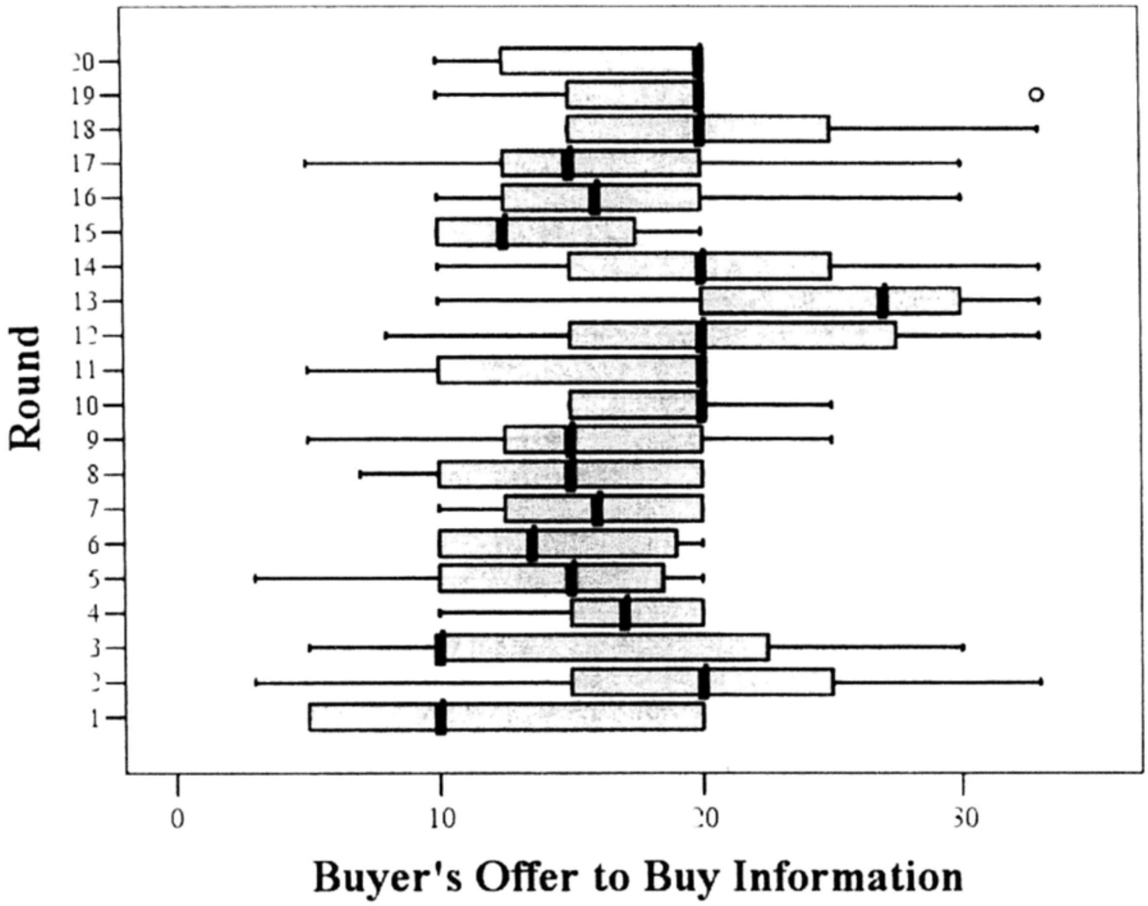
From the percentage of V_L sellers who mimic the V_H sellers across periods as plotted below, we notice that though the aggregate mean value of β is 29.6%, the V_L sellers actually learnt to mimic less and gradually towards an average of 23.4% mimicking proportion after 12 rounds of plays.

Percentage of low-type sellers mimicking high-type sellers (β)



We then study the pattern of buying information across periods. The following table shows the average offers to buy information, and the proportion of buyers who opt to buy information in each round. The box-and-whisker plot shows the actual distribution of the offers to buy information across periods.

Round	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Average Offer to Buy Information	$12	$19	$15	$16	$14	$14	$16	$15	$16	$19	$16	$21	$25	$21	$14	$17	$16	$21	$19	$17
Proportion of Buyers who Buy Information	56%	70%	67%	50%	64%	67%	73%	80%	88%	56%	73%	70%	67%	56%	50%	78%	70%	67%	78%	89%



It seems that buyers were able to derive \$16 to be the optimal offer to buy information after a few rounds of trails, so the offers were concentrated at around \$16 from Round 4 – 9. However, because there were too many V_L sellers trying to mimic V_H sellers on the first 8 rounds, so buyers increase their offers to buy information starting Round 10. Though the V_L sellers were later learnt to mimic less towards the equilibrium level starting Round 13, there were only a small portion of buyers realized it and decreased their offers to buy information towards the equilibrium level accordingly.

Proposed Market Mechanism

From Section, 3.2.3, we analyzed the proposed market mechanism using a game theoretical approach, and showed that buyers would compare the value between $(1-p)(rV_L - V_L)$ and $(1-p)(rV_L - V_H) + p(rV_H - V_H)$, and then offer $\alpha = p(rV_H - V_H) \leq I$ to buy information and offer V_L to buy the commodity if they fail to buy information given $(1-p)(rV_L - V_L)$ is larger; otherwise buyers would offer $\alpha = (1-p)(V_H - V_L)$ to buy information and offer V_H to buy the commodity if they fail to buy information.

However, from the ultimatum game literature, we know that buyers cannot claim the whole pie size and offer V_L to expect sellers with low-quality commodity to accept with probability 1; nor buyers can assume both types of sellers would accept when offering V_H. Instead, buyers can only demand a portion of the pie size, say π. Therefore, in reality, buyers will offer either $rV_L - \pi(rV_L - V_L)$ or $rV_H - \pi(rV_H - V_H)$ depends on which of the following is larger:

$$[(1-p)\{rV_L - [rV_L - \pi(rV_L - V_L)]$$
$$= (1-p)\pi(rV_L - V_L)$$

$$(1-p)\{(rV_L - [rV_H - \pi(rV_H - V_H)]\} + p\{rV_H - [rV_H - \pi(rV_H - V_H)]\}$$
$$= (1-p)r(V_L - V_H) + \pi(rV_H - V_H)$$

The optimal offer to buy information is $p\pi(rV_H - V_H) \leq I$ in the first case; and the following in the second case:

$$(1-p)\{[rV_H - \pi(rV_H - V_H)] - [rV_L - \pi(rV_L - V_L]\}$$
$$= (1-p)[(1-\pi)r(V_H - V_L) + \pi(V_H - V_L)] \leq I$$

From the ultimatum game literature, we learnt that a commonly acceptable demand is 60% of the pie size, so we would assume $\pi = 0.6$ when we analyze our experimental results.

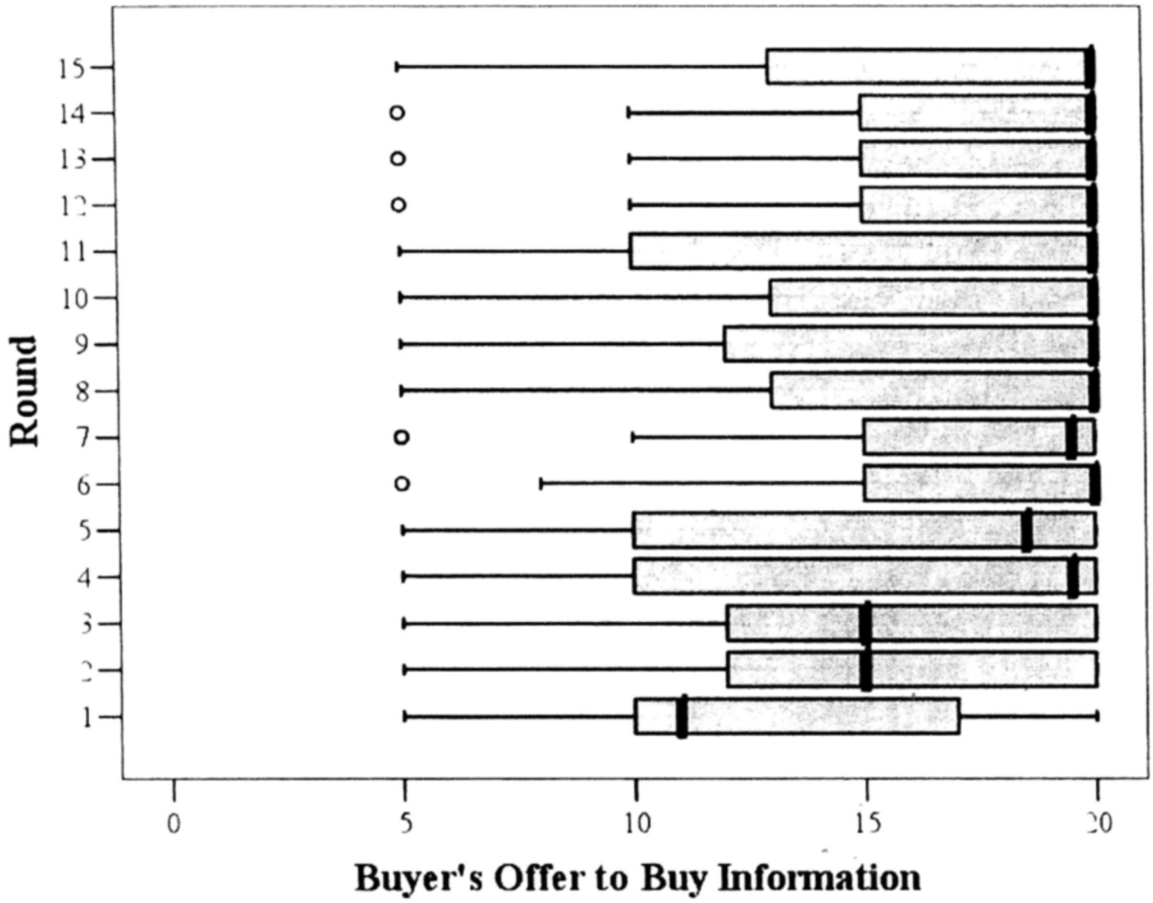
We have $(1-p)\pi(rV_L - V_L) > (1-p)r(V_L - V_H) + \pi(rV_H - V_H)$ in all of the three sets of experimental parameters, so buyers would offer $p\pi(rV_H - V_H) \leq I$ to buy information, and offer $rV_L - \pi(rV_L - V_L)$ for sellers with low-quality commodity and $rV_H - \pi(rV_H - V_H)$ for sellers with high quality commodity. In case buyers fail to buy information, they would offer $rV_L - \pi(rV_L - V_L)$.

In Parameter Set 1, buyers are supposed to offer \$18 to buy information. Calculation is as follows:

$$\begin{aligned} & p\pi(rV_H - V_H) \\ & = 0.3 * 0.6 * (1.5 * 200 - 200) \\ & = 18 \end{aligned}$$

The following table and box-and-whisker plot show the average offers to buy information, the proportion of buyers who opt to buy information in each round, and the distribution of the offers to buy information across periods. After a few rounds of learning, buyer's offers to buy information have moved towards the equilibrium prediction.

Round	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Average Offer to Buy Information	\$13	\$14	\$14	\$16	\$16	\$17	\$16	\$16	\$16	\$16	\$16	\$17	\$17	\$17	\$17
Proportion of Buyer who Buy Information	83%	94%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%

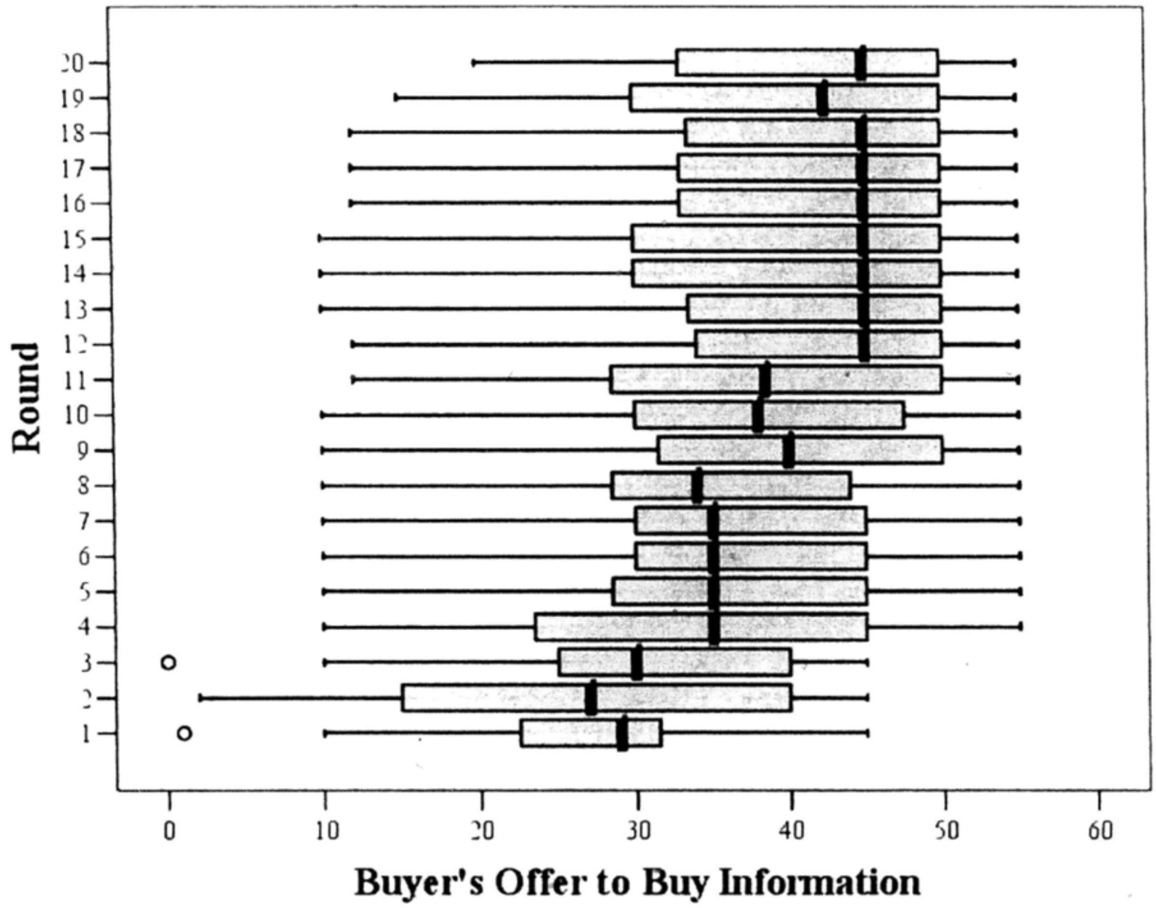


In Parameter Set 2, buyers are supposed to offer $45 to buy information. Calculation is as follows:

$$
\begin{aligned}
& p\pi(rV_H - V_H) \\
&= 0.5 * 0.6 * (2 * 150 - 150) \\
&= 45
\end{aligned}
$$

The following table and box-and-whisker plot show the average offers to buy information, the proportion of buyers who opt to buy information in each round, and the distribution of the offers to buy information across periods. After a few rounds of learning, buyer's offers to buy information have moved towards the equilibrium prediction – especially starting Round 12, the median is exactly $45.

Round	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Average Offer to Buy Information	$27	$27	$29	$34	$34	$36	$36	$35	$39	$38	$38	$40	$40	$39	$39	$40	$41	$40	$39	$41
Proportion of Buyer who Buy Information	94%	88%	100%	88%	94%	88%	88%	94%	88%	88%	94%	88%	88%	94%	94%	88%	88%	88%	94%	82%

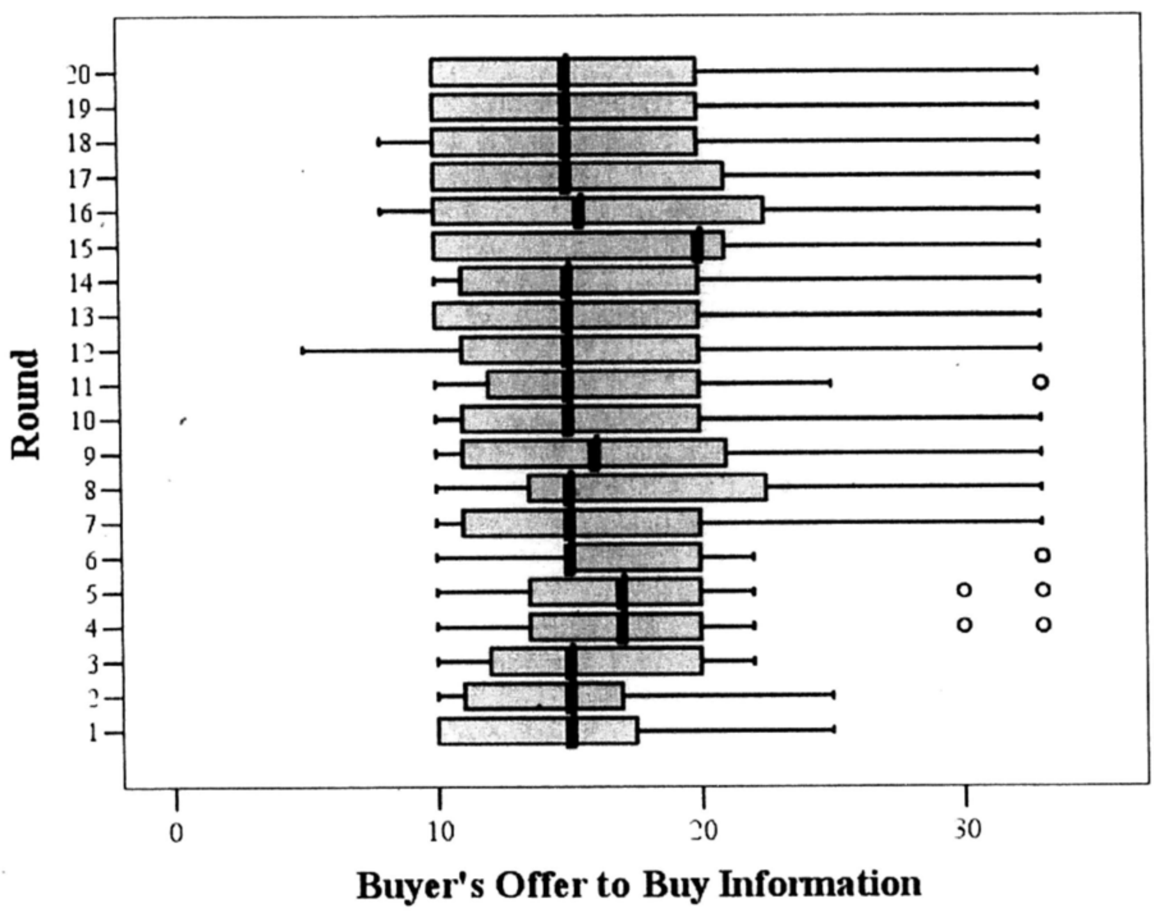


In Parameter Set 3, buyers are supposed to offer \$23.4 to buy information. Calculation is as follows:

$$
\begin{aligned}
& p\pi(rV_H - V_H) \\
& = 0.3 * 0.6 * (2 * 130 - 130) \\
& = 23.4
\end{aligned}
$$

The following table and box-and-whisker plot show the average offers to buy information, the proportion of buyers who opt to buy information in each round, and the distribution of the offers to buy information across periods. The buyer's offer never moves close to the equilibrium prediction at \$23.4. However, we are aware that Parameter Set 3 is different from Set 1 and Set 2 in term of the relation between rV_L and V_H. In Set 3, $rV_L > V_H$, and we found 41%[11] of buyers offer $V_H \le x \le rV_L$, which is much more than $rV_L - \pi(rV_L - V_L)$, when they do not have any information about the quality of the commodity. These relatively large offers when without information were not found in Set 1 and Set 2. Surprisingly, when the V_H sellers get these offers $V_H \le x \le rV_L$, which is essentially claiming 77% to 100% of the pie size from the V_H sellers, 61% of the V_H sellers actually choose to accept! Therefore, it makes sense for buyers to offer less than the equilibrium prediction to buy information.

Round	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Average Offer to Buy Information	$15	$15	$16	$18	$18	$18	$17	$19	$18	$17	$18	$17	$17	$18	$18	$18	$17	$17	$17	$16
Proportion of Buyer who Buy Information	65%	71%	76%	88%	88%	88%	88%	88%	94%	88%	88%	88%	88%	88%	88%	94%	94%	100%	100%	100%



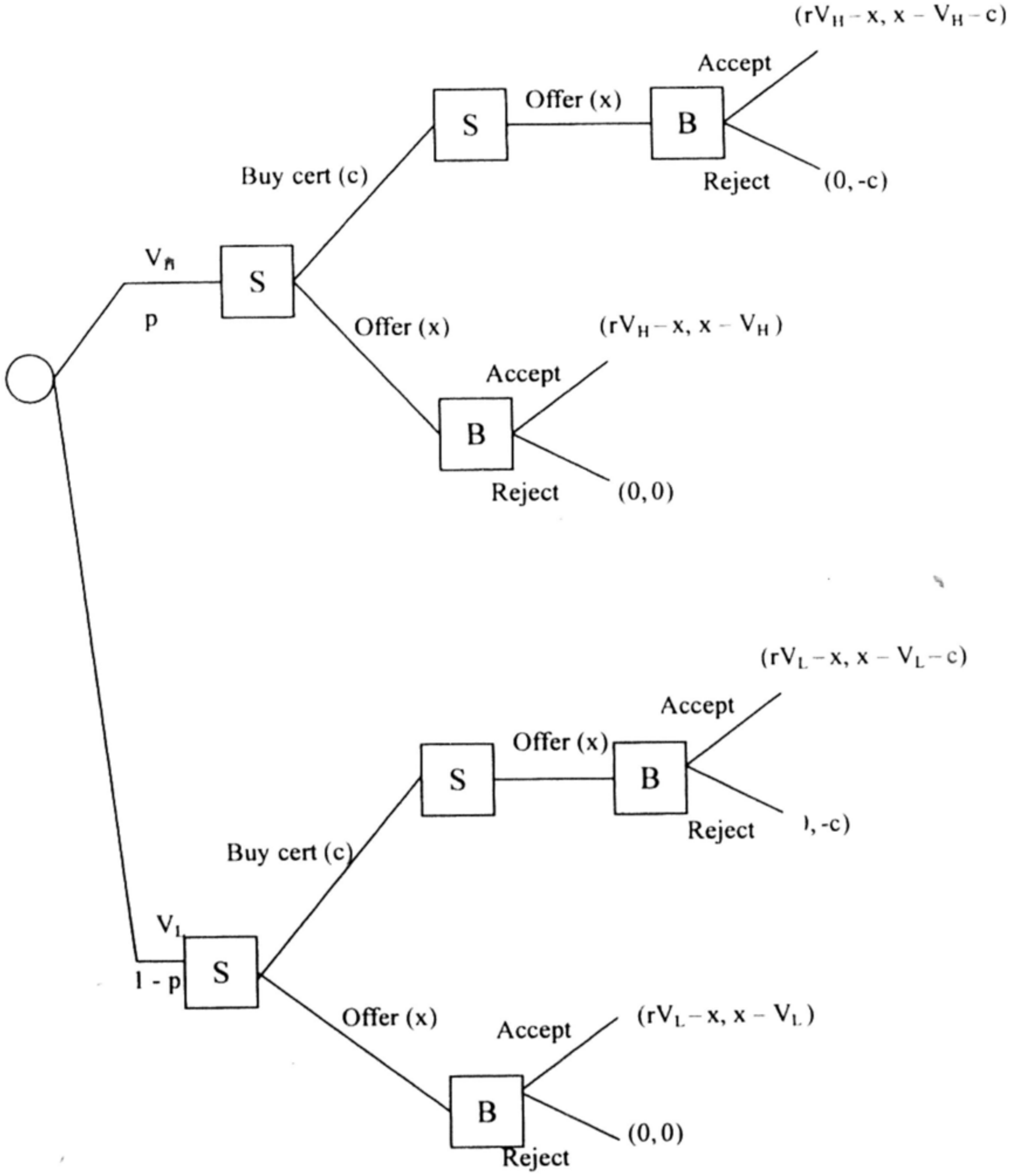
[11] There were 5 offers less than $80 ($V_L$), and 1 offer larger than $260 ($rV_H$), so we took these offers out from the percentage calculation.

3.5 Conclusions

In this chapter, we demonstrated that deadweight loss is unavoidable in the prevailing market mechanism, and showed that our proposed market mechanism can eliminate deadweight loss in many market conditions. The argument was also supported by the experimental data.

We also proposed a behavioral game theory, which add in the fairness consideration, to study the experimental data, and the results were promising. We found that subjects generally evaluate value of information rationally given the fairness consideration.

There are two potential extensions to further research into the problems addressed in this chapter. On one hand, we can study whether our proposed behavioral game theory can also explain the behaviors found in other economic experiments. On the other hand, we could study if there exists other market mechanisms that can also minimize deadweight loss. For instance, suppose there is a third party organization (e.g. ISO) offering reliable certificate for the quality of the commodities at cost c, and seller can choose to buy certificate before he offers x to buyer. Then, buyer can choose to accept or reject seller's offer. The following decision tree summarizes the model.



Depends on the market parameter values, seller would have different strategies. Hence, we separate our discussions in two cases.

Case 1: $prV_H + (1-p)rV_L \le V_H$

As shown in the previous analysis of the basic model in Section 3.2.1, the expected payoff of V_H seller if he does not buy certificate is $(rV_L - V_L) \times \frac{x' - V_H}{x' - V_L}$, where x' can be any values between $Max(V_H, pr(V_H - V_L) + rV_L)$ and rV_H. Since the V_H seller can earn $rV_H - V_H - c$ if he buys certificate, so the value of the search cost will impose a further restriction on x' as follows:

$$(rV_L - V_L) \times \frac{x' - V_H}{x' - V_L} \ge rV_H - V_H - c$$
$$(rV_L - V_L)x' - (rV_L - V_L)V_H \ge (rV_H - V_H - c)x' - (rV_H - V_H - c)V_L$$
$$(rV_L - V_L - rV_H + V_H + c)x' \ge cV_L$$
$$\because rV_L - V_L - rV_H + V_H + c > 0$$
$$\therefore x' \ge \frac{cV_L}{rV_L - V_L - rV_H + V_H + c}$$

If $x' < \frac{cV_L}{rV_L - V_L - rV_H + V_H + c}$, then the V_H seller will buy certificate, and expect to get $rV_H - V_H - c$, else the V_H seller expects to get $(rV_L - V_L) \times \frac{x' - V_H}{x' - V_L}$.

The V_L seller always expects to get $rV_L - V_L$, and buyer expects to get 0.

Case 2: $prV_H + (1-p)rV_L > V_H$

As shown in the previous analysis of the basic model in Section 3.2.1, the expected payoff of the V_H seller if he does not buy certificate is $prV_H + (1-p)rV_L - V_H$, hence the V_H seller will pay up to $(1-p)(rV_H - rV_L)$ to buy certificate, and then offer rV_H to expect to get $rV_H - V_H - c$; else he offers $prV_H + (1-p)rV_L$, and expects to get $prV_H + (1-p)rV_L - V_H$.

For the V_L seller, he expects to get $(rV_L - V_L)$ if the V_H seller buy certificate, else the V_L seller would get $prV_H + (1-p)rV_L - V_L$. For buyer, she always expects to get 0.

The above analysis shows one of the possibilities we can extend our model about value of information, and run experiments to evaluate the market efficiency of different kind of market mechanisms.

Chapter 4

A Prescriptive Model with Point Prediction for Ultimatum Game

4.1 Introduction

Within the existing ultimatum game literature it is widely held by economists that game theory fails to predict the subjects' behaviors accurately. Implicit in this evidence is the conjecture of altruistic concerns and the matter of fairness (see, for example, Bolton, et. al. 1998; Fehr and Schmidt 1999). While it is commonly known that the decision of accepting or rejecting an offer in ultimatum games depends on the Respondent's tolerance of unfairness, there have been no prescriptive models in the literature for suggesting the optimal offer that the Proposer should propose. In this chapter, we demonstrate that the History-Consistent Rationality model (hereafter, HCR model) can yield point estimation of the optimal offers that the Proposer should propose in ultimatum games. This kind of quantitative prediction is different from the past literature which focuses on qualitative prediction.

Our research contributions are of two-fold. First, our experimental design simulates closer to the real market condition to allow us to better understand how our economy works. In the existing literatures, scholars have studied ultimatum games with asymmetric information to approximate the real life bargaining situation, as people often do not know how much there is at stake for the other person (Mitzkewitz & Nagel, 1993; Croson, 1996; Kagel et al., 1996). In our research, we replicate the property market condition by allowing market information to be available to subjects under asymmetric information – consider a customer planning to purchase a house, he would certainly try to collect more information and bargain for a good price to complete the deal. After a certain period of time of haggling and negotiating, he will reach a final stage to make (or receive) a "take it of leave it" offer. Due to asymmetric information, it is in most likelihood that he does not know the real cost to the house owner and the real market value of this particular house. The best thing he can do is to observe the recent market transaction prices of the nearby properties to assist him in making a good decision. In our experiment, subjects played repeated ultimatum games with asymmetric information up to twenty periods, and the market information of all accepted and rejected offers in the previous periods is made available to every subject, including both the Proposers and the Respondents (corresponding to sellers and buyers in the house-searching case). We ran two sessions with different pie sizes to approximate the low and high real estate markets.

Secondly, we adopt a prescriptive model that suggests the optimal strategies players should adopt, and found that players do, to a large extent, follow our prescriptive model. Raiffa (1982) conjectured that subjects in economic games do not consider their opponents as perfectly rational game players, but rather formulating their strategies as if they are making decision under uncertainty. We follow his logic and consider the Proposers in the ultimatum game treat each Respondent's cutoff price for acceptance as a random variable governed by a probability distribution $f(x)$. Therefore, Proposers should choose an offer x to maximize his expected payoff, $xF(x)$. Our experimental design replicating a house searching problem provides sufficient conditions to testify our conjecture as 1) the game is played repeatedly with different opponents and the historical market information is made available to the players, which allows Proposers to construct $f(x)$

from historical data and make the optimal offer that maximize $xF(x)$ – if it is without repetition, market information will be irrelevant and estimate of $f(x)$ cannot be formed; 2) the game is played with unknown pie-size, so offers will not converge to 50:50 split too quickly, thus providing enough data points for us to test our model.

Stein et al. (2007) compared how people make decision under private information and public information conditions, and showed that people follow very simple heuristics under private information, but they would take into account the decisions and outcomes of all the group members if information is public. The HCR model[12] we adopt in our analysis shares similar ideas, and we use it to track the subjects' behaviors and conclude that subjects do consider the decisions and outcomes of all other participants when they make their own decision. The HCR model predicts the Proposers' optimal offers based on the information of the previous market transaction prices (accepted and rejected offers), and successfully yield an accurate point prediction that is on average within 5% absolute deviation of the total pie size for each subject's actual behaviors in 20 rounds. The HCR model is robust in predicting the subjects' behaviors with different pie sizes.

The next section discusses the research design and methodology. In Section 4.3, a History-Consistent Rationality Model is adopted to predict and explain subject behaviors across periods in a repeated ultimatum game. Section 4.4 summarizes the major findings and concludes.

[12] Detailed description of HCR model is provided in Section 4.3.3.

4.2. Experimental Design

The ultimatum game is a stylized bargaining situation that has been used to examine a broad range of behaviors (Camerer & Thaler, 1995). In its simplest form, the Proposer proposes an allocation of a fixed sum of money; and the Respondent chooses either accept or reject the proposal. If the proposal is accepted, the money will be distributed accordingly. Else, both parties receive nothing.

In our experiments, we simulate the real estate market condition by allowing subjects to access the historical market information in a repeated ultimatum games with unknown pie size. Our experimental design also provides sufficient conditions to test the HCR model, which suggests that people make decision based on historical information and their knowledge about the game. In our experiment, 1) the game is played repeatedly with different opponents, and the historical market information is made available to the players, which allows Proposers to construct $f(x)$ from historical data and make the optimal offer that maximize $xF(x)$ – if it is without repetition, market information will be irrelevant and estimate of $f(x)$ cannot be formed; 2) the game is played with unknown pie-size, so offers will not converge to 50:50 split too quickly, thus providing enough data points for us to test our model.

Two experimental sessions with different pie sizes, HK\$136 and HK\$217 were conducted. We intentionally made the pie sizes difficult to be guessed by the Respondents to avoid offers being converged too quickly, so that we could gather sufficient data to verify our proposed model. Forty and thirty six business students participated in the two separated sessions respectively, and each session lasted about 60 minutes. Subjects were randomly assigned to the role of Proposer or Respondent at the beginning of the experimental session, and played the same role for the entire session. In each game, however, they were matched with a different, anonymous opponent. The entire session consisted of 20 periods, but the number of games of play was unknown to the subjects. In each game, the randomly paired subjects are asked to distribute a fixed amount, which is the private information to the Proposer. After the Proposer makes a proposal, the Respondent has to decide whether to accept or reject the proposal without knowing the total pie size. The common knowledge that both Proposers and Respondents possess is the game history, i.e. the accepted offers and rejected offers in the market during the previous rounds.

Prior to the start of the play, self-paced instructions were presented via individual PowerPoint presentations that included interactive questions to assess understanding of the game [The game instruction is shown in Appendix 3]. Experiments were conducted via computers in a laboratory arranged so that it is impossible for participants to know the identity of the other negotiators or to see others' screens. The Proposers' proposed amounts and the decision of acceptance or rejection by the Respondents are all transmitted via the terminals. No other communications among players were allowed. Each screen also displayed a complete market history of accepted offers and rejected offers. To motivate participants, they are informed that they would be paid the average of their net payoff from five randomly selected periods. For the session with HK$136 pie size, HK$20 is given to each subject as seed money at the beginning of the experiment. On average, participants earned HK$82 for a session[13].

[13] The amount of potential winning is very attractive to the undergraduate participants. For comparison, the hourly rate for an on-campus job is HK$50.

4.3. Prescriptive Models for Ultimatum Game

All models with perfect rationality assumption, such as Perfect Bayesian Equilibrium, predict the Proposer should propose a minimum amount to the Respondent, as a rational Respondent accepts any amounts that are greater than zero.

Models without perfect rationality assumption can be divided into two types. The first type is qualitative in nature, such as Bolton (1991), Fehr and Schmidt (1999) and Trautmann (2006), which contains variables that are neither measurable nor observable by players in the ultimatum game. Thus, these models only give a qualitative prediction. For instance, it is not possible for players to observe the value of α and β of each other in the ultimatum game, which are the key parameters in the Fehr-Schmidt model. Furthermore, our data show that the offers are increasing across periods, which indicates that either the Proposers are updating their believes about the distribution of Respondents' α across periods, or the values of α and β are simply not a fixed value for each individual as suggested by Fehr and Schmidt.

Another type of models without perfect rationality assumption is quantitative in nature, but most of these models also predict the Proposers should offer a minimal amount. For instance, Camerer et al. (2004) proposed a renowned Cognitive Hierarchy Model, which relaxes the perfect rationality assumption and suggests that players only do k steps of the iterative thinking process, and assume their opponents are distributed, according to a normalized Poisson distribution, from step 0 (who simply randomized their choice) to step $k - 1$. Apparently, this model predicts Proposers either randomize their offers (if $k = 0$), or will propose a minimal amount when $k \geq 1$.

In reality, researchers found Proposers typically offer 30% to 40% on average, with a 50-50 split often the mode in the ultimatum games. Those offers less than 20% of the pie size are frequently rejected (Camerer and Thaler, 1995). To account for this phenomenon, we analyze two repeated ultimatum game experiments with unknown pie size to the Respondents, and adopt the History-Consistent Rationality model (HCR model) – a bounded rationality model derived from the concept of fictitious play, which was proposed by Lee and Ferguson (2010), to calculate Proposer's optimal offer. The HCR model is a prescriptive model that could quantify the optimal strategies that players should adopt. The experimental result illustrates that the HCR model successfully yields an accurate point prediction that is on average within 5% absolute deviation of the total pie size for each subject behavior in 20 rounds. Two ultimatum experiments with different pie size were tested, and the HCR model is robust in both experimental conditions.

4.3.1 Description of Experiment Results

Figure 4.1a & 4.1b summarize the acceptance and rejection rates across periods for pie sizes equal to HK$136 and HK$217 respectively. Figure 4.2a & 4.2b, 4.3a & 4.3b, and 4.4a & 4.4b show the summary of all offers, accepted offers and rejected offers made by Proposers across periods for pie sizes equal to HK$136 and HK$217 respectively.

Figure 4.1a Acceptance Rate Across Periods (Pie Size = HK$136)

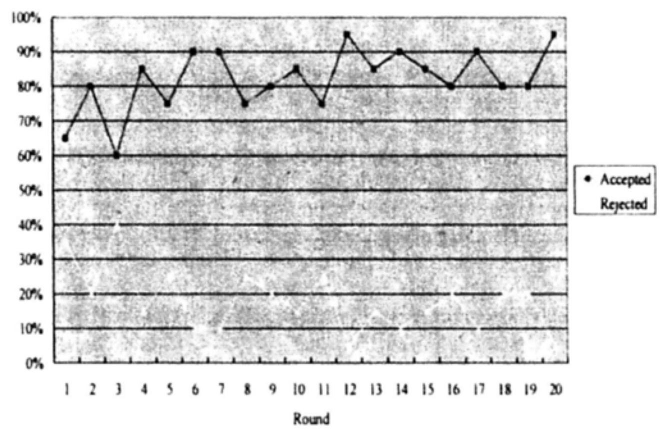
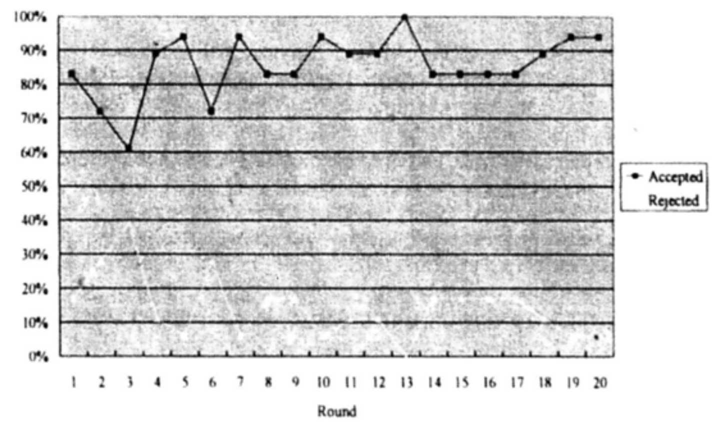


Figure 4.1b Acceptance Rate Across Periods (Pie Size = HK$217)



The graphs show that the acceptance rate is more fluctuated in the first few rounds of the game. This suggests that subjects are able to formulate strategies to stabilize acceptance rate in order to improve their payoffs after they learnt each other's behaviors from the market history. This is consistent with the rationale of the HCR model which assumes players respond to each other rationally, but their rationality is bounded by their knowledge about the game and how others play from the historical data.

Figure 4.2a All Offers Across Period (Pie Size = HK$136)

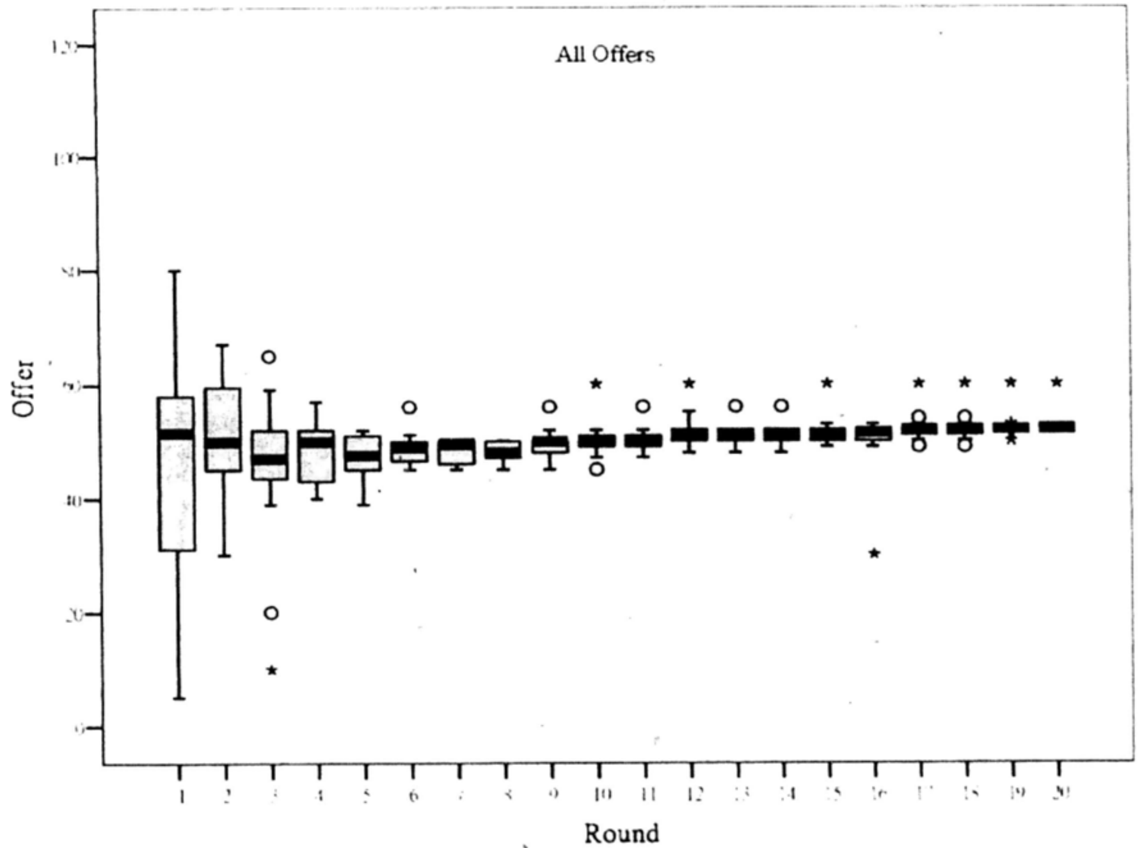


Figure 4.2b All Offers Across Period (Pie Size = HK$217)

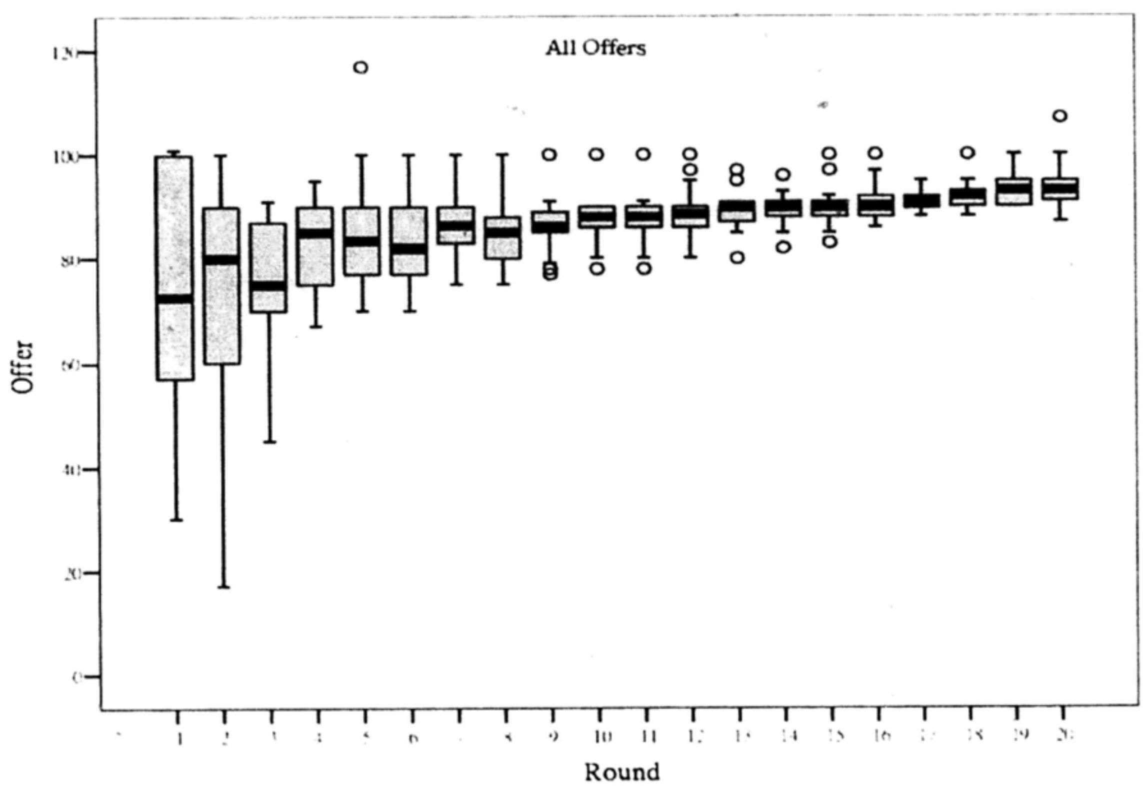


Figure 4.3a Accepted Offers Across Period (Pie Size = HK$136)

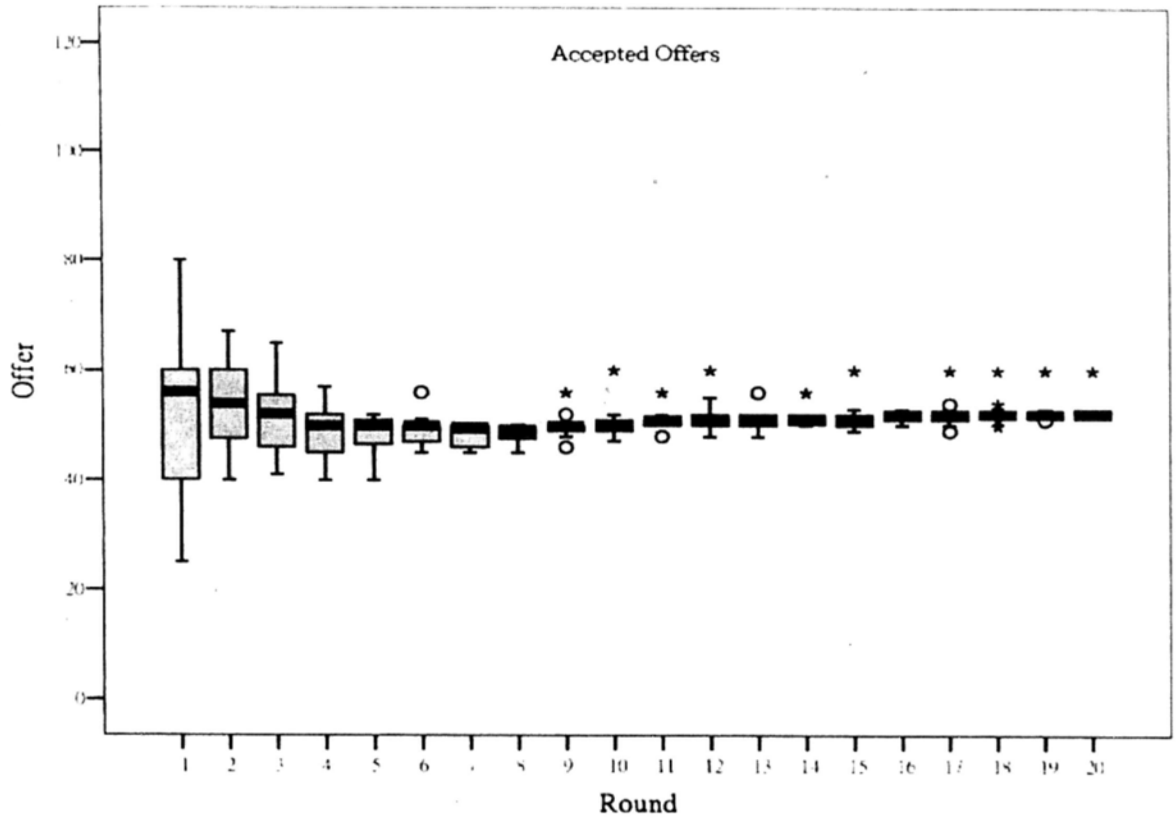


Figure 4.3b Accepted Offers Across Period (Pie Size = HK$217)

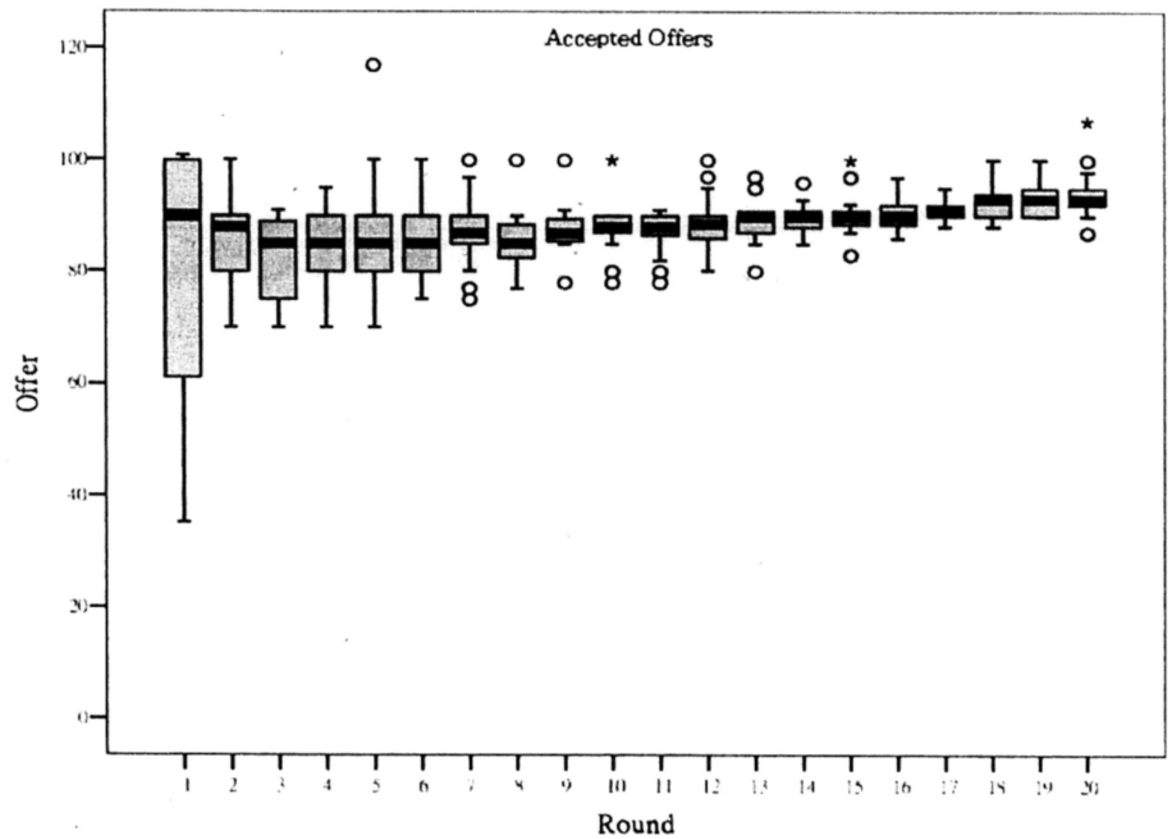


Figure 4.4a Rejected Offers Across Period (Pie Size = HK$136)

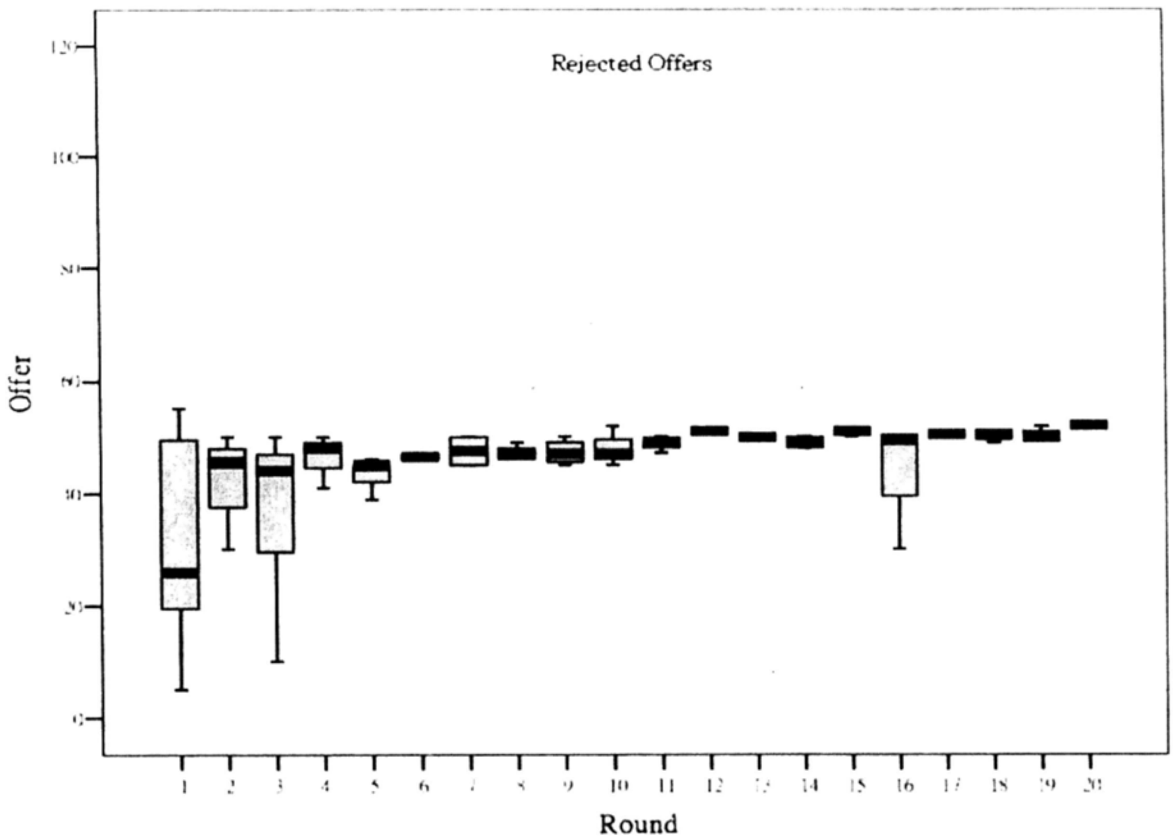
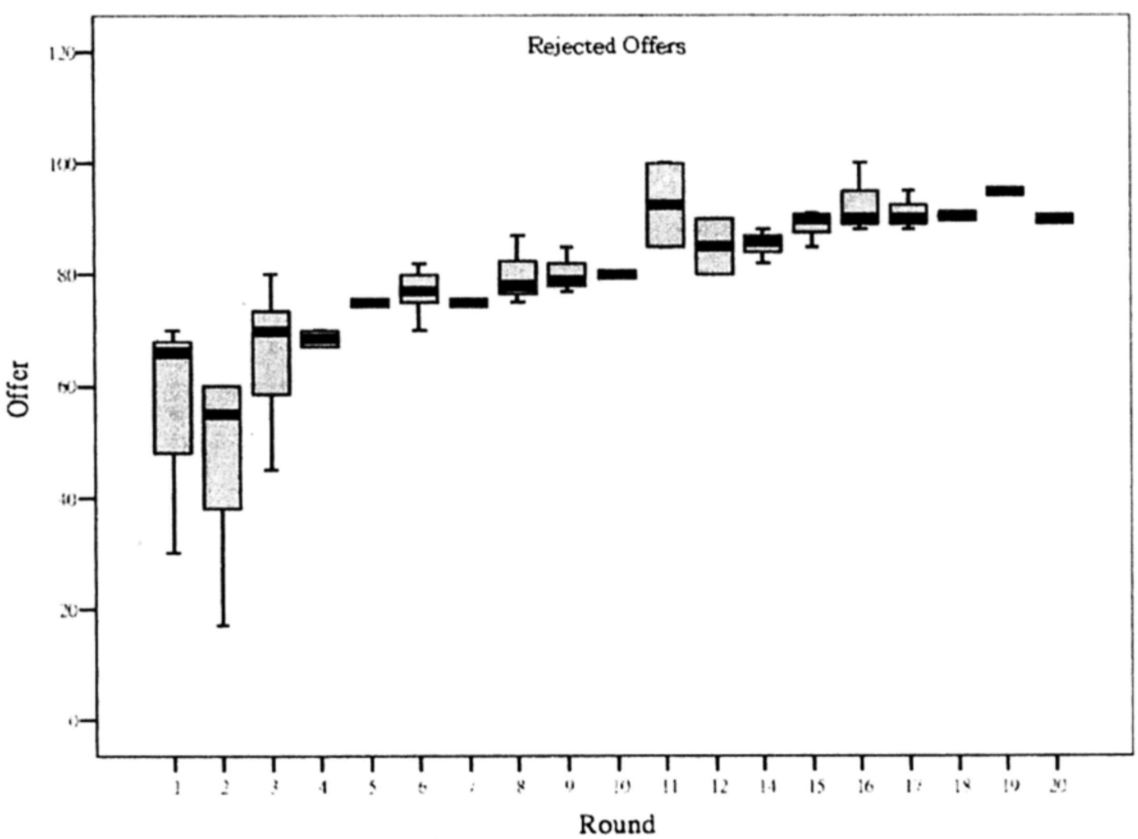


Figure 4.4b Rejected Offers Across Period (Pie Size = HK$217)



From the box-and-whisker plots, it is puzzling to observe that the accepted offers are concentrated at around HK$50 for pie size equal to HK$136, although there were offers of HK$65, HK$66, HK$67 and HK$80 at the initial periods, which signal the Respondents that the total pie size is not less than HK$130. Accepting HK$50 means the Respondents are willing to accept an offer that is less than 40% of the total pie size, which is inconsistent to the literature findings. In contrast, the accepted offers converge to a value that is more than 40% of the total pie size in the HK$217 case. This discrepancy is possibly due to the fact that HK$50 is a well-recognized natural focal point for the undergraduate participants in the HK$136 case, as the hourly rate for an on-campus job is HK$50. This also serves as a potential explanation about the disparity of predictive powers found between the Focal Point Prediction and HCR Prediction for the two different pie sizes as discussed in Section 4.2 and 4.3.

Taking a closer look at the individual subject behavior by examining the current trial proposed offer (p_t) in relation to the previous trail proposed offer (p_{t-1}) of each individual subject, we find an adaptation process among subjects. Respondents always accept offers that are larger than the maximum offer in the previous round, and accept more than 90% of the offers that are larger than the mean offer in the previous round, but reject more than a quarter of the offers that are less than the mean offer in the previous round. Details are summarized in Table 4.1a & 4.1b. For Proposers, as shown in Table 4.2a & 4.2b, they usually propose a slightly smaller offer if it was accepted in the previous round, with a mean difference of -0.82 and a standard deviation of 5.25 for pie size equals to HK$136, and a mean difference of -0.59 and a standard deviation of 5.22 for pie size equals to HK$217. The two-tailed t-tests show the mean differences are significantly different from zero with p-values equal to 0.00 and 0.03 for HK$136 and HK$217 pie sizes respectively. On the other hand, if Proposers' offers were rejected in the previous round, they would propose a substantially higher offer, with a mean difference of +5.74 and a standard deviation of 10.60 for pie size equal to HK$136, and a mean difference of +10.44 and a standard deviation of 13.10 for pie size equal to $217. The two-tailed t-tests show the mean differences are significantly different from zero with p-values equal to 0.00 for both pie sizes.

An intuitive explanation for the above phenomenon is that Proposers prefer more than less, and are very afraid of being rejected and earning nothing, so they would adjust their offers based on historical results. In Section 4.2 and 4.3, we will compare two different models with different assumptions about how subjects use historical information to make decisions. Generally, the observed behaviors fit the foundation of HCR model, which assumes players respond to each other with bounded rationality of players' knowledge of the game and historical data.

Table 4.1a Adaptive Behavior for Respondents (Pie Size = HK$136)

	Acceptance rate	Rejection rate
$p_t \geq \overline{p_{t-1}}$	95% (195 cases)	5% (11 cases)
$p_t < \overline{p_{t-1}}$	69% (120 cases)	31% (54 cases)

* p_t stands for the proposed offer in period t

$\overline{p_{t-1}}$ stands for the mean offer in the previous period

Table 4.1b Adaptive Behavior for Respondents (Pie Size = HK$217)

	Acceptance rate	Rejection rate
$p_t \geq \overline{p_{t-1}}$	94% (187 cases)	6% (11 cases)
$p_t < \overline{p_{t-1}}$	74% (107 cases)	26% (37 cases)

* p_t stands for the proposed offer in period t

$\overline{p_{t-1}}$ stands for the mean offer in the previous period

Table 4.2a Adaptive Behavior for Proposers (Pie Size = HK$136)

Offer was accepted in the previous round		Offer was rejected in the previous round	
Current offer	Percentage	Current offer	Percentage
$p_t > p_{t-1}$	22%	$p_t > p_{t-1}$	72%
$p_t = p_{t-1}$	53%	$p_t = p_{t-1}$	25%
$p_t < p_{t-1}$	24%	$p_t < p_{t-1}$	3%

* p_t stands for the proposed offer in period t

Table 4.2b Adaptive Behavior for Proposers (Pie Size = HK$217)

Offer was accepted in the previous round		Offer was rejected in the previous round	
Current offer	Percentage	Current offer	Percentage
$p_t > p_{t-1}$	31%	$p_t > p_{t-1}$	86%
$p_t = p_{t-1}$	44%	$p_t = p_{t-1}$	8%
$p_t < p_{t-1}$	25%	$p_t < p_{t-1}$	6%

* p_t stands for the proposed offer in period t

There is also a rising trend of the average offer, which could be an indication of the learning effect among subjects. Again, HCR model can capture this. The rising trend can best be understood by studying the time series plots in Figure 4.5a & 4.5b.

Figure 4.5a Time Series Plot of Offers (Pie Size = HK$136)

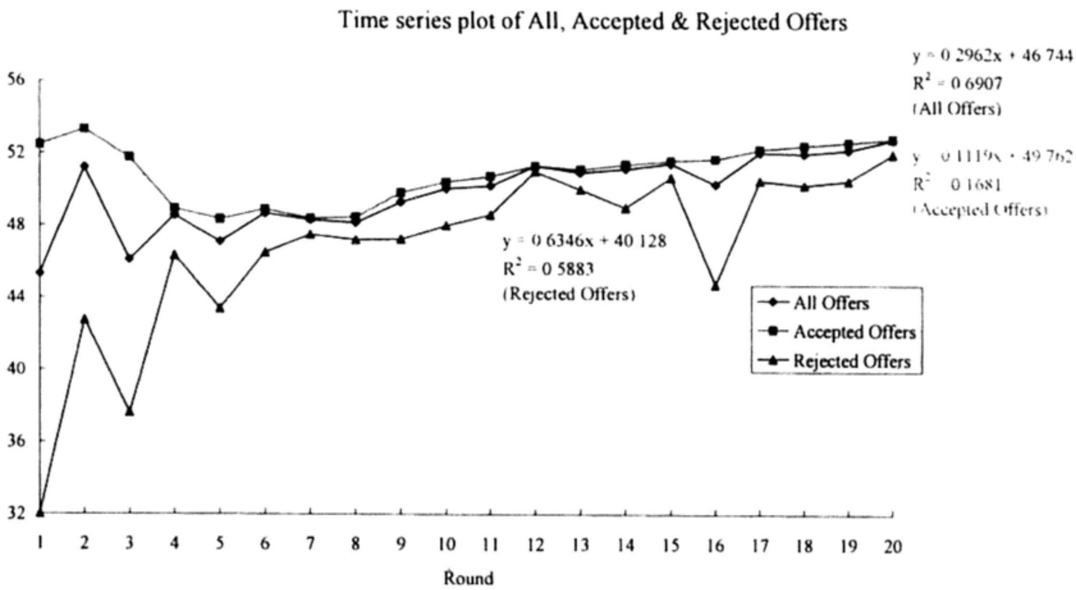
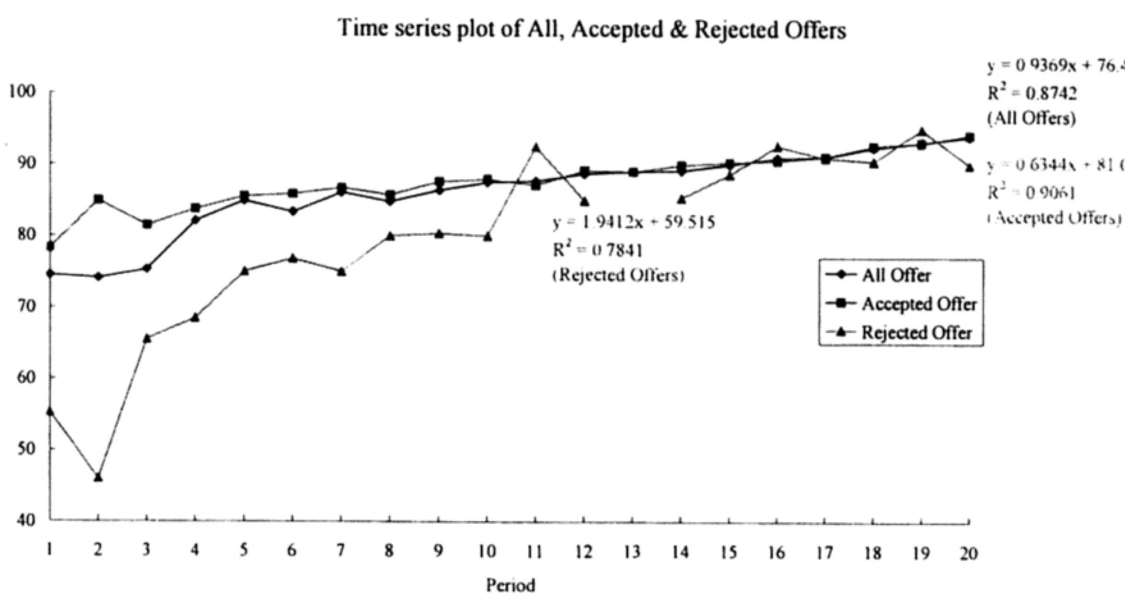


Figure 4.5b Time Series Plot of Offers (Pie Size = HK$217)



From the time series plots, it provides evidence that the mean accepted offer is highly correlated with the period number for the HK$217 pie size. The regression equation is $y = 0.634x + 81.091$, where y stands for mean accepted offer and x stands for period number. The value of R^2 is 0.9061, and the model is highly significant with p-value equals to 0.00. Apparently, the mean accepted offer is rising across periods, from HK$78.33 at the beginning to HK$94.18 at the end. The mean accepted offer in the last period is $94.18, which equals to 43.4% of the total pie size. For the HK$136 pie size, the mean of all offers is correlated with the period number. The regression equation is $y = 0.296x + 46.744$, where y stands for mean of all offers and x stands for period number. The value of R^2 is 0.6907, and the model is also highly significant with p-value equals to 0.00. The mean accepted offer in the final period is $52.84, which is equivalent to 38.9% of the total pie size. The mean accepted offers expressed in percentage of the total pie size in the final round between the two different pie sizes are statistically different with p-value equals to 0.00. The ultimatum experiment of $217 pie size exhibits a stronger learning effect, probably due to 1) a larger pie size which gives the Proposers a larger room for profits, and also higher incentives for the Responders to learn, where the Respondents have no knowledge about the actual pie size; 2) $50 is a natural focal point when the pie size is equal to $136.

One of the logical explanations for the change of offers across periods is that subjects were using market information (historical data) to determine their strategies. HCR model essentially captures this kind of human behavior and decision making process. In the next two sections, we study two different models that use historical information to help subjects make their decisions.

4.3.2 Focal Point Prediction

Schelling (1960) conjectured that focal point is important for decision makers to settle a bargaining problem. He believed that individuals generally use information contained in the labels of strategies to decide which strategies to choose, and showed how the use of mutually recognized signs could help players to reach a mutually beneficial outcome. Janssen (2006) further developed the idea of focal point, and proposed two principles, namely Principle of Insufficient Reason (PIR) and Principle of Individual Team Member Rationality (PITMR), which assist players to figure out the relevant focal point. PIR basically suggests that a rational choice cannot discriminate between strategies that share the same characteristics, while PITMR states that individuals would play their part of a strategy combination that is Pareto-optimal, if there exists a unique Pareto-optimal strategy combination among the strategy sets that respect PIR. Janssen (2006) went on in his paper to explain the contradicting findings against backward induction found in ultimatum literature, and suggested that one way to discriminate between focal point consideration and fairness consideration is to exploit differences between modal responses and average responses in an experiment.

Following Janssen's argument, we define focal point as the mode of the accepted offers in the previous two periods, as most of the subjects indicated in an ex-post experiment survey [Appendix 4] that they used the historical market information in the previous two rounds to assist them to make decision. Table 4.4a & 4.4b show the absolute difference between the Focal Point predicted offer and the actual offer that each subject made in each period.

Table 4.4a Absolute Difference between Focal Point Prediction and Actual Offers (Pie Size = HK$136)

Period/Player	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Average
3	14	10	21	5	8	8	50	14	4	8	1	18	40	15	14	19	14	8	12	5	14 40
4	2	3	11	4	3	0	12	12	5	0	3	2	12	7	2	11	4	0	4	2	4 95
5	2	0	5	2	6	1	12	10	2	0	0	7	13	7	6	7	1	4	1	12	4 90
6	6	4	5	1	4	2	2	4	2	1	2	2	7	7	2	7	5	6	4	2	3 75
7	4	2	5	1	2	0	0	4	0	1	0	0	0	5	0	5	0	0	0	5	1 70
8	0	2	4	3	3	0	0	4	0	1	2	0	3	2	0	5	0	2	1	5	1 85
9	1	2	2	4	2	2	0	6	0	0	0	0	0	4	0	5	0	1	1	0	1 50
10	1	1	1	3	3	2	2	10	1	1	0	0	0	2	0	5	1	1	1	0	1 75
11	0	1	2	3	1	2	2	6	1	1	1	0	0	2	0	2	1	0	1	0	1 30
12	0	1	0	0	5	2	2	10	2	1	2	0	0	0	1	2	1	0	1	0	1 50
13	0	0	0	1	2	2	2	6	1	1	2	0	0	0	1	2	1	0	2	0	1 15
14	1	1	0	1	2	2	2	6	2	1	1	0	0	0	1	2	1	2	2	0	1 35
15	0	2	1	1	0	1	1	9	1	0	0	1	1	1	0	2	0	0	1	1	1 15
16	1	2	0	0	2	1	1	1	1	0	1	1	1	1	1	2	1	2	2	21	2 10
17	0	1	1	1	0	2	0	8	0	1	0	2	2	1	0	3	0	0	1	0	1 15
18	1	2	1	1	0	0	0	8	0	1	0	2	2	0	0	3	0	0	1	0	1 10
19	0	1	1	2	0	0	0	8	0	0	1	0	2	0	0	2	0	0	1	0	0.90
20	0	1	0	0	1	0	1	8	0	0	1	1	0	0	0	0	1	0	1	1	0 80
Average	1 83	2 00	3.33	1 83	2 44	1 50	4 94	7 44	1 22	1 00	0 94	2 00	4 61	3 00	1 56	4 67	1 72	1 44	2 06	3 00	2 63

Table 4.4b Absolute Difference between Focal Point Prediction and Actual Offers (Pie Size = HK$217)

Period\Player	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	Average
3	20	0	3	15	20	33	0	45	20	15	13	30	15	20	5	1	2	10	14.83
4	20	5	10	5	5	23	3	20	20	15	1	0	8	10	5	5	0	0	8.61
5	5	30	5	15	20	7	15	47	0	5	12	10	12	15	10	22	18	20	14.89
6	10	10	15	5	8	8	0	15	10	10	3	5	3	0	5	1	5	5	6.56
7	0	15	2	15	13	25	12	22	0	10	13	5	8	10	10	11	13	15	11.06
8	2	15	0	11	15	25	12	8	10	10	13	5	7	10	3	14	11	5	9.78
9	8	2	7	6	1	15	2	6	0	0	5	0	1	0	1	4	4	5	3.72
10	7	5	5	3	3	15	5	4	2	3	2	5	1	5	0	4	5	5	4.39
11	12	0	8	2	2	10	0	1	3	2	3	10	4	0	5	1	0	0	3.50
12	10	5	5	2	0	7	0	4	4	2	0	10	4	0	3	1	0	10	3.72
13	10	0	5	0	5	7	0	0	4	2	1	0	4	0	3	0	0	0	2.28
14	8	0	5	1	3	6	0	2	3	2	0	2	4	2	2	1	0	0	2.28
15	5	0	3	0	2	7	1	7	1	1	2	2	0	0	2	0	0	10	2.39
16	3	2	3	0	1	7	5	4	0	1	0	2	0	5	2	2	0	10	2.61
17	1	5	2	1	2	4	5	2	0	0	2	0	0	5	1	1	1	0	1.78
18	0	10	0	3	3	3	5	2	0	0	3	0	1	5	1	3	1	10	2.78
19	0	7	0	3	4	6	5	0	2	0	3	0	2	5	1	6	3	10	3.17
20	5	3	0	3	5	17	5	3	2	1	4	0	2	8	1	3	5	10	4.28
Average	7.00	6.33	4.33	5.00	6.22	12.50	4.17	10.67	4.50	4.39	4.44	4.78	4.22	5.56	3.33	4.44	3.78	6.94	5.70

In the above tables, the row represents the Period Number, while the column represents the Player ID. The value in each cell represents the absolute difference between the Focal Point predicted offer and the particular player's actual offer in that period. For instance, the value "5 in the fifth row, third column in Table 4.4a is calculated as the absolute difference between 45 (Player 5 s actual offer in Period 7) and 50 (the Focal Point predicted offer, which is the mode of all accepted offers in Period 5 and 6). The last row shows the average of the absolute differences between player's actual offers and the Focal Point predicted offers for individual player, while the last column shows the average of the absolute differences between players' actual offers and Focal Point predicted offers for each period.

A regression analysis shows the absolute differences are decreasing across periods for both pie sizes, which suggests that focal point prediction is closer to the actual behaviors when subjects gain more experience and get more information from the historical transactions. For the $136 pie size, the regression equation is $y = -0.386x + 7.062$, with R^2 equals to 0.414, and the model is significant with p-value equals to 0.00. For the $217 pie size, the regression equation is $y = -0.632x + 12.966$, with R^2 equals to 0.618, and the model is also significant with p-value equals to 0.00. For both equations, y refers to the absolute difference between the Focal Point predicted offer and the player's actual offer, and x is the period number.

On average, Focal Point yields an absolute difference of HK$2.63 and HK$5.70 from the actual offers proposed by all players from the third to the final periods for HK$136 pie size and HK$217 pie size respectively. In both cases, the overall average absolute difference between predicted and actual offers is within 3% of the total pie size.

4.3.3 HCR Prediction

This section investigates whether changes in offers across periods can be better explained and predicted by the History-Consistent Rationality Model (HCR model) proposed by Lee and Ferguson (2010).

The HCR model assumes players respond to each other "rationally", but their rationality is bounded by their knowledge about the game and how others play, and their knowledge is derived from historical data. In other words, players behave rationally given the information learned from history. The Proposer's offer is predicted as follows:

> Based on history, for each game the proposer forms a belief about the probability, $f(p_t)$, that an offer p_t will be accepted. The proposer then chooses an offer p_t to maximize his expected payoff – $p_t f(p_t)$. Although proposers may form beliefs in different way, intuitively, each proposer's belief $f(p_t)$ can be estimated by fitting a logistic regression model. For Game t, the dependent variable A_t of the logistic model is defined as follows:
>
> $$A_t = \begin{cases} 1 & \textit{if the proposer's offer was accepted} \\ 0 & \textit{otherwise} \end{cases}$$
>
> As the memory capacity of human beings is limited, we can assume that the proposers will only use previous x periods (i.e. from $t\text{-}x\text{-}1$ to $t\text{-}1$ periods) to estimate the value of $f(p_t)$. A questionnaire [Appendix 4] is distributed to each

subject after the experiment to ask them how many periods (if any) did they use for making decision. Most of the subjects indicated they only used the previous two periods. Hence, we use two-period historical data to predict subject behaviors.

Table 4.5a Absolute Difference between HCR Prediction and Actual Offers

(Pie Size = HK$136)

Period/Player	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Average
3	9.33	5.33	16.33	9.67	3.33	3.33	45.33	9.33	0.67	3.33	3.67	13.33	35.33	10.33	9.33	14.33	9.33	3.33	7.33	0.33	10.63
4	7.01	2.01	16.01	1.01	8.01	5.01	17.01	17.01	0.01	5.01	2.01	7.01	17.01	12.01	7.01	16.01	9.01	5.01	9.01	7.01	8.46
5	5.79	3.79	8.79	5.79	9.79	4.79	15.79	13.79	5.79	3.79	3.79	10.79	16.79	10.79	9.79	10.79	4.79	7.79	4.79	15.79	8.69
6	7.46	5.46	6.46	2.46	5.46	3.46	3.46	2.54	3.46	2.46	3.46	3.46	8.46	8.46	3.46	8.46	6.46	7.46	5.46	3.46	5.06
7	5.72	3.72	6.72	2.72	3.72	1.72	1.72	5.72	1.72	2.72	1.72	1.72	1.72	6.72	1.72	6.72	1.72	1.72	1.72	6.72	3.42
8	2.50	0.50	1.50	0.50	0.50	2.50	2.50	1.50	2.50	1.50	0.50	2.50	0.50	0.50	2.50	2.50	2.50	0.50	1.50	2.50	1.60
9	1.50	0.50	0.50	1.50	0.50	4.50	2.50	8.50	2.50	2.50	2.50	2.50	2.50	1.50	2.50	2.50	2.50	1.50	1.50	2.50	2.35
10	3.72	3.72	3.72	5.72	5.72	0.72	0.72	7.28	1.72	1.72	2.72	2.72	2.72	4.72	2.72	7.72	1.72	3.72	1.72	2.72	3.40
11	2.45	3.45	4.45	5.45	3.45	0.45	0.45	3.55	1.45	1.45	1.45	2.45	2.45	4.45	2.45	4.45	1.45	2.45	1.45	2.45	2.61
12	3.20	2.20	3.20	3.20	1.80	1.20	1.20	6.80	1.20	2.20	1.20	3.20	3.20	3.20	2.20	5.20	2.20	3.20	2.20	3.20	2.76
13	2.64	2.64	2.64	1.64	0.64	0.64	0.64	3.36	1.64	1.64	0.64	2.64	2.64	2.64	1.64	4.64	1.64	2.64	0.64	2.64	2.03
14	1.50	1.50	0.50	1.50	2.50	2.50	2.50	6.50	2.50	1.50	1.50	0.50	0.50	0.50	1.50	1.50	1.50	2.50	2.50	0.50	1.80
15	1.49	0.51	2.49	0.49	1.49	0.49	0.49	7.51	0.49	1.49	1.49	2.49	2.49	2.49	1.49	3.49	1.49	1.49	0.49	2.49	1.84
16	0.00	3.00	1.00	1.00	3.00	2.00	2.00	0.00	2.00	1.00	2.00	0.00	0.00	0.00	2.00	1.00	2.00	3.00	3.00	20.00	2.40
17	1.12	0.12	2.12	2.12	1.12	0.88	1.12	6.88	1.12	2.12	1.12	3.12	3.12	2.12	1.12	4.12	1.12	1.12	0.12	1.12	1.85
18	1.70	1.30	1.70	1.70	0.70	0.70	0.70	7.30	0.70	1.70	0.70	2.70	2.70	0.70	0.70	3.70	0.70	0.70	0.30	0.70	1.59
19	1.29	0.29	2.29	3.29	1.29	1.29	1.29	6.71	1.29	1.29	0.29	1.29	3.29	1.29	1.29	3.29	1.29	1.29	0.29	1.29	1.76
20	1.01	0.01	1.01	1.01	0.01	1.01	0.01	6.99	1.01	1.01	0.01	0.01	1.01	1.01	1.01	1.01	0.01	1.01	0.01	0.01	0.91
Average	3.30	2.23	4.52	2.82	2.95	2.07	5.52	6.74	1.77	2.14	1.71	3.47	5.91	4.08	3.02	5.64	2.86	2.80	2.45	4.19	3.51

Table 4.5b Absolute Difference between HCR Prediction and Actual Offers

(Pie Size = HK$217)

Period/Player	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	Average
3	0.33	20.33	17.33	5.33	0.33	12.67	20.33	24.67	0.33	5.33	7.33	9.67	5.33	0.33	15.33	21.33	18.33	10.33	10.83
4	10.70	4.30	0.70	4.30	14.30	13.70	6.30	10.70	10.70	5.70	10.30	9.30	1.30	0.70	4.30	4.30	9.30	9.30	7.23
5	5.97	19.03	5.97	4.03	9.03	3.97	4.03	36.03	10.97	5.97	1.03	0.97	1.03	4.03	0.97	11.03	7.03	9.03	7.78
6	2.37	17.63	7.37	2.63	15.63	0.37	7.63	22.63	2.37	2.37	4.63	2.63	4.63	7.63	2.63	8.63	12.63	12.63	7.61
7	8.55	6.45	6.55	6.45	4.45	16.45	3.45	13.45	8.55	1.45	4.45	3.55	0.55	1.45	1.45	2.45	4.45	6.45	5.59
8	7.17	5.83	9.17	1.83	5.83	15.83	2.83	1.17	0.83	0.83	3.83	4.17	2.17	0.83	6.17	4.83	1.83	4.17	4.41
9	7.15	2.85	6.15	6.85	1.85	15.85	2.85	5.15	0.85	0.85	5.85	0.85	1.85	0.85	1.85	4.85	4.85	5.85	4.29
10	8.69	3.31	6.69	1.31	1.31	13.31	3.31	2.31	0.31	1.31	0.31	6.69	0.69	3.31	1.69	2.31	3.31	3.31	3.53
11	8.14	3.86	4.14	1.86	1.86	13.86	3.86	4.86	0.86	1.86	0.86	6.14	0.14	3.86	1.14	2.86	3.86	3.86	3.77
12	9.00	6.00	4.00	1.00	1.00	8.00	1.00	3.00	3.00	1.00	1.00	9.00	3.00	1.00	2.00	0.00	1.00	11.00	3.61
13	9.00	1.00	4.00	1.00	6.00	8.00	1.00	1.00	3.00	1.00	0.00	1.00	3.00	1.00	2.00	1.00	1.00	1.00	2.50
14	8.00	0.00	5.00	1.00	3.00	6.00	0.00	2.00	3.00	2.00	0.00	2.00	4.00	2.00	2.00	1.00	0.00	0.00	2.28
15	3.71	1.29	1.71	1.29	3.29	8.29	2.29	5.71	0.29	0.29	3.29	0.71	1.29	1.29	0.71	1.29	1.29	11.29	2.74
16	4.62	0.38	4.62	1.62	0.62	5.38	3.38	5.62	1.62	2.62	1.62	3.62	1.62	3.38	3.62	0.38	1.62	8.38	3.04
17	2.50	3.50	3.50	0.50	0.50	2.50	3.50	3.50	1.50	1.50	0.50	1.50	1.50	3.50	2.50	0.50	0.50	1.50	1.94
18	1.50	8.50	1.50	1.50	1.50	1.50	3.50	3.50	1.50	1.50	1.50	1.50	0.50	3.50	2.50	1.50	0.50	8.50	2.56
19	4.00	3.00	4.00	1.00	0.00	2.00	1.00	4.00	2.00	4.00	1.00	4.00	2.00	1.00	3.00	2.00	1.00	6.00	2.50
20	1.00	1.00	4.00	1.00	1.00	13.00	1.00	7.00	2.00	3.00	0.00	4.00	2.00	4.00	3.00	1.00	1.00	6.00	3.06
Average	5.69	6.01	5.36	2.47	3.97	8.93	3.96	8.68	2.98	2.37	2.64	3.96	2.03	2.43	3.16	3.96	4.08	6.59	4.40

Table 4.5a & 4.5b show the absolute difference between the HCR predicted offer[14] and the actual offer that each subject made in each period. The data show a generally decreasing trend of mean absolute differences across periods for both pie sizes, which suggests that the subjects follow closer to the HCR model when they gain more experience. The decreasing trend is statistically significant at 1% level. For the $136 pie size, the regression equation is $y = -0.421x + 9.347$, with R^2 equals to 0.629, and the model is significant with p-value equals to 0.00. For the $217 pie size, the regression equation is $y = -0.394x + 8.931$, with R^2 equals to 0.736, and the model is also significant with p-value equals to 0.00. For both equations, y refers to the absolute difference between the HCR predicted offer and the player's actual offer, and x is the period number.

[14] We use the minimum offer in the previous round as the HCR predicted offer whenever the logistic regression fails to estimate the parameters. This happens in period 8, 9 & 14 for $136 pie size, and period 12, 13, 14, 17, 18, 19 & 20 for $217 pie size.

The overall mean absolute difference between the HCR predicted offers and the actual offers of all players is HK$3.51 and HK$4.40 for HK$136 and HK$217 pie sizes respectively, which is less than 3% of the total pie size in both cases. These absolute differences detected between the predicted and actual offers may be contributed from the different risk attitude among subjects, as HCR model assumes risk neutrality. Table 4.6a & 4.6b summarize the percentage of times that a subject makes risk-averse and risk-seeking offers during the entire experimental session for HK$136 and HK$217 pie sizes respectively, where risk-averse is counted when the subject makes larger offers than the predicted offers, and vice versa for risk-seeking.

Table 4.6a Risk Attitude of Subject Behaviors (Pie Size = HK$136)

Player ID	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Risk Adverse	22%	33%	17%	17%	22%	28%	22%	72%	28%	22%	28%	22%	17%	17%	22%	0%	22%	22%	28%	11%
Risk Seeking	78%	67%	83%	83%	78%	72%	78%	28%	72%	78%	72%	78%	83%	83%	78%	100%	78%	78%	72%	89%

Table 4.6b Risk Attitude of Subject Behaviors (Pie Size = HK$217)

Player ID	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Risk Adverse	11%	94%	6%	72%	94%	78%	100%	33%	33%	39%	89%	22%	33%	94%	28%	89%	78%	89%
Risk Seeking	89%	6%	94%	28%	6%	22%	0%	67%	67%	61%	11%	78%	67%	6%	72%	11%	22%	11%

The data illustrate an interesting phenomenon that many players are risk-seeking when the pie size is small ($136), while more players are risk-averse when the pie size is large ($217). This is consistent with the utility literature that subjects tend to be more risk-averse when the stake size is larger. As it is widely reported in the economic literature that it is practically very difficult to accurately measure individual utility function (e.g. lack of incentive to answer the utility questions, or subjects simply cannot tell their preference accurately), we tested the HCR model with risk neutrality assumption as with many other economic models.

4.4 Conclusions

In this chapter, historical market information is added to the ultimatum game under asymmetric information condition to study the real property market. A predictive model, the History-Consistent Rationality model (HCR model) is adopted to explain and predict the subject behaviors. The experiment data supported the rationale of HCR model under different sets of parameters, and showed that there was only a minimal difference between the HCR predicted behaviors and the actual behaviors. We conjecture that a significant portion of people searching for a house would also benchmark the reasonable price based on the recent transactions.

Focal Point and HCR models both predict the subject behaviors reasonably well, which suggests that people tend to deploy the successful strategy used by others to be their own strategy. Compared with the Focal Point prediction, HCR model predicts better when pie size is equal to HK$217, but is less optimal when pie size is equal to HK$136. The mean absolute differences between the HCR model prediction accuracy and Focal Point prediction accuracy are statistically significant at 1% level. Table 4.7a & 4.7b study the accuracy of HCR prediction and show the p-value of the paired-sample t-test about the difference between the HCR predicted offers and the actual offers of all subjects in each period. For pie size equals to $217, more than half of the paired-sample t-tests are insignificant at 5% level, which means HCR prediction is not statistically different from the actual behaviors. On the other hand, for pie size equals to $136, most of the paired-sample t-tests are significant, which means HCR prediction is not a good approximation to the actual offers. As mentioned in Section 4.1, a potential explanation for the discrepancy is that when there exists a natural focal point (in the case of HK$136, HK$50[15] seems to be an obvious natural focal point for our subjects), subjects no longer play strategically by analyzing historical data, but simply choose the value that is well recognized by many other subjects. On the other hand, when there is no obvious natural focal point available, subjects start their thinking process to strive for a better outcome, thus the HCR model predicts better.

Table 4.7a Paired-sample t-test across periods (Pie Size = $136)

Period	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
p-value	0.00	0.00	0.00	0.00	0.00	0.11*	0.00*	0.00	0.00	0.00	0.00	0.00*	0.05	0.79	0.00	0.17	0.03	0.60

Table 4.7b Paired-sample t-test across periods (Pie Size = $217)

Period	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
p-value	0.08	0.51	0.15	0.01	0.13	0.67	0.09	0.49	0.18	0.00*	0.00*	0.00*	0.16	0.45	0.00*	0.00*	0.00*	0.00*

remark: p-value with * indicates the logistic regression fails to estimate the parameters, and we use the minimum offer in the previous round as an approximation of the HCR predicted offer.

[15] HK$50 is the hourly wage of a campus job to the students, and our experiment lasts for one hour.

Chapter 5

Conclusions

In this chapter, we summarize the major findings and insights in this dissertation, and discuss possible extensions of the model applications.

5.1 Summary of the Major Findings

In Chapter 3, we demonstrated that deadweight loss is unavoidable in the prevailing market mechanism, and showed that our proposed market mechanism can eliminate deadweight loss in many market conditions. The argument was supported by the experimental data. We also proposed a behavioral game theory, which added in the fairness consideration, to explain the reality, and the results were promising.

In Chapter 4, historical market information is added to the traditional ultimatum game with asymmetric information to better approximate the real life situation. A predictive model – the History-Consistent Rationality Model is introduced to explain and predict the subject behaviors across periods. It is shown that the HCR model predict subject behaviors very well under various conditions, with a minimal deviation in a random manners from the actual behaviors.

5.2 Future Research

There are many ways that the ideas and models discussed in this dissertation can be adopted and generalized to the other areas.

On one hand, we can study whether our proposed behavioral game theory in Chapter 3 can explain the behaviors found in other economic experiments, and investigate if there exist other market mechanisms that can minimize deadweight loss and at the same time enhance market equity.

On the other hand, the robustness of History-Consistent Rationality Model mentioned in Chapter 4 can also be tested by running other experiments that have history in nature. At this moment, ultimatum game and bargaining with outside option (Lee and Ferguson, 2010) was tested. We can consider running repeated centipede game, trust game, p-beauty game, etc. to verify the robustness of the model.

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APPENDIX 1

Self-paced Instructions for Subjects to Understand the Market Game under Prevailing Mechanism

Greetings!

You are about to participate in an economic study. At the end of the experiment you will be paid according to your performance.

Please read the instructions very carefully. The instruction consists of two parts. The first part describes the market game you will be playing. In the second part, we describe the experiment in details. The computer will then ask you questions to check your understanding.

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The Market Game - Setting

- ❑ In this experiment, you will play a simple and the same game many times. Each game involves two players – Buyer and Seller. In the beginning of the experiment, the computer will randomly assign you as either Buyer or Seller. Once assigned, your role will remain the same throughout the entire experiment.
- ❑ In each game, each Buyer will be randomly paired with a Seller. Then, in next period, the computer will randomly match buyer and seller again, so you will be paired with different players in different periods.
- ❑ The rule of the game remains the same for each game in the entire experiment.

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The Market Game – Background Information

There are Buyers and Sellers in the market.

- Each Seller has a commodity that is valued at either $100 or $200, depending on its quality.
- The Seller knows its quality but the Buyer does not.
- The commodity is worth more to the Buyers than to the Sellers at a ratio 1.5. In other words, the low-quality and high-quality commodities are worth ($100 * 1.5) = $150 and ($200 * 1.5) = $300 respectively to the Buyer.
- There are 30% of the Sellers possessing high-quality commodities, and 70% of the Sellers possessing low-quality commodities in the market.
- Each Seller sets its own price in the market, and the Buyer chooses to immediately accept or reject this set price, or bid for information about the quality of the commodity from a third party before making his/her decision to accept or reject Seller's offer.

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The Market Game – Bidding for Information

If the Buyer chooses to bid for information about the quality of the commodity (i.e. high or low quality) from a third party, then

- **Buyer states the maximum price he/she is willing to pay for the information.**
- **The computer will then draw a random number *c* that is between $0 and $20. Any integers between $0 and $20 is equally likely to be drawn.**
- **If the random number *c* is smaller than or equal to the maximum price stated by the Buyer, then the Buyer acquires the information about the quality of the commodity by paying *c*.**
- **If the random number *c* is larger than the maximum price stated by the Buyer, then the Buyer does not get any information about the quality of the commodity, nor does he need to pay any cost.**

Afterwards, the Buyer chooses to accept or reject the offer proposed by the Seller.

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The Market Game - Process

Each game proceeds as follows:

1. Seller makes an offer to sell his/her commodity to Buyer.
2. Buyer can choose to immediately accept or reject Seller's offer, or bid for information about the quality of the commodity from a third party.
3. Say if the Seller who possesses a low-quality commodity proposes to sell it at $123, and the Buyer accepts it, then
   - ❑ Seller's profit = $23 (i.e. $123 - $100),
   - ❑ Buyer's profit = $27 (i.e. $100 * 1.5 - $123).
4. If Buyer rejects Seller's offer, then both parties get $0.
5. The payoff structure for Buyers and Sellers basically remains the same if Buyer chooses to bid for information. The only difference is that if the Buyer successfully buys information, he/she will need to pay for the information cost.

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The Market Game

Seller's Profit

If Buyer accepts, Seller gets what he/she proposes to Buyer, minus the value of the commodity to the Seller.

If Buyer rejects, Seller gets zero profit.

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The Market Game

Buyer's Profit

If Buyer accepts the offer , he/she gets the value of the commodity, minus the amount he/she pays to the Seller and the information cost (if any).

If Buyer rejects the offer, he/she gets zero profit, minus the information cost (if any).

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Example 1

Suppose that the Seller who possesses a high-quality commodity proposes to sell it at $211

Seller ← Accept — Buyer

Seller	Buyer
$11	$89

If the Buyer **accepts** the offer, the profit for the Seller will be $11 (i.e. $211 - $200), and the profit for Buyer will be $89 (i.e. $200 * 1.5 - $211).

Seller ← Reject — Buyer

Seller	Buyer
$0	$0

If the Buyer **rejects** the offer, then both parties will get zero profit.

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Example 2

Suppose that the Seller who possesses a high-quality commodity proposes to sell it at $211, and the Buyer decides to pay for a maximum price of $10 to buy information

Seller ← Accept — Buyer

$11 | $81

If the computer generates $8 as the random number, then the Buyer will pay $8 and be informed that the seller possesses a high-quality commodity.

Then, if the Buyer chooses to **accept**, the Seller will get $11 (i.e. $211 - $200), and the Buyer will get $81 (i.e. $200 * 1.5 - $211 - $8).

Seller ← Reject — Buyer

$0 | -$8

If the Buyer **rejects** the offer after knowing its quality type, then the Seller gets $0, and the Buyer pays $8 for the information cost.

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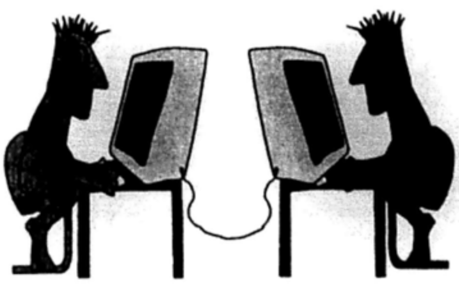
Now that you are familiar with the game that we are going to play, we will then explain in detail the settings and the procedures of the experiment.

If you make good decisions, you increase your chances of earning a considerable amount of money.

[redacted]

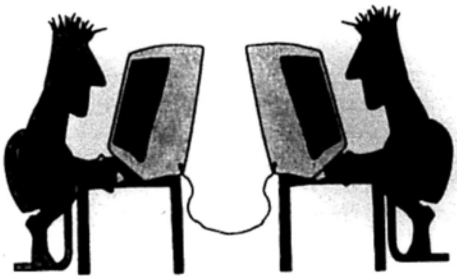
The Market Game



After you have finished reading the instructions, the computer will randomly match you with another participant in the lab for the first game. You will be randomly matched again with a different participant in each new game. You will never be matched with the same participant in two consecutive games.

[redacted]

The Market Game

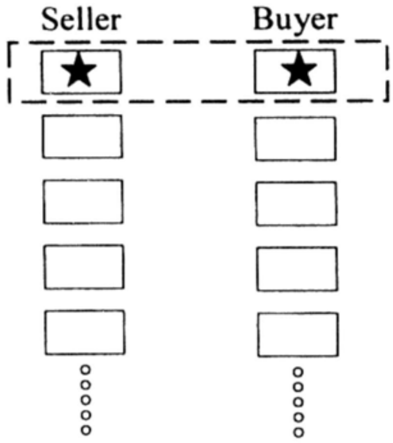


Because you are interacting via computer, you will not know the identity of your game partner, nor will he/she know yours in any games. Your identity will not be revealed even after the session is completed.

The Market Game

Before the game starts, the computer will tell you which role you will play.

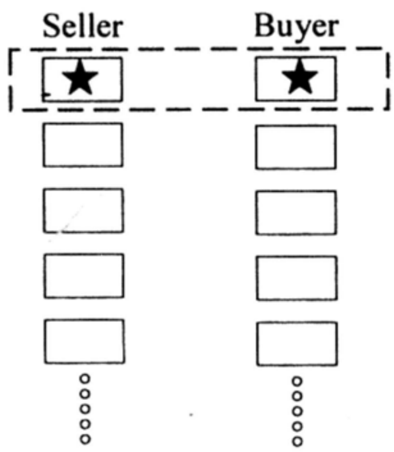
The Market Game



In each market game, one of you will be the Seller (possessing either low-quality or high-quality commodity) who makes the offer, and the other will be the Buyer who decides whether to accept or reject the offer, or to buy information about the quality of the commodity from a third party.

[redacted]

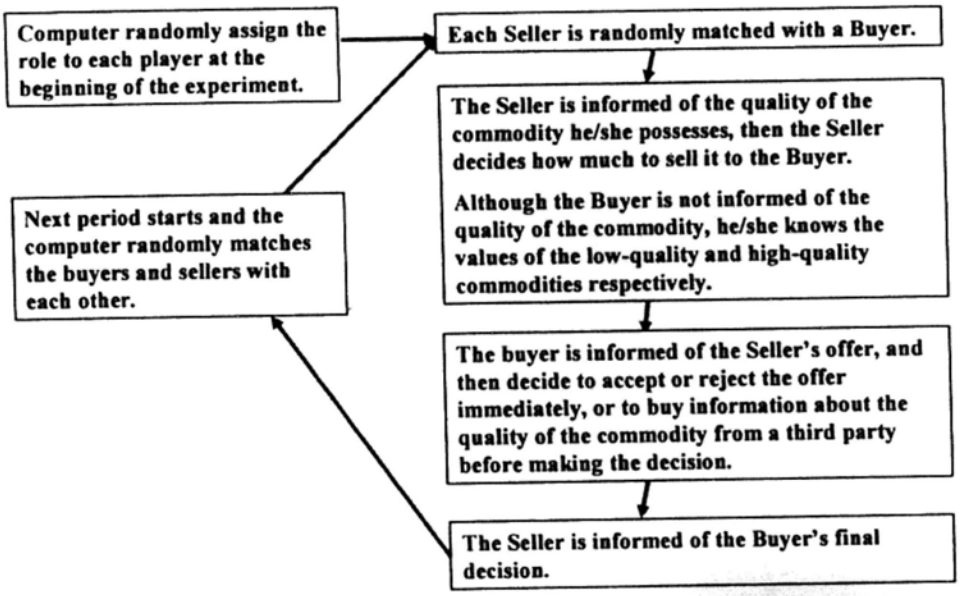
The Market Game



The computer will randomly assign you to the role of either Seller (with low-quality or high-quality commodity) or Buyer at the beginning of the session. Once assigned, your role remains fixed throughout the experiment.

[redacted]

Sequence of Play: The Market Game



[redacted]

Just to make sure that you understand the game, we would like to ask you several questions. There are totally 8 questions to assess your understanding. Please raise your hand anytime if you have any questions or are unclear on any answers.

[redacted]

Market Setting

What is the percentage of sellers possessing high-quality commodity in the market?

- 30%
- 70%
- It is not known.

YOU ARE SELLER

Sorry, this is not the correct answer.
As stated in the second slide of the instruction, there are 30% of the Sellers in the market with high-quality commodities.

Click here if you want to answer the question again

Click here if you want to review the instructions all over again

Very good.

Let's try another one

[redacted]

YOU ARE SELLER

Assume that you are the **Seller** who possesses a high-quality commodity. As mentioned in the previous slides, the commodity is worth $200 to you, and $300 to the Buyer. You offer $234 and the Buyer accepts your offer. What is your profit for this game?

- $34 ($234 - $200)
- $100 ($300 - $200)
- $234

YOU ARE SELLER

Sorry, this is not the correct answer.
If the Buyer accepts your offer, your profit is equal to your offered amount of money, minus the value of commodity to you. In this case, because the Buyer accepted your offer of $234, your profit for this game is $234 - $200 = $34.

Click here if you want to answer the question again

Click here if you want to review the instructions all over again

Let's try another one

YOU ARE SELLER

Assume that you are the **Seller** who possesses a high-quality commodity. As mentioned in the previous slides, the commodity is worth $200 to you, and $300 to the Buyer. You offer $222 and the Buyer rejects your offer. What is your profit for this game?

- $22 ($222 - $200)
- $78 ($300 - $222)
- $0

YOU ARE SELLER

Sorry, this is not the correct answer.
If the Buyer rejects your offer, your profit for this game is $0.

Click here if you want to answer the question again

Click here if you want to review the instructions all over again

Very good.

Let's try another one

YOU ARE BUYER

Assume that you are the **Buyer**. The Seller offers you $200 and you decide to accept the offer. What is your profit for this game?

- $0 or $100, depending on the quality of the commodity.
- -$50 or $100, depending on the quality of the commodity.
- $0

YOU ARE BUYER

Sorry, this is not the correct answer.
If you accepts the Seller's offer, your profit is equal to value of the commodity to you, minus the offered amount. Since you do not know which type (high-quality or low-quality) of the commodity the Seller possessed, your payoff would depend – if the Seller possesses low-quality commodity, then you get -$50 (i.e. $100 * 1.5 - $200) ; else if the Seller possess high-quality commodity, then you get $100 (i.e. $200 * 1.5 - $200).

Click here [redacted] if you want to answer the question again

Click here [redacted] if you want to review the instructions all over again

Let's try another one

[redacted] [redacted]

YOU ARE BUYER

Assume that you are **BUYER**. The Seller offers you $180 and you decide to reject the offer. What is your profit for this game?

- $180
- $0
- -$30 or $120, depending on the quality of the commodity.

YOU ARE BUYER

Sorry, this is not the correct answer.
If you reject the offer, both Seller's and your profit will be $0.

Click here if you want to answer the question again

Click here if you want to review the instructions all over again

Very good.

Let's try another one

[redacted]

YOU ARE BUYER

Assume that you are **BUYER**. The Seller offers you $120, and you decide to offer $10 to buy information about the commodity type. What is the likelihood you could get the information?

- 50%
- 52%
- Not sure

YOU ARE BUYER

Sorry, this is not the correct answer.
If you offer $10 to buy information, the computer will randomly draw a number that is between $0 and $20. Any integers between $0 and $20 are equally likely to be drawn. Therefore, there are 11 (0, 1, 2 , 9, 10) out of 21 (0, 1, 2, , 19, 20) cases you can successfully buy the information. Hence, the likelihood for you to acquire the information is 11 / 21 = 52%.

Click here [redacted] if you want to answer the question again

Click here [redacted] if you want to review the instructions all over again

Let's try another one

[redacted]

YOU ARE BUYER

Assume that you are **BUYER**. The Seller offers you $120 and you decide to offer $20 to buy information about the commodity type. The computer randomly draw a number 18. How much would you need to pay for the information?

- $20
- $18
- Not sure

YOU ARE BUYER

Sorry, this is not the correct answer.
If you offer $20 to buy information, and the computer randomly draw a number 18, then you only need to pay $18 to acquire the information about the quality of the commodity. In other words, you always pay the number that is generated by the computer if the number is smaller than or equal to your offer. Else, if the random number is larger than your offer, you do not need to pay anything, but you do not get any information about the quality of the commodity.

Click here if you want to answer the question again

Click here if you want to review the instructions all over again

Very good.

Let's try one more

[redacted] [redacted]

YOU ARE BUYER

> Assume that you are **BUYER**. The Seller offers you $120 and you decide to offer $10 to buy information about the commodity type. The computer randomly draw a number 12. How much would you need to pay for the information?

- $0
- $10
- $12

YOU ARE BUYER

Sorry, this is not the correct answer.
If you offer $10 to buy information, and the computer randomly draw a number 12, then you do not need to pay anything, but you do not acquire the information about the quality of the commodity. In other words, if the random number generated by the computer is larger than your offer, you won't pay anything, but you also do not get any information about the quality of the commodity.

Click here if you want to answer the question again

Click here if you want to review the instructions all over again

How do we pay you for your participation?

Your payoff for the session will be equal to the seed money ($30) plus the **weighted average** of the profits you earned in 4 randomly selected games with a weighting of 10%, 20%, 30% and 40% in sequential order. That means later games are relatively more important in determining your final payoffs.

For instance, if the computer select periods 2, 6, 8, 13 for payment, and you earned $100, $0, $150 and $50 for these four periods accordingly, then your payment for this experiment would be $30 (seed money) + $75 (i.e. $100 * 10% + $0 * 20% + $150 * 30% + $50 * 40%) = $105.

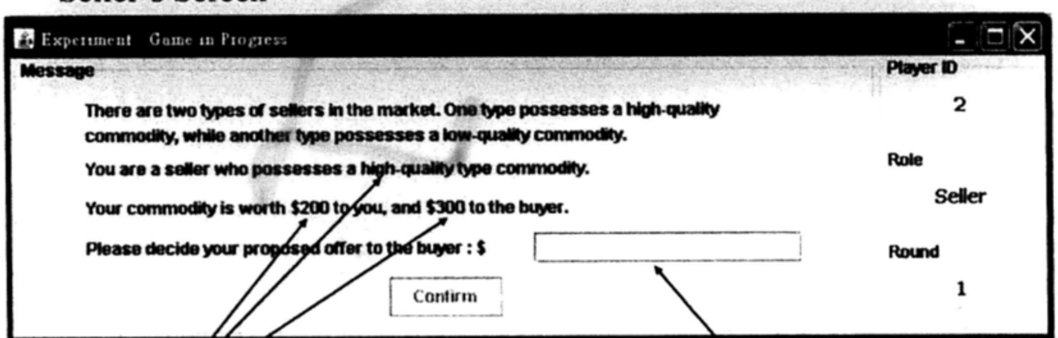
Computer Display

Now that you understand the game, the final set of slides will familiarize you with the display screens you will see as you play.

Let's get familiar with Seller's screens first

[redacted]

Seller's Screen

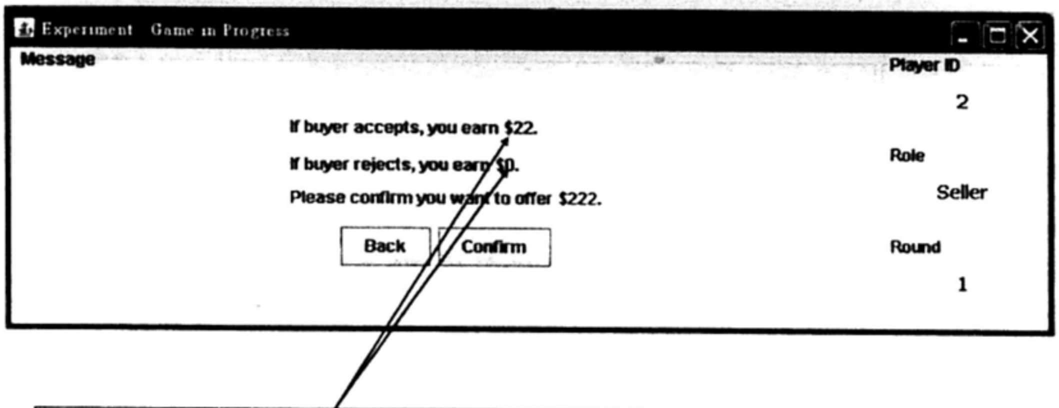


At the start of the experiment, the Seller is informed of the commodity type he/she possesses, and also the relevant values of the commodity.

The Seller is then being asked to decide his/her proposed offer to sell the commodity to the Buyer.

[redacted]

Seller's Screen

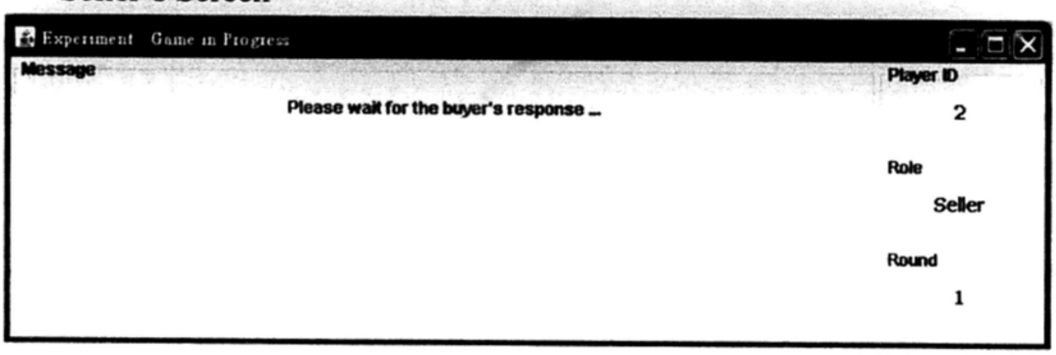


Say if the Seller decided to sell the commodity to the Buyer at $222, then the computer will calculate the Seller's potential profits, which are based on the decision of the Buyer (accept or reject the offer).

You can then click "Confirm" to continue, or click "Back" to change your offered amount.

[redacted]

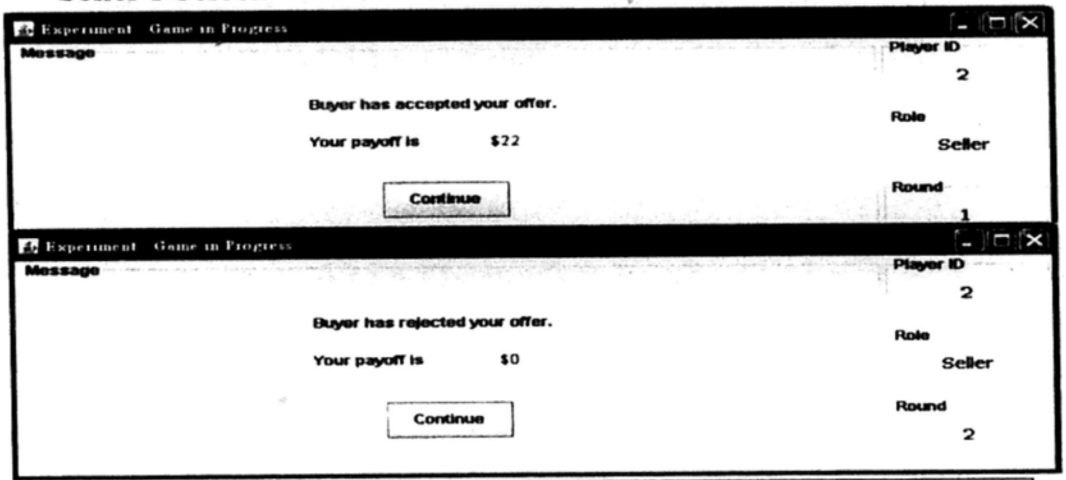
Seller's Screen



After you have confirmed your proposed offer, you would need to wait for the Buyer's response

[redacted]

Seller's Screen



After the Buyer has made his/her decision, you would see the results (accept / reject) and your corresponding payoffs – you will see one of the above screens depending on the Buyer's decision.

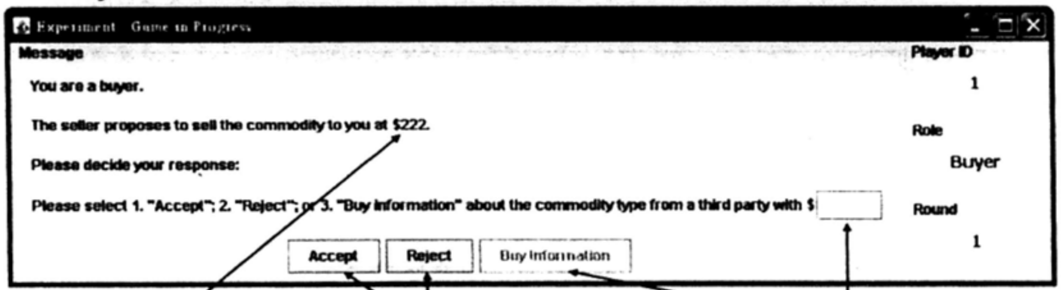
Please then click "Continue" to proceed to the next round.

[redacted]

Now, let's see what happens to Buyer

[redacted]

Buyer's Screen



The first screen will show you the offer that the Seller proposed to you.

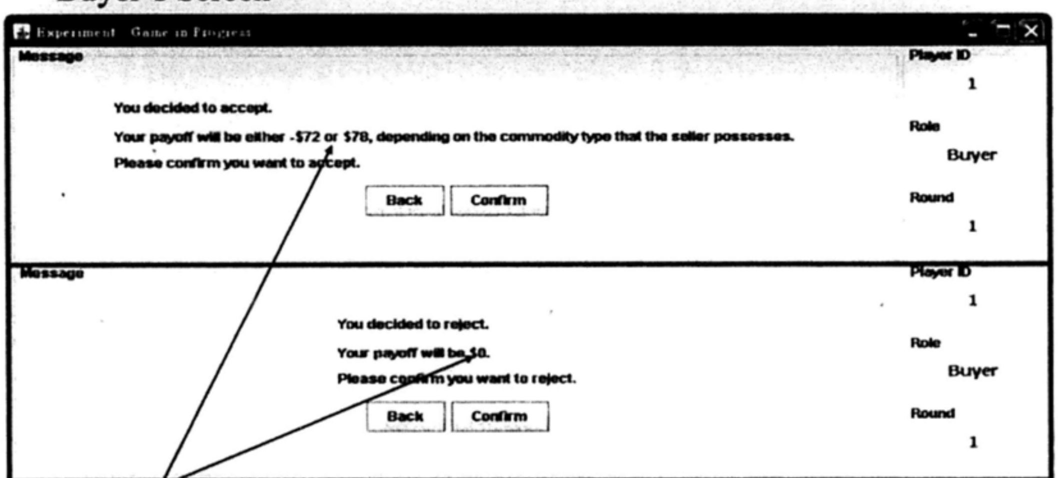
If you want to immediately accept or reject the offer, then you can click the relevant button.

On the other hand, if you want to try to buy information from a third party, you can enter the maximum amount you would pay for the information in the box, and then click the button "Buy Information".

Note: Due to java program issue, you may see the amount you entered in the previous round shows up again, but you can simply highlight and change it to the new amount you decide for the current round.

[redacted]

Buyer's Screen

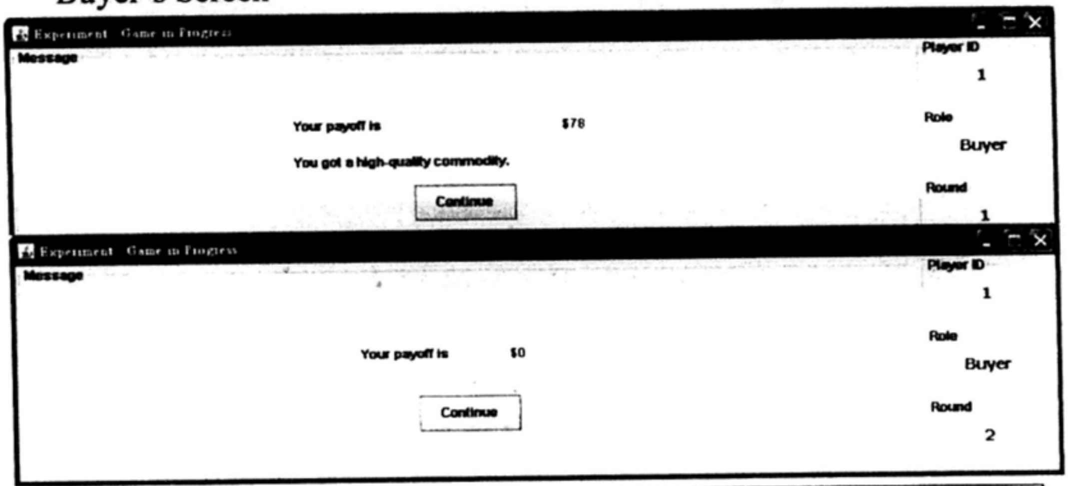


If you decide to accept or reject the offer immediately, the computer will calculate your potential payoffs.

You can then click the "Confirm" button to continue, or you can click "Back" to change your decision.

[redacted]

Buyer's Screen

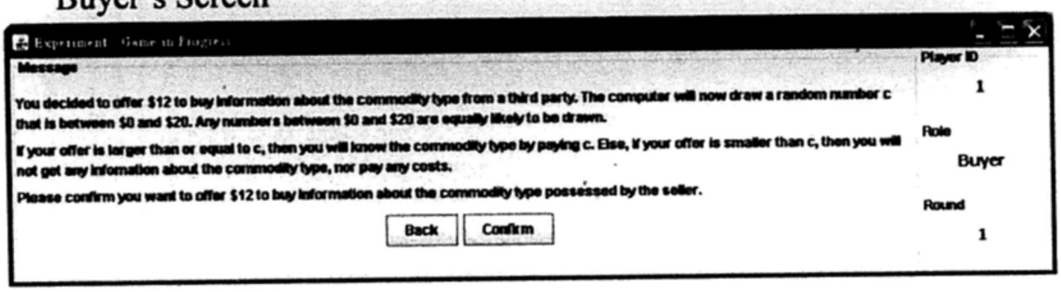


After your have clicked the "Confirm" button, you would see your results (e.g. it shows whether you get a high-quality or low-quality commodity if you accept the offer) and corresponding payoffs.

Please then click "Continue" to proceed to the next round.

[redacted] [redacted]

Buyer's Screen

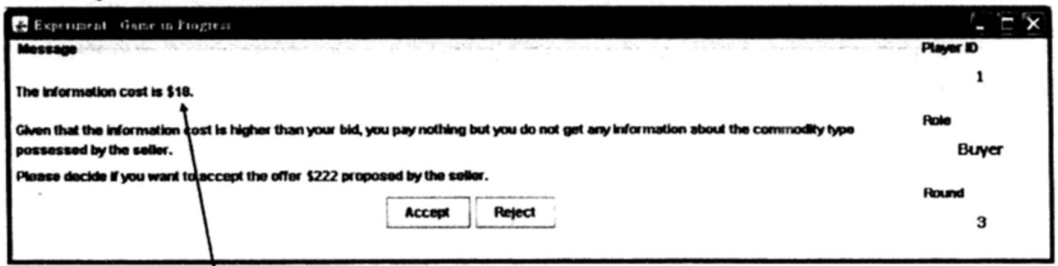


On the other hand, if you decide to state your maximum amount to buy information, say $12, then the computer will tell you that it is going to draw a random number that is between 0 and 20, and only if your stated amount is not less than the random number, then you would pay the random amount generated by the computer and know the quality of the commodity.

You can then click "Confirm" to continue, or click "Back" to change your decision.

[redacted] [redacted]

Buyer's Screen

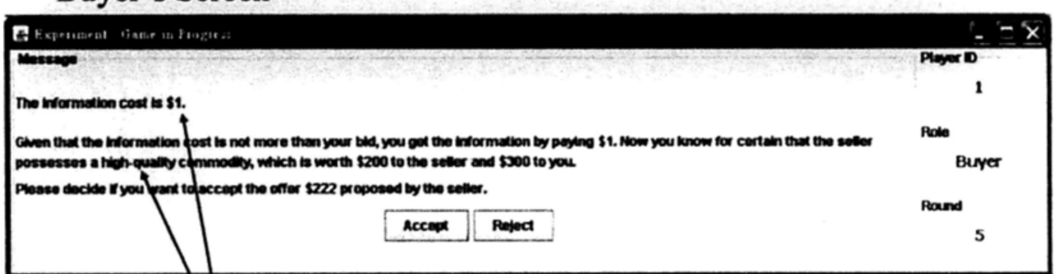


Next , the computer will show you the random number. In this example, the random number, $18, is larger than the Buyer's stated maximum amount ($12), so the Buyer does not get any information about the quality of the commodity, nor pay any cost.

The Buyer will then have to decide whether to accept or reject the Seller's proposed offer, $222, for buying the commodity.

[redacted]

Buyer's Screen

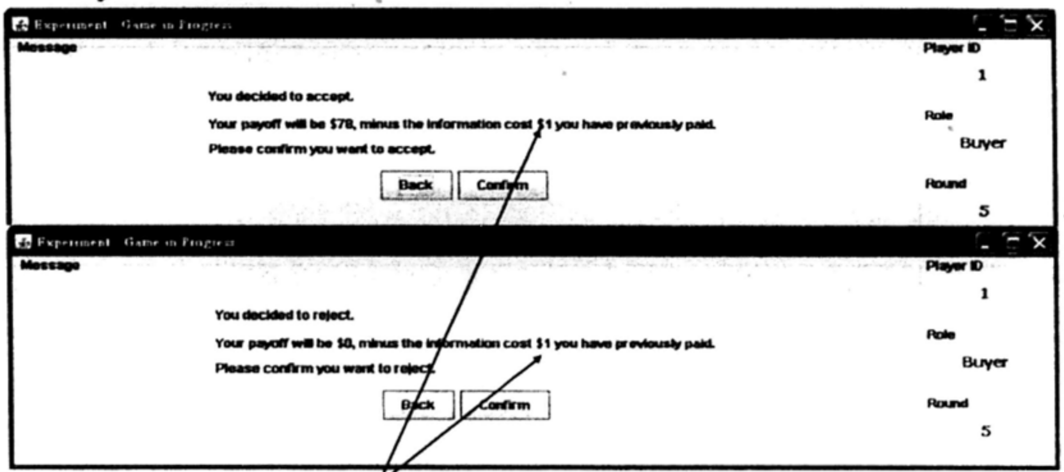


On the other hand, if the random number ($1 in this example) is not more than the Buyer's stated maximum amount ($12), then the Buyer will pay for the cost ($1) and know the quality of the commodity.

The Buyer will then have to decide whether to accept or reject the Seller's proposed offer, $222, for buying the commodity.

[redacted]

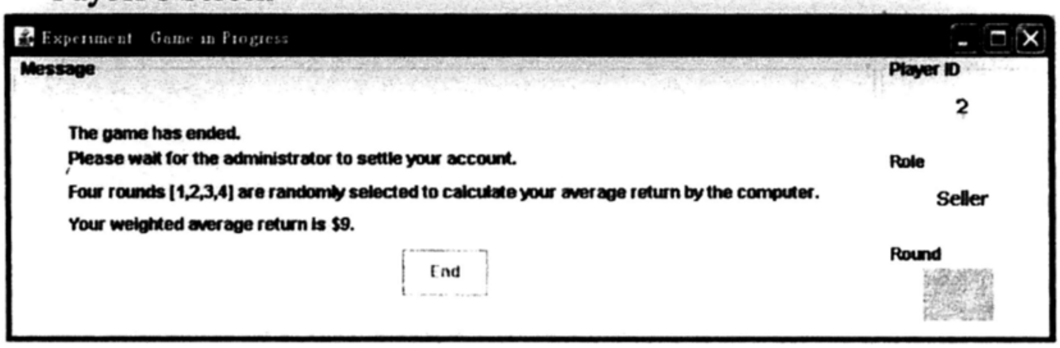
Buyer's Screen



After you have acquired the information, you would have to pay for the information cost ($1 in this example) no matter you decide to accept or reject the Seller's offer afterwards.

[redacted]

Payoff's Screen



At the end of the experiment, the computer will randomly select 4 games to calculate your weighted average payoff. Please wait for the experimenter to jot down your payoff, then we will pay you that amount accordingly.

Please do NOT close the screen after the game is over!!

The computer may not function properly if you do so, and hence we may not be able to pay you correctly.

[redacted]

This ends the introduction to the game. Please move to the computer next to you and wait for the experimenter's instruction to start the game.

We will start as soon as everyone has finished reading the instruction.

Click this arrow to read the instruction again.

APPENDIX 2

Self-paced Instructions for Subjects to Understand the Market Game under Proposed Mechanism

Greetings!

You are about to participate in an economic study. At the end of the experiment you will be paid according to your performance.

Please read the instructions very carefully. The instruction consists of two parts. The first part describes the market game you will be playing. In the second part, we describe the experiment in details. The computer will then ask you questions to check your understanding.

Next Page

The Market Game - Setting

- ❑ In this experiment, you will play a simple and the same game many times. Each game involves two players – Buyer and Seller. In the beginning of the experiment, the computer will randomly assign you as either Buyer or Seller. Once assigned, your role will remain the same throughout the entire experiment.
- ❑ In each game, each Buyer will be randomly paired with a Seller. Then, in next period, the computer will randomly match Buyer and Seller again, so you will be paired with different players in different periods.
- ❑ The rule of the game remains the same for each game in the entire experiment.

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The Market Game – Background Information

There are Buyers and Sellers in the market.

- ❑ Each Seller has a commodity that is valued at either $100 or $200, depending on its quality.
- ❑ The Seller knows its quality but the Buyer does not.
- ❑ The commodity is worth more to the Buyers than to the sellers at a ratio 1.5. In other words, the low-quality and high-quality commodities are worth ($100 * 1.5) = $150 and ($200 * 1.5) = $300 respectively to the Buyer.
- ❑ There are 30% of the Sellers possessing high-quality commodities, and 70% of the Sellers possessing low-quality commodities in the market.

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The Market Game - Process

Each game proceeds as follows:

1. Buyer can either makes an offer to buy commodity from the Seller immediately, or the Buyer can bid for information about the quality of the commodity possessed by the Seller from a third party before making any offers to the Seller.
2. Seller can then choose to accept or reject Buyer's offer.
3. Say if the Buyer proposes an offer of $123, and a Seller who possesses a low-quality commodity accepts it, then
   - ❑ Seller's profit = $23 (i.e. $123 - $100),
   - ❑ Buyer's profit = $27 (i.e. $100 * 1.5 - $123).
4. If Seller rejects Buyer's offer, then both parties get $0.
5. The payoff structure for Buyers and Sellers basically remains the same if Buyer chooses to bid for information. The only difference is that if the Buyer successfully buys the information, he/she will need to pay for the information cost.

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The Market Game – Bidding for Information

If the Buyer chooses to bid for information about the quality of the commodity (i.e. high or low quality) from a third party, then

- ❑ Buyer states the maximum price he/she is willing to pay for the information.
- ❑ The computer will then draw a random number *c* that is between $0 and $20. Any integers between $0 and $20 is equally likely to be drawn.
- ❑ If the random number *c* is not larger than the maximum price stated by the Buyer, then the Buyer acquires the information about the quality of the commodity by paying *c*.
- ❑ If the random number *c* is larger than the maximum price stated by the Buyer, then the Buyer does not get any information about the quality of the commodity, nor does he need to pay any costs.

Afterwards, the Buyer proposes an offer to buy the commodity from the Seller.

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The Market Game

Buyer's Profit

If Seller accepts the offer , Buyer gets the value of the commodity, minus the amount he/she proposes to Seller and the information cost (if any).

If Seller rejects the offer, Buyer gets zero profit, minus the information cost (if any).

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The Market Game

Seller's Profit

If Seller accepts, Seller gets what Buyer offers, minus the value of the commodity to the Seller.

If Seller rejects, he/she gets zero profit.

Back Page **Next Page**

Example 1

Suppose that the Buyer proposes to buy the commodity at $222 from the Seller

Seller —Accept→ Buyer
$22 | $78

If Seller who possesses a **high-quality** commodity **accepts** the offer, the profit for the Seller will be $22 (i.e. $222 - $200), and the profit for Buyer will be $78 (i.e. $200 * 1.5 - $222).

Seller —Accept→ Buyer
$122 | -$72

If Seller who possesses a **low-quality** commodity **accepts** the offer, the profit for the Seller will be $122 (i.e. $222 - $100), and the profit for Buyer will be -$72 (i.e. $100 * 1.5 - $222).

Seller —Reject→ Buyer
$0 | $0

If Seller **rejects** the offer, then both parties will get zero profit.

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Example 2

Suppose that Buyer decides to pay for a maximum price of $10 to buy information from a third party, and the random cost generated by the computer is $8

Seller —Accept→ Buyer

$22 | $70

The Buyer will pay $8 and get the information. Suppose the information reveals that the Seller possesses a high-quality commodity.

Then, if Buyer offers $222, and Seller chooses to **accept**, the Seller will get $22 (i.e. $222 - $200), and the Buyer will get $70 (i.e. $200 * 1.5 - $222 - $8).

Seller —Reject→ Buyer

$0 | -$8

If the Seller **rejects** the offer after the Buyer has bought the information, then the Seller gets $0 and the Buyer pays **$8** for the information cost without getting anything.

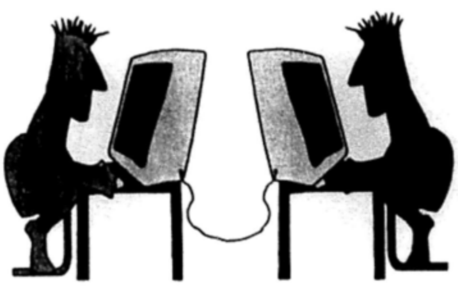
Back Page **Next Page**

Now that you are familiar with the game that we are going to play, we will then explain in detail the settings and the procedures of the experiment.

If you make good decisions, you increase your chances of earning a considerable amount of money.

[redacted] [redacted]

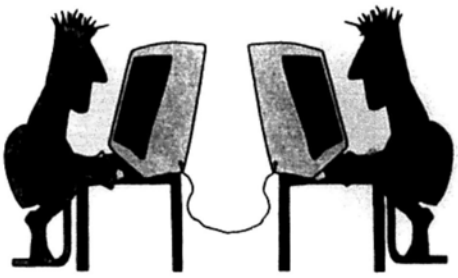
The Market Game



After you have finished reading the instructions, the computer will randomly match you with another participant in the lab for the first game. You will be randomly matched again with a different participant in each new game. You will never be matched with the same participant in two consecutive games.

[redacted] [redacted]

The Market Game

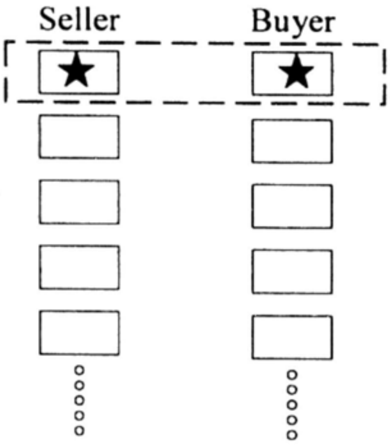


Because you are interacting via computer, you will not know the identity of your game partner, nor will he/she know yours in any games. Your identity will not be revealed even after the session is completed.

The Market Game

Before the game starts, the computer will tell you which role you will play.

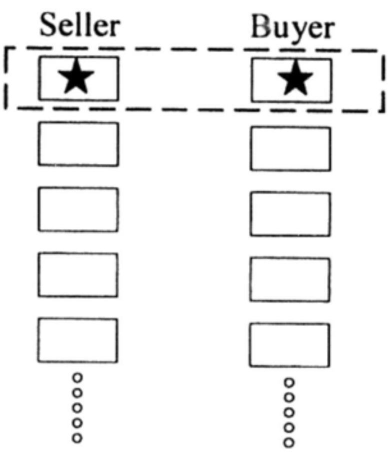
The Market Game



In each market game, one of you will be the Seller (possessing either low-quality or high-quality commodity), and the other will be the Buyer, who decides to make an offer immediately, or to buy information about the quality of the commodity from a third party before making any offers to the Seller.

[redacted] [redacted]

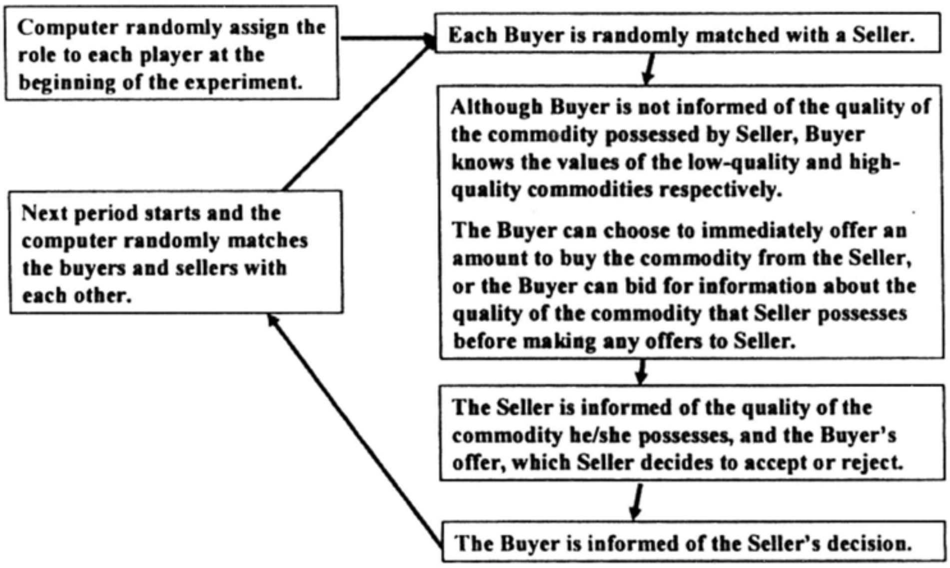
The Market Game



The computer will randomly assign you to the role of either Seller (with low-quality or high-quality commodity) or Buyer at the beginning of the session. Once assigned, your role remains fixed throughout the experiment.

[redacted] [redacted]

Sequence of Play: The Market Game



[redacted] [redacted]

Just to make sure that you understand the game, we would like to ask you several questions. There are totally 8 questions to assess your understanding. Please raise your hand anytime if you have any questions or are unclear on any answers.

[redacted]

Market Setting

What is the percentage of sellers possessing high-quality commodity in the market?

- 30%
- 70%
- It is not known.

YOU ARE SELLER

Sorry, this is not the correct answer.
As stated in the second slide of the instruction, there are 30% of the Sellers in the market with high-quality commodities.

Click here if you want to answer the question again

Click here if you want to review the instructions all over again

Very good.

Let's try another one

[redacted]

YOU ARE SELLER

Assume that you are the **Seller** who possesses a high-quality commodity. As mentioned in the previous slides, the commodity is worth $200 to you, and $300 to the Buyer. Buyer offers $234 to buy your commodity, and you accept the offer. What is your profit for this game?

- $34 ($234 - $200)
- $100 ($300 - $200)
- $234

YOU ARE SELLER

Sorry, this is not the correct answer.
If you accepts Buyer's offer, your profit is equal to the Buyer's offered amount of money, minus the value of commodity to you. In this case, because you accepted the offer of $234, your profit for this game is $234 - $200 = $34.

Click here [redacted] if you want to answer the question again

Click here [redacted] if you want to review the instructions all over again

Very good.

Let's try another one

[redacted]

YOU ARE SELLER

Assume that you are the **Seller** who possesses a high-quality commodity. As mentioned in the previous slides, the commodity is worth \$200 to you, and \$300 to the Buyer. Buyer offers \$234 to buy your commodity, and you reject the offer. What is your profit for this game?

- \$22 (\$222 - \$200)
- \$78 (\$300 - \$222)
- \$0

YOU ARE SELLER

Sorry, this is not the correct answer.
If you reject the offer, your profit for this game is \$0.

Click here if you want to answer the question again

Click here if you want to review the instructions all over again

Very good.

Let's try another one

[redacted] [redacted]

YOU ARE BUYER

> Assume that you are **Buyer**. You offers $200 to buy Seller's commodity, and Seller accepts the offer. What is your profit for this game?

- $0 or $100, depending on the quality of the commodity.
- -$50 or $100, depending on the quality of the commodity.
- $0

YOU ARE BUYER

Sorry, this is not the correct answer.
If Seller accepts your offer, your profit is equal to the value of the commodity to you, minus the offered amount. Since you do not know which type (high-quality or low-quality) of the commodity the Seller possessed, your payoff depends – if the Seller possesses a low-quality commodity, then you get -$50 (i.e. $100 * 1.5 - $200) ; else if the Seller possess a high-quality commodity, then you get $100 (i.e. $200 * 1.5 - $200).

Click here [redacted] if you want to answer the question again

Click here [redacted] if you want to review the instructions all over again

Very good.

Let's try another one

[redacted]

YOU ARE BUYER

Assume that you are **BUYER**. You offer $180 to buy commodity, but Seller decides to reject your offer. What is your profit for this game?

► $180

► $0

► -$30 or $120, depending on the quality of the commodity.

YOU ARE BUYER

Sorry, this is not the correct answer.
If Seller rejects the offer, both Seller's and your profit will be $0.

Click here if you want to answer the question again

Click here if you want to review the instructions all over again

Very good.

Let's try another one

YOU ARE BUYER

> Assume that you are **BUYER**. You decide to offer $10 to buy information about the commodity type. What is the likelihood you could get the information?

- ▶ 50%
- ▶ 52%
- ▶ Not sure

YOU ARE BUYER

Sorry, this is not the correct answer.
If you offer $10 to buy information, the computer will randomly draw a number that is between $0 and $20. Any integers between $0 and $20 are equally likely to be drawn. Therefore, there are 11 (0, 1, 2 , 9, 10) out of 21 (0, 1, 2, , 19, 20) cases you can successfully buy the information. Hence, the likelihood for you to acquire the information is 11 / 21 = 52%.

Click here [redacted] if you want to answer the question again

Click here [redacted] if you want to review the instructions all over again

Let's try another one

[redacted] [redacted]

YOU ARE BUYER

Assume that you are **BUYER**. You decide to offer $20 to buy information about the commodity type. The computer randomly draw a number 18. How much would you need to pay for the information?

- $20
- $18
- Not sure

YOU ARE BUYER

Sorry, this is not the correct answer.
If you offer $20 to buy information, and the computer randomly draw a number 18, then you only need to pay $18 to acquire the information about the quality of the commodity. In other words, you always pay the number that is generated by the computer if the number is smaller or equal to your offer. Else, if the random number is larger than your offer, you do not need to pay anything, but you do not get the information about the quality of the commodity.

Click here if you want to answer the question again

Click here if you want to review the instructions all over again

Very good.

Let's try one more

YOU ARE BUYER

Assume that you are **BUYER**. You decide to offer $10 to buy information about the commodity type. The computer randomly draw a number 12. How much would you need to pay for the information?

- ► $0
- ► $10
- ► $12

YOU ARE BUYER

Sorry, this is not the correct answer.
If you offer $10 to buy information, and the computer randomly draw a number 12, then you do not need to pay anything, but you do not acquire the information about the quality of the commodity. In other words, if the random number generated by the computer is larger than your offer, you won't pay anything, but you also do not get any information about the quality of the commodity.

Click here if you want to answer the question again

Click here if you want to review the instructions all over again

How do we pay you for your participation?

Your payoff for the session will be equal to the seed money ($30) plus the **weighted average** of the profits you earned in 4 randomly selected games with a weighting of 10%, 20%, 30% and 40% in sequential order. That means later games are relatively more important in determining your final payoffs.

For instance, if the computer select periods 2, 6, 8, 13 for payment, and you earned $100, $0, $150 and $50 for these four periods accordingly, then your payment for this experiment would be $30 (seed money) + $75 (i.e. $100 * 10% + $0 * 20% + $150 * 30% + $50 * 40%) = $105.

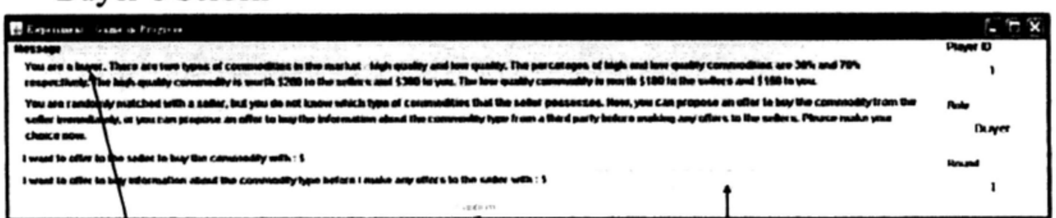
Computer Display

Now that you understand the game, the final set of slides will familiarize you with the display screens you will see as you play.

Let's get familiar with Buyer's screens first

[redacted]

Buyer's Screen



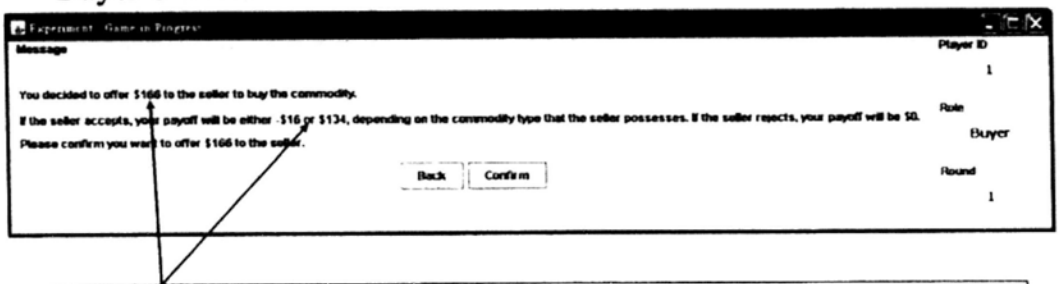
The first screen will tell you which role you will be playing (i.e. Buyer), and the relevant values of the low and high quality commodities to you and to the Seller.

You can then make your decision: 1) put an offer in the first cell to buy commodity from the Seller immediately; or 2) put a maximum price you are willing to pay for information in the second cell to buy information about the quality of the commodity from a third party.

After you have made your choice, please click "Confirm" to continue.

[redacted]

Buyer's Screen

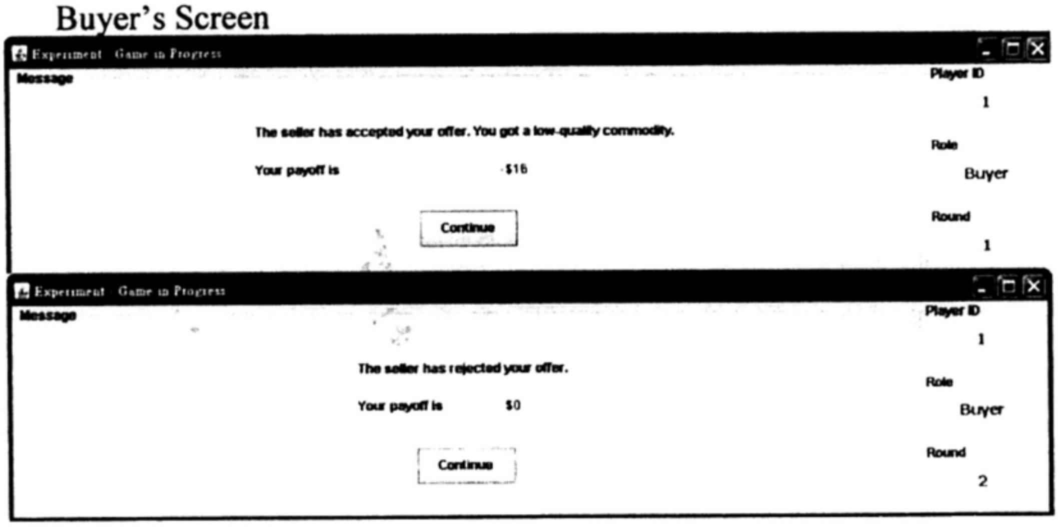


Say if you decide to offer $166 to buy the commodity from the Seller, the computer will calculate your potential profit for you (in this case, -$16 if Seller turns out to possess a low-quality commodity, and $134 if Seller possesses a high-quality commodity).

You can then click the "Confirm" button to continue, or you can click "Back" to change your decision.

[redacted]

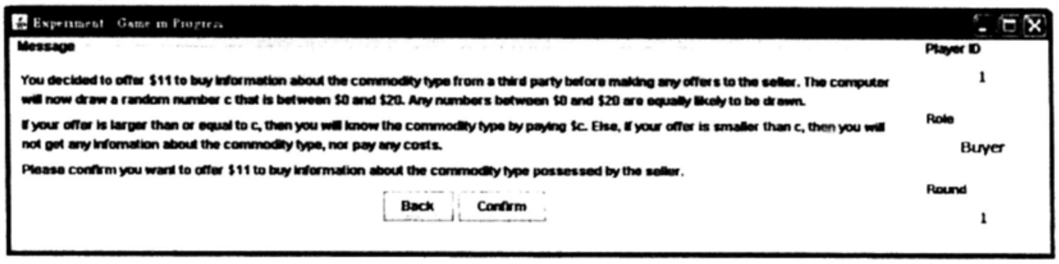
Buyer's Screen



After the Seller has made the decision, the computer will tell you whether your offer was accepted or rejected, and your relevant payoffs.

[redacted]

Buyer's Screen

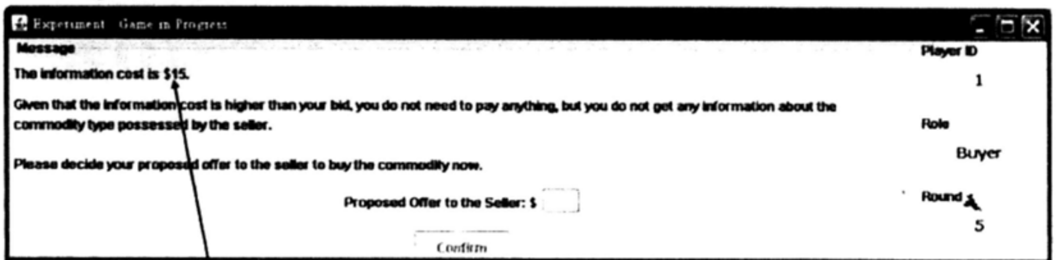


On the other hand, if you decide to state your maximum amount to buy information, say $11, then the computer will tell you that it is going to draw a random number between 0 and 20, and only if your stated amount is not less than the random number, then you would get the information about the quality of the commodity by paying the random amount generated by the computer.

You can then click the "Confirm" button to continue, or you can click "Back" to change your decision.

[redacted]

Buyer's Screen

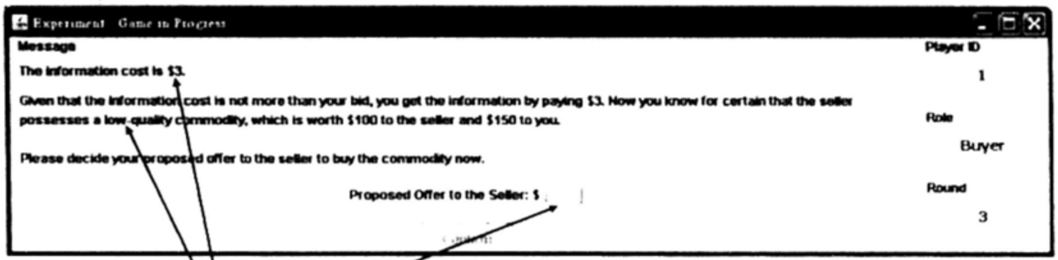


Next , the computer will show you the random number. In this example, the random number $15 is larger than the Buyer's stated maximum amount ($11), so the Buyer does not get any information about the quality of the commodity, nor pay any cost.

The Buyer will then have to decide how much to offer to the Seller to buy the commodity.

[redacted]

Buyer's Screen

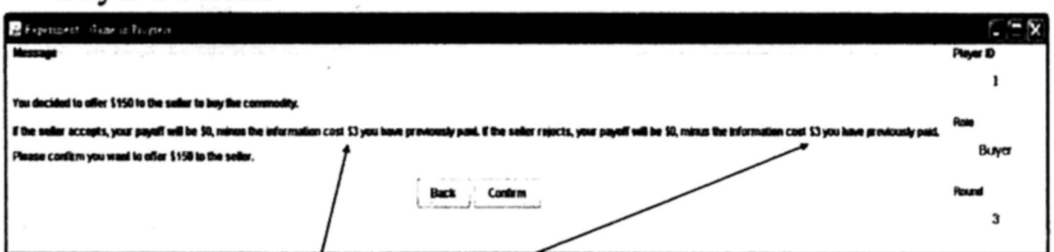


On the other hand, if the random number ($3 in this example) is not more than the Buyer's stated maximum amount ($11), then the Buyer will pay for the cost ($3) and know the quality of the commodity.

The Buyer will then have to decide how much to offer to the Seller to buy the commodity.

[redacted]

Buyer's Screen



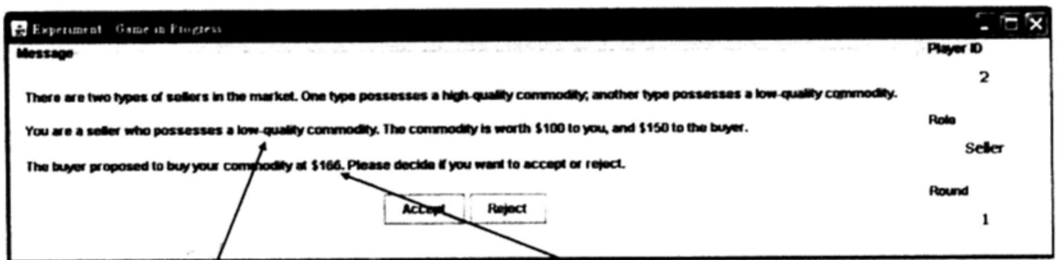
After you have acquired the information, you would have to pay for the information cost ($3 in this example) no matter how much you decide to offer to the Seller to buy the commodity afterwards, and also independent of the decision (accept or reject) from the Seller.

[redacted]

Now, let's see what happens to Seller

[redacted]

Seller's Screen

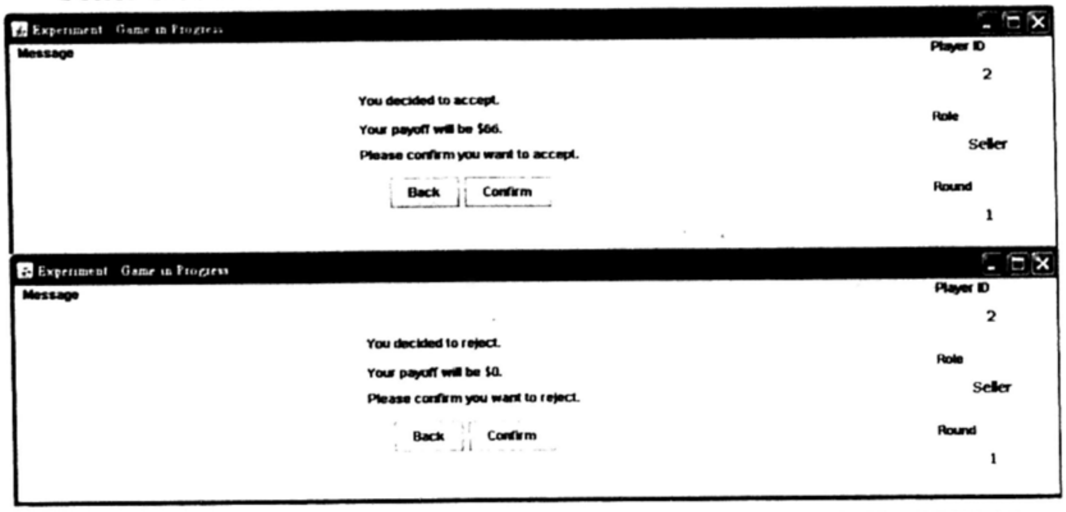


At the start of the experiment, the Seller is informed of the commodity type he/she possesses, and also the relevant values of the commodity.

The Seller is also informed of the proposed offer from the Buyer to buy the commodity. Then, the Seller can choose to accept or reject the offer.

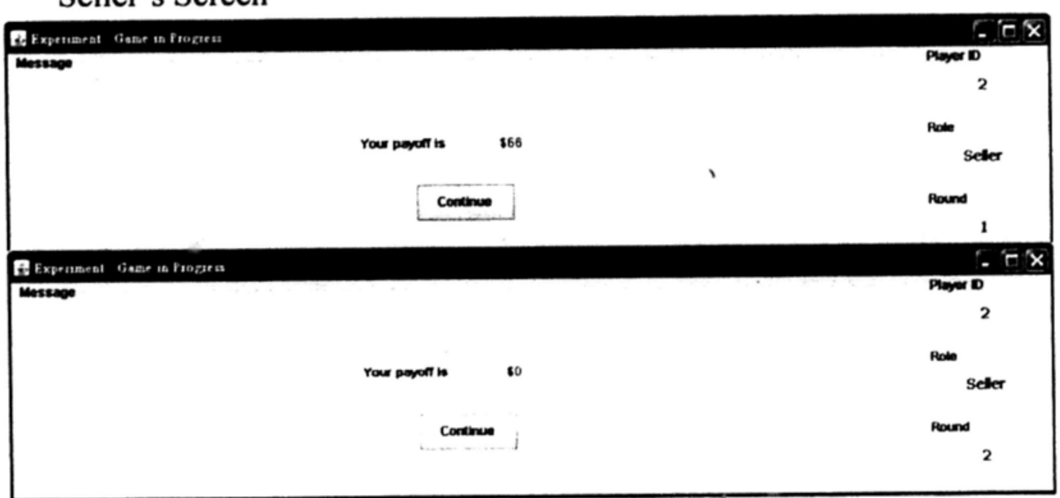
[redacted]

Seller’s Screen



Depending on your choice (accept or reject Buyer’s offer), you will see one of the above screens, which shows you the relevant payoff of your decision.

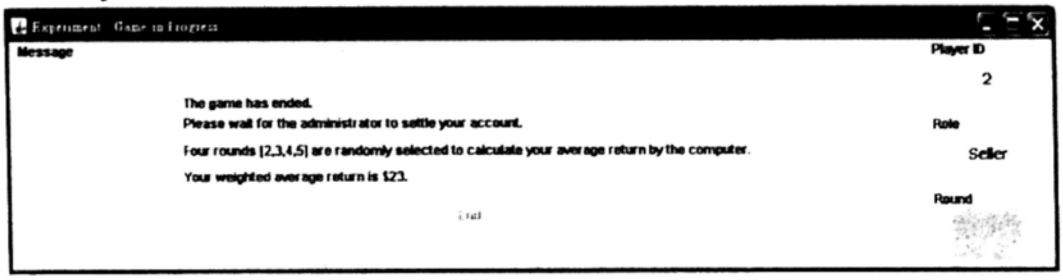
Seller’s Screen



After you have confirmed your decision, you will see one of the above screens showing your relevant payoff.

Please then click “Continue” to proceed to the next round.

Payoff Screen



At the end of the experiment, the computer will randomly select 4 games to calculate your weighted average payoff. Please wait for the experimenter to jot down your payoff, then we will pay you that amount accordingly.

Please do NOT close the screen after the game is over!!

The computer may not function properly if you do so, and hence we may not be able to pay you correctly.

This ends the introduction to the game. Please move to the computer next to you and wait for the experimenter's instruction to start the game.

We will start as soon as everyone has finished reading the instruction.

Click this arrow to read the instruction again.

APPENDIX 3

Self-paced Instructions for Subjects to Understand the Ultimatum Game

Greetings!

You are about to participate in a bargaining study. At the end of the experiment you will be paid according to your performance.

Please read the instructions very carefully. The instruction consists of two parts. The first part describes the ultimatum game you will be playing. In the second part we describe the experiment in detail. The computer will then ask you questions to check your understanding.

Next Page

The Ultimatum Game

- ❑ In this experiment, you will play a simple and the same game many times. Each game involves two players – Player 1 and Player 2. In the beginning of the experiment, computer will randomly assign you as either Player 1 or Player 2. Once assigned, your role will remain the same throughout the entire experiment.
- ❑ In each game, each Player 1 will be randomly paired with another Player 2. Then, each pair will decide how to divide a certain amount of money between themselves.
- ❑ The amount of money to be divided between the two players will remain the same for each game in the entire experiment. However, only Player 1 will be told how much that amount is and Player 2 will not.

Back Page Next Page

The Ultimatum Game

Each game proceeds as follows:

- In each game, Player 1 first makes a monetary offer to Player 2. The amount that Player 1 proposes to give Player 2 cannot exceed the total amount of money available.
- Then, Player 2 can choose to either accept or reject Player 1 s offer.
- If Player 2 accepts Player 1 s offer, then Player 2 gets the offered amount of money, and Player 1 gets the remaining amount of money. Otherwise, if Player 2 rejects Player 1 s offer, both players get nothing.

"Offered Amount of Money" + "Remaining Amount of Money" = "Total Amount of Money"

Back Page Next Page

The Ultimatum Game

Player 2's Profit

Player 2 will get what Player 1 proposes to him if he accepts the offer. Otherwise, he gets zero profit.

Back Page Next Page

The Ultimatum Game

Player 1's Profit

Player 1 will get the remaining amount of money only if Player 2 accepts the offer. Otherwise, he gets zero profit.

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Example

Suppose that the total amount of money is $1500, and Player 1 makes a $660 offer to Player 2

Player 1 ←Accept— Player 2

$840 $660

If Player 2 **accepts** the offer, the profit for Player 1 will be $840 ($1500 - $660), and the profit for Player 2 will be $660.

Player 1 ←Reject— Player 2

$0 $0

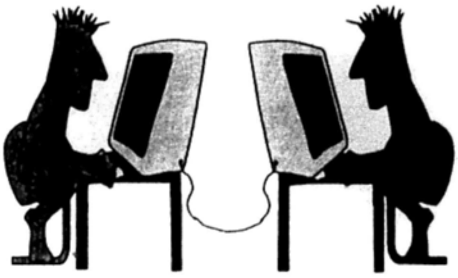
If Player 2 **rejects** the offer, both Players will get zero profit.

Back Page Next Page

Now that you are familiar with the game that we are going to play, we will then explain in detail the settings and the procedures of the experiment.

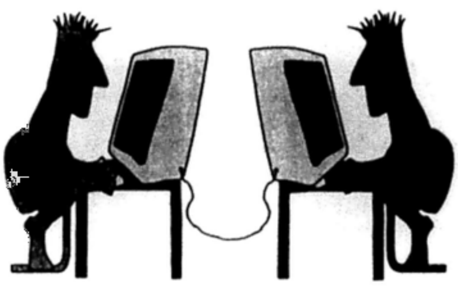
If you make good decisions, you increase your chances of earning a considerable amount of money.

The Ultimatum Game



After you have finished reading the instructions, the computer will randomly match you with another participant in the lab for the first game. You will be randomly matched again with a different participant in each new game. You will never be matched with the same participant in two consecutive games.

The Ultimatum Game



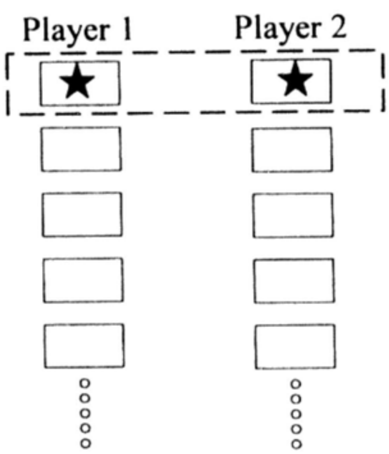
Because you are interacting via computer, you will not know the identity of your negotiation partner, nor will she/he know yours in any game. Your identities will not be revealed even after the session is completed.

The Ultimatum Game

Before the game starts, the computer will tell you which role you will play.

[redacted]

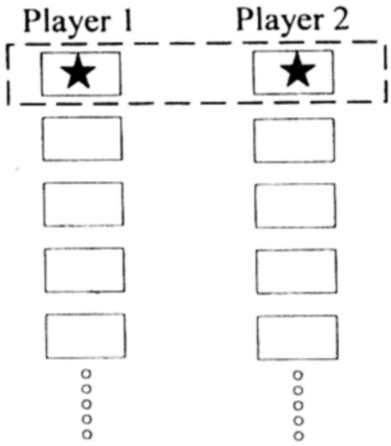
The Ultimatum Game



In each ultimatum game, one of you will be the Player 1 (★) who makes the offer, and the other will be the Player 2 (★) who decides whether to accept or reject the offer.

[redacted]

The Ultimatum Game

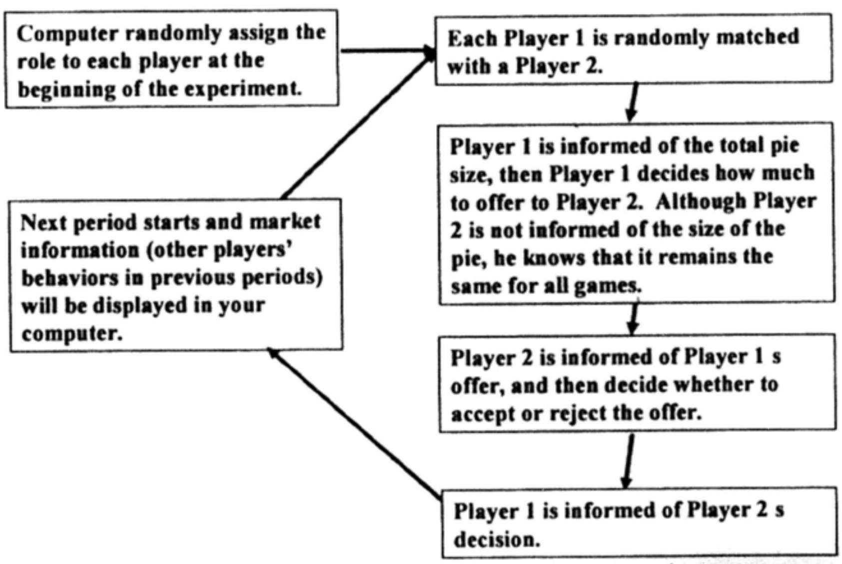


In each ultimatum game, one of you will be the Player 1 (★) who makes the offer, and the other will be the Player 2 (★) who decides to accept or reject the offer.

The computer will randomly assign you to the role of either Player 1 or Player 2 at the beginning of the session. Once assigned, your role remains fixed throughout the experiment.

[redacted]

Sequence of Play: The Ultimatum Game



[redacted]

Just to make sure that you understand the game, we would like to ask you several questions.

[redacted]

YOU ARE PLAYER 1

Assume that you are **Player 1**. The total pie is, $3000. You offer $1175 and Player 2 accepts your offer. What is your profit for this game?

- $1825 ($3000 - $1175)
- $1175

YOU ARE PLAYER 1

Sorry, this is not the correct answer.
If Player 2 accepts your offer, your profit is equal to the remaining amount of money. In this case, because Player 2 accepted your offer of $1175, your profit for this game is $3000 - $1175 = $1825.

Click here if you want to answer the question again

Click here if you want to review the instructions all over again

Very good.

Let's try another one

YOU ARE PLAYER 1

Assume that you are **Player 1**. The total pie is $2500. You offer $1000 and Player 2 rejects your offer. What is your profit for this game?

- $1000
- $1500 ($2500 - $1000)
- $0

YOU ARE PLAYER 1

Sorry, this is not the correct answer.
If Player 2 rejects your offer, your profit for this game is $0.

Click here if you want to answer the question again

Click here if you want to review the instructions all over again

Very good.

Let's try another one

YOU ARE PLAYER 2

> Assume that you are **Player 2**. Player 1 offers you $600 and you decide to accept the offer. What is your profit for this game?

- $0
- $600

YOU ARE PLAYER 2

Sorry, this is not the correct answer.
If you accepts Player 1 s offer, your profit is equal to the offer. In this case, because you accepted the $600 offer, your profit for this game is $600.

Click here if you want to answer the question again

Click here if you want to review the instructions all over again

Let's try another one

YOU ARE PLAYER 2

Assume that you are **Player 2**. Player 1 offers you $1000 and you decide to reject the offer. What is your profit for this game?

- $1000
- $0

YOU ARE PLAYER 2

Sorry, this is not the correct answer.
If you reject the offer, both Player 1 s and your profit will be $0.

Click here if you want to answer the question again

Click here if you want to review the instructions all over again

Very good.

Let's try one more

YOU ARE PLAYER 2

Assume that you are **Player 2**. Player 1 offers you $1200 and you decide to reject the offer. What is the profit for Player 1 in this game?

- $1200
- $0
- Amount of Money in Total Pie - $1200

Sorry, this is not the correct answer.
If you reject the offer, both your profit and Player 1 s profit will be $0.

Click here if you want to answer the question again

Click here if you want to review the instructions all over again

How do we pay you for your participation?

Your payoff for the session will be equal to the **average** of the profits you earned in 5 randomly selected games.

Computer Display

Now that you understand the game, the next few slides will familiarize you with the display screens you will see as you play.

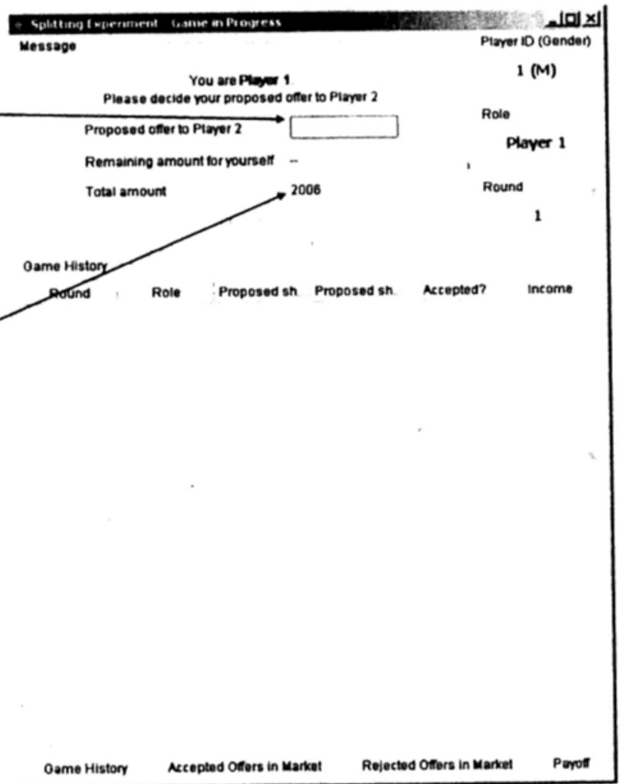
Let’s get familiar with Player 1 s screen first

[redacted]

Player 1 s Screen

Player 1 is asked to enter his proposed offer to Player 2 at the beginning of the game.

This is the total amount available for each game, which will be randomly generated by the computer at the beginning of the session. The amount shown here ($2,006) is only an example.

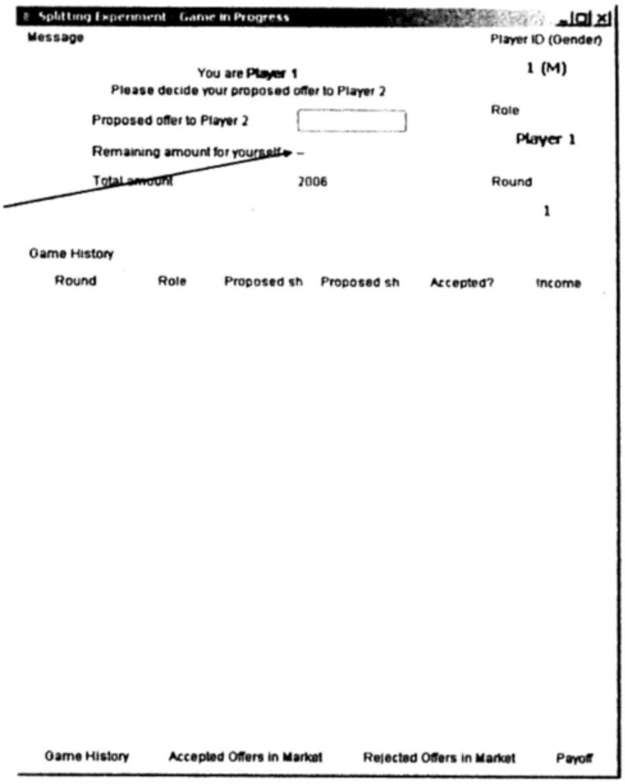


[redacted]

Player 1 s Screen

This is the remaining amount for yourself, which is equal to the total amount minus your proposed offer to Player 2. This remaining amount will be automatically calculated by the computer once you have entered your proposed offer to Player 2.

[redacted]

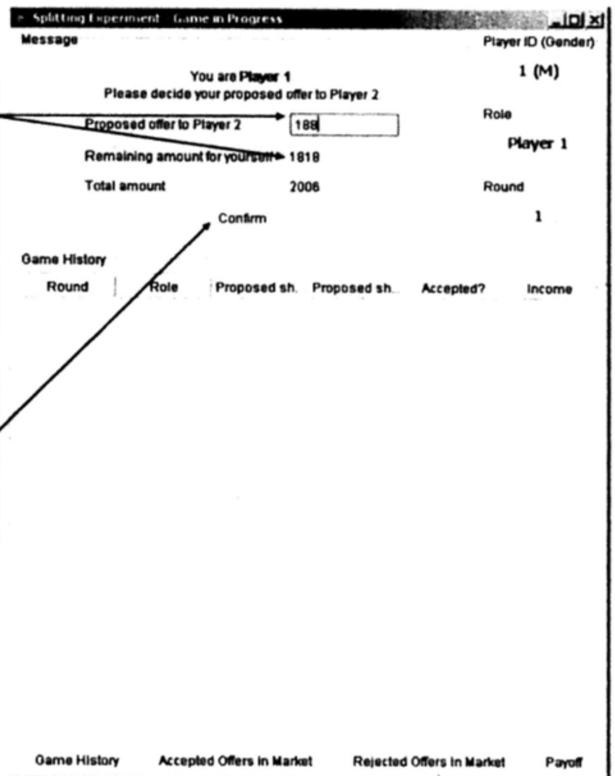


Player 1 s Screen

For example, if you entered $188 in your proposed offer to Player 2, the remaining amount will be automatically calculated as $1818 ($2006 - $188).

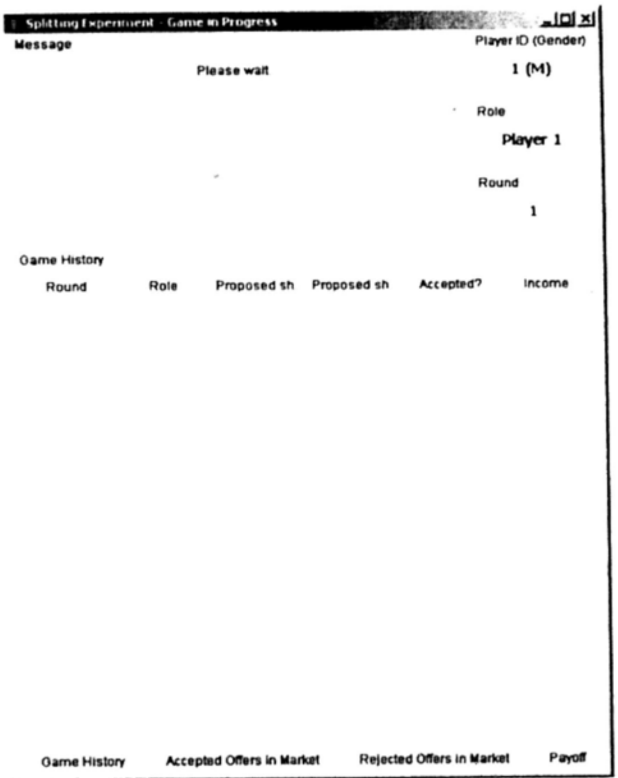
After you have made your decision and entered the proposed offer to Player 2, click the "confirm" button.

[redacted]



Player 1 s Screen

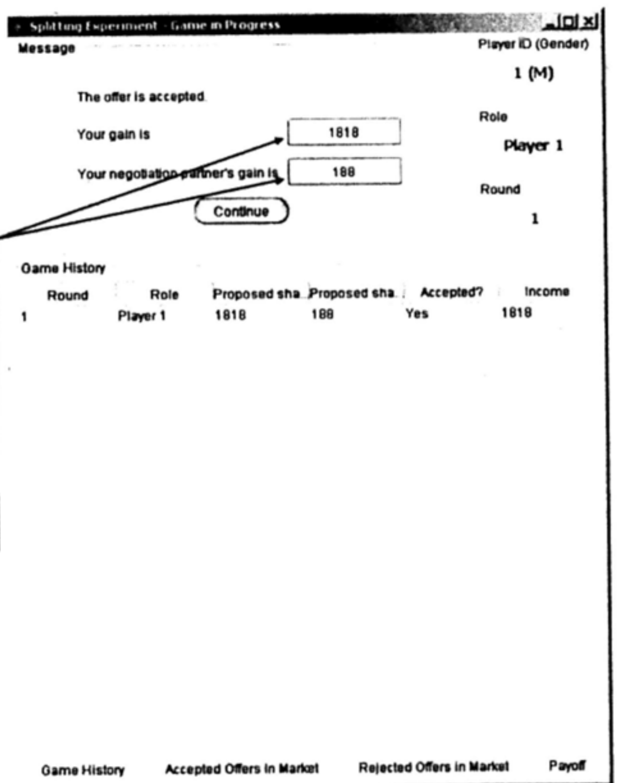
After clicking the "confirm" button, you will be asked to wait for Player 2 s decision.



[redacted]

Player 1 s Screen

If your offer is accepted by Player 2, then the computer will tell you your gain, which is equal to the remaining amount (in this example, $1818). The computer will also show your negotiation partner's gain, which is equal to your offer (in this example, $188).



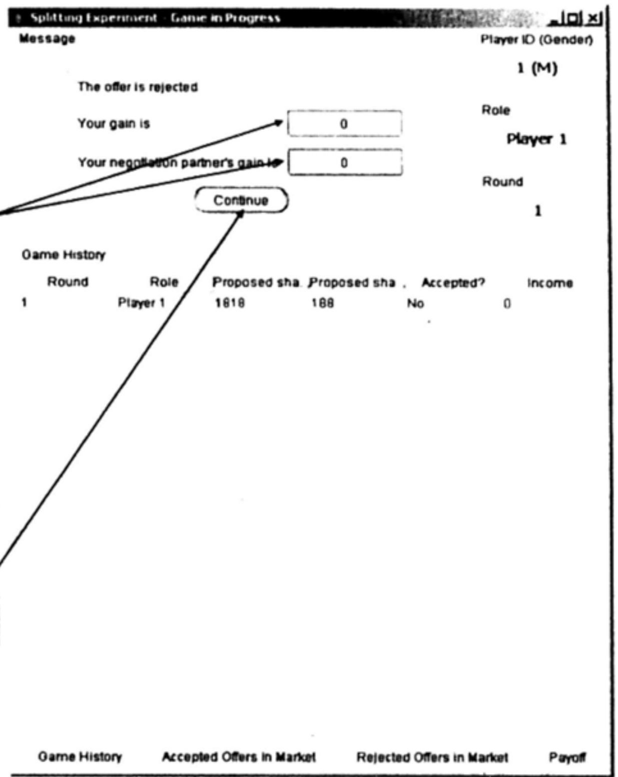
[redacted]

Player 1 s Screen

On the other hand, if your offer is rejected by Player 2, the computer will tell you that both your and your negotiation partner's gains are zero (because offer being rejected means zero profit to both parties).

Then, please click the button "Continue" to proceed to the next round.

[redacted]



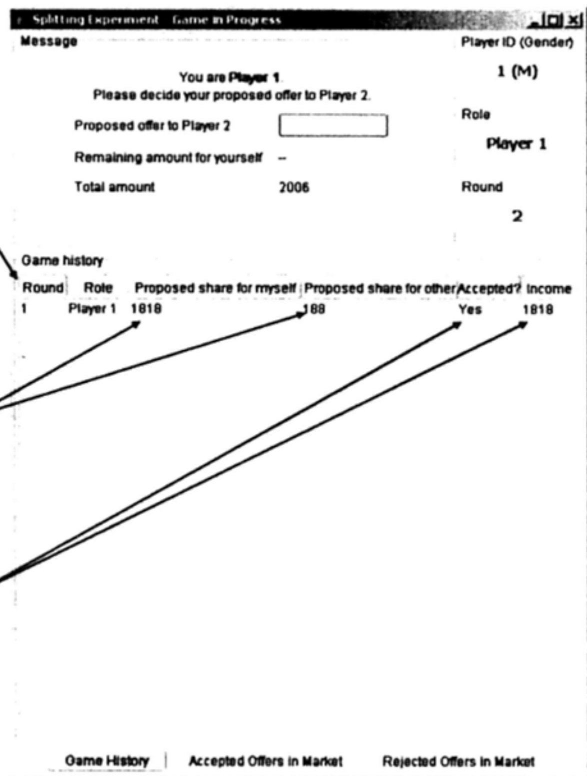
Player 1 s Screen

Starting from the second round, the game history will be displayed, showing your performance in the previous rounds.

These are your proposed shares for yourself and your negotiation partners.

This is your income for the round, depending on whether your offer was accepted by Player 2.

[redacted]

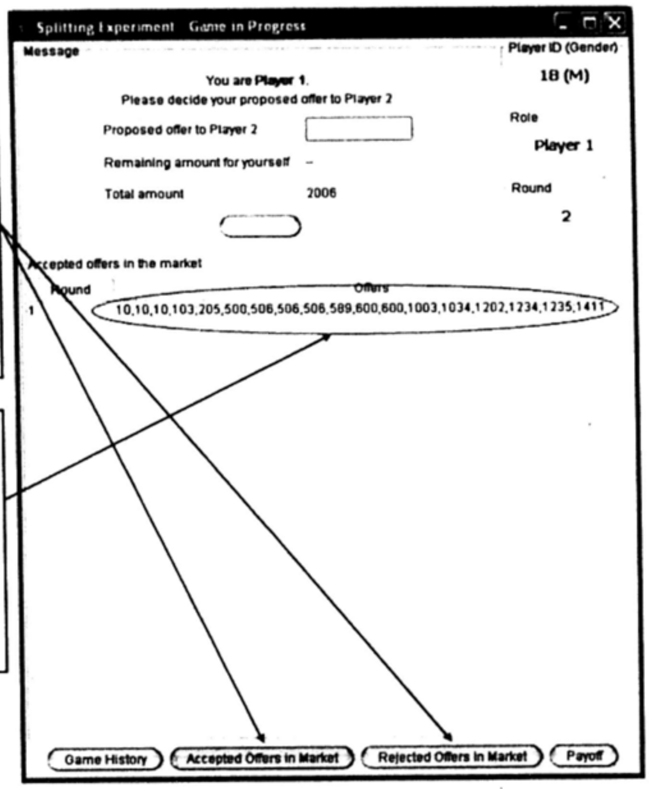


Player 1 s Screen

You may also click the other buttons such as “Accepted Offers in Market□ or “Rejected Offers in Market” to see the market information in the previous rounds.

This is the list of all accepted offers in Round 1 (sorted in ascending order), when you click the button “Accepted Offers in Market□

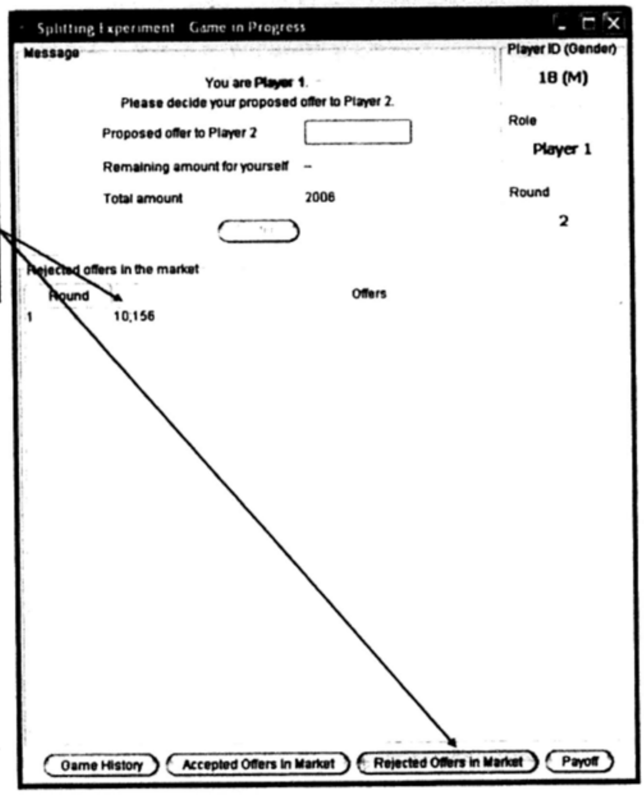
[redacted]



Player 1 s Screen

If you click the button “Rejected Offers in Market□ you can also see the rejected offers in the previous round.

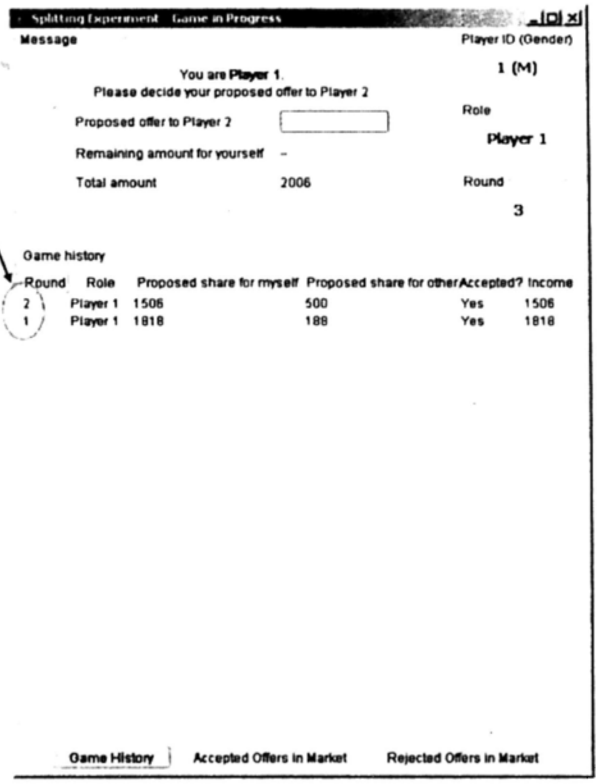
[redacted]



Player 1 s Screen

When historical records of more than one round are displayed, the records are sorted by descending order of rounds - the most recent records are displayed first.

[redacted]



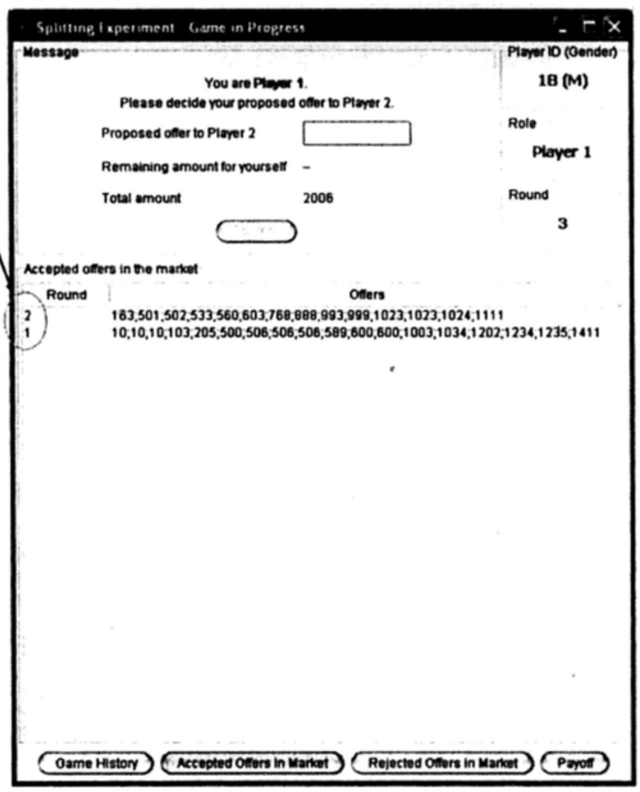
Player 1 s Screen

The same arrangement is used for both

Accepted Offers in Market, and

Rejected Offers in Market

[redacted]

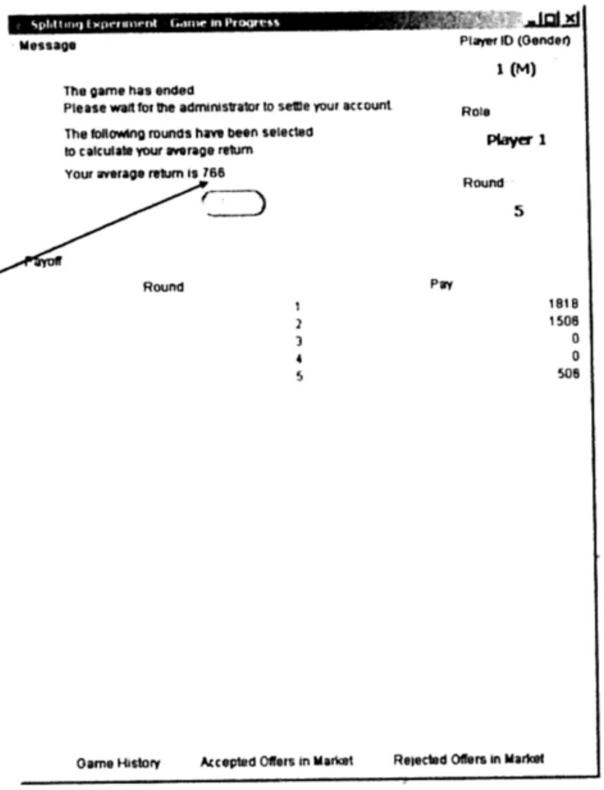


Player 1 s Screen

At the end of the experiment, the computer will randomly select 5 games to calculate your average payoff. We will then pay you that amount accordingly.

Please do NOT close the screen after the game is over!!

The computer may not function properly if you do so and hence we cannot pay you with the correct amount of payment.



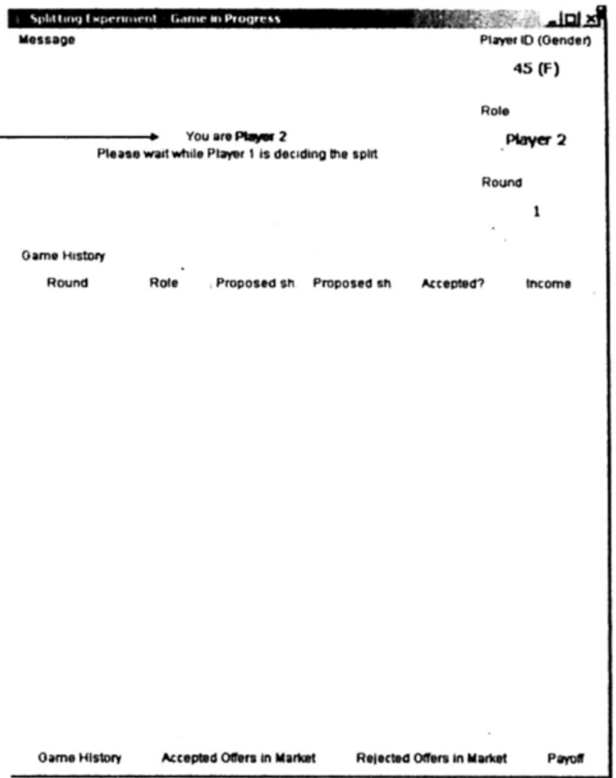
[redacted]

Now, let's see what happens to Player 2

[redacted]

Player 2 s Screen

If you' re Player 2, you will be asked to wait for Player 1 s decision at the beginning of each game.



[redacted]

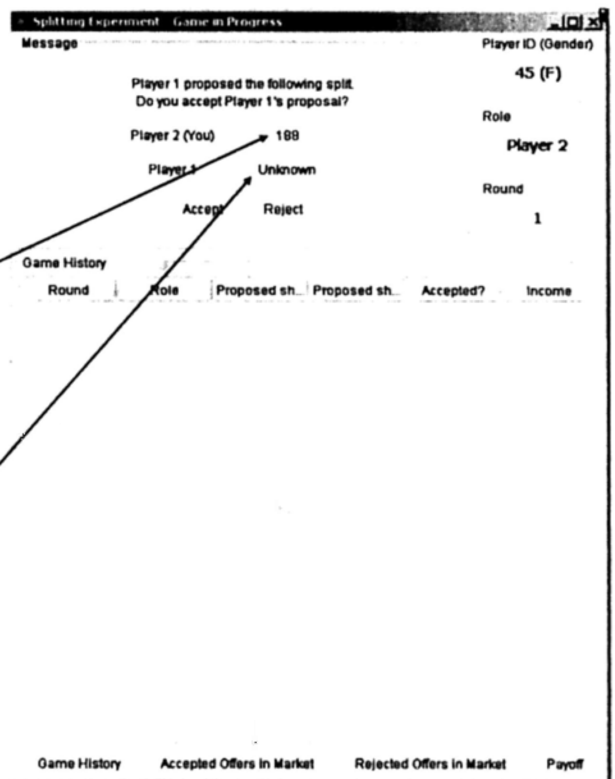
Player 2 s Screen

After Player 1 has made his offer, you will be informed of his decision.

This is his offer to you.

However, you will not know how much Player 1 has kept for himself because you do not know the size of the pie □ the total amount available for split - an information that only Player 1 has.

Although you do not know the total amount of money in each round, you know this amount is the same in all games.



[redacted]

Player 2 s Screen

You can then decide whether to

Accept

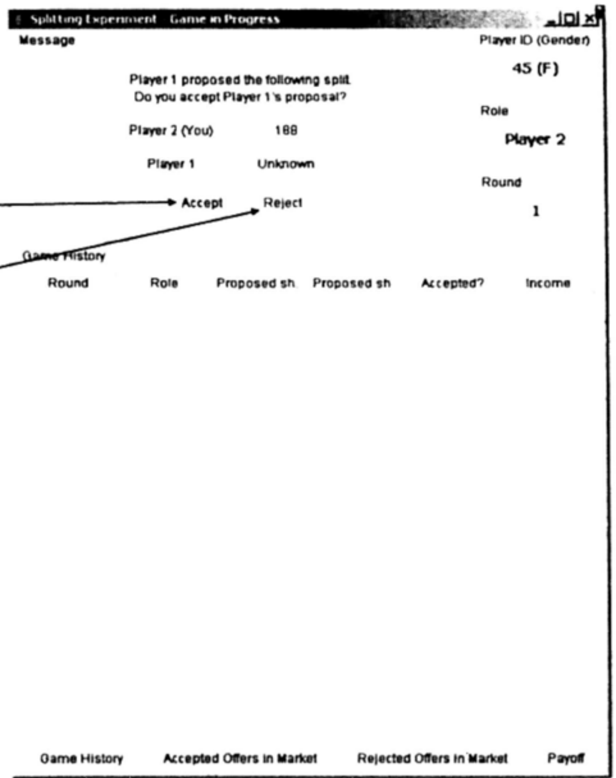
or

Reject

Player 1 s offer.

Please click the relevant button based on your decision.

[redacted]

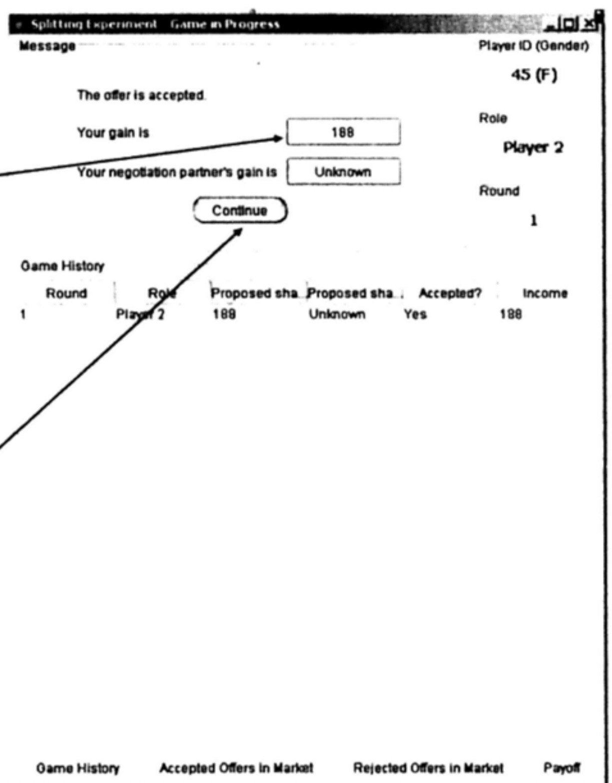


Player 2 s Screen

For example, if you click the "Accept" button, the screen will then show your gain, which is equal to the accepted offer (in this example, $188)

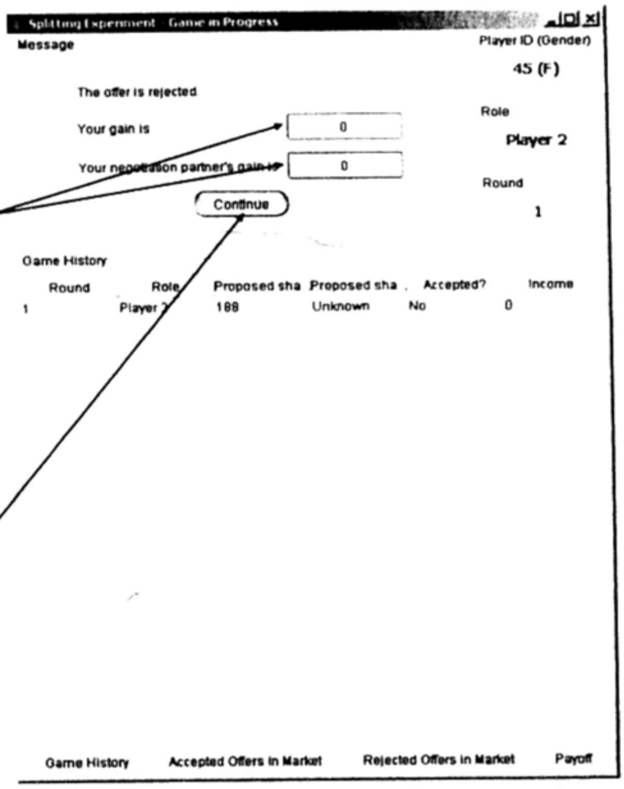
Then, please click the "continue" button to proceed to the next round.

[redacted]



Player 2 s Screen

If you click the "Reject□ button, the screen will then show that both you and your negotiation partner get nothing.

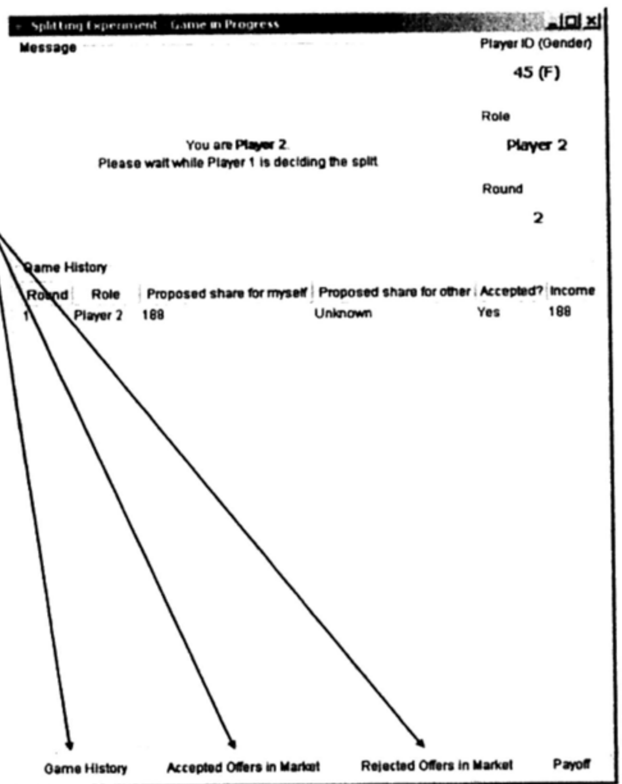


Then, please click the "continue" button to proceed to the next round.

[redacted]

Player 2 s Screen

The historical data are displayed in the same way you saw in Player 1 s screen.



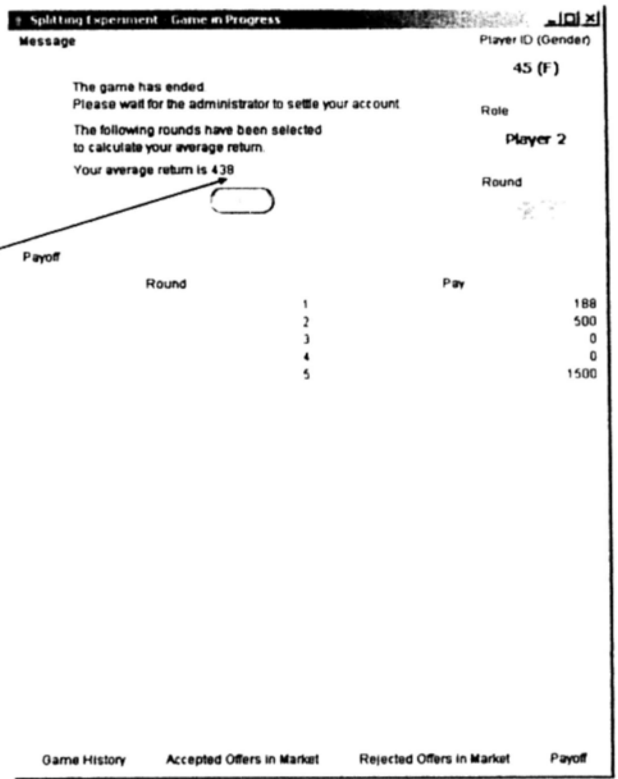
[redacted]

Player 2 s Screen

At the end of the experiment, the computer will randomly select 5 games to calculate your average payoff. We will then pay you that amount accordingly.

Please do NOT close the screen after the game is over!!

The computer may not function properly if you do so and hence it may not be able to calculate your payment correctly.



This ends the introduction to the game. Please move to the computer next to you and wait for the experimenter's instruction to start the game.

We will start as soon as everyone has finished reading the introduction.

Click this arrow to read the instruction again.

APPENDIX 4

Sample Questionnaire Distributed to Subjects after the Ultimatum Game Experiment

Thanks for participating in our experiment. Now, the experiment is over and we would like you to answer the following questions based on the games you have just played.

1. Your role in this experiment:

   ☐ Player 1 ☐ Player 2 (Please check one)

2. During the experiment, did you use the historical data to help you making decisions?

   ☐ Always ☐ Sometimes ☐ Never (Please check one)

3. If you answered "Always" or "Sometimes" in Question 2, how many periods of historical data did you consider? Please check one answer below.

   ☐ Only the previous period.

   ☐ The previous two periods.

   ☐ The previous three periods.

   ☐ The previous four periods.

   ☐ The previous five periods.

   ☐ The previous _____ periods. (Please enter a number if you consider more than 5 periods of historical data.)

   ☐ All previous periods.