Kirstein, Annette; Kirstein, Roland

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Less Rationality, More Efficiency: a Laboratory Experiment on "Lemons" Markets

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Less Rationality, More Efficiency: a Laboratory Experiment on "Lemons" Markets.[†]

Roland Kirstein[*] Annette Kirstein[**]

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Abstract

In this paper we experimentally test a theory of boundedly rational behavior in a "lemons market." We analyzed two different market designs, for which perfect rationality implies complete and partial market collapse, respectively. Our empirical observations deviate substantially from these predictions of rational choice theory: Even after 20 repetitions, the actual outcome is closer to efficiency than expected.

Our bounded rationality approach to explaining these observations starts with the insight that perfect rationality would require the players to perform an infinite number of iterative reasoning steps. Boundedly rational players, however, carry out only a limited number of such iterations. We have determined the iteration type of the players independently from their market behavior. A significant correlation exists between the iteration types and the observed price offers.

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Encyclopedia of Law and Economics: *0710, 5110*

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[*]Corresponding author: Center for the Study of Law and Economics (CSLE), University of Saarland, D-66041 Saarbrücken, Germany. rol@rolandkirstein.de, http://rolandkirstein.de. I am indebted to the Thyssen Stiftung for the generous financial support of my research trip.

[**]SFB 504 "Bounded Rationality," University Mannheim, and Institut für Wirtschaftstheorie and Operations Research, University of Karlsruhe, D-76128 Karlsruhe, Germany, Kirstein@wiwi.uni-karlsruhe.de.

1 Introduction

In his landmark paper on "lemons markets," George Akerlof identified asymmetric information as a source of inefficient market outcomes and even market collapse.[1] We have run a series of experiments in which the participants had to trade in a lemons market. The prices offered by the uninformed buyers, as well as the amount of goods traded, were much higher than those predicted by rational choice theory. Consequently, the empirical extent of the market failure was smaller than expected.[2]

One way to explain such behavior requires relaxing the assumption that players are perfectly rational. Many models of bounded rationality exist.[3] For example, Stahl/Wilson (1995, 128) have defined and tested boundedly rational archetypes of players who can be distinguished with respect to their "model of other players and their ability to identify optimal choices given their priors." They distinguish two ways in which players can deviate from the classical theory of decision-making under uncertainty: in their priors about other players or in their capability of choosing best responses given their priors.[4]

The concept of bounded rationality that we propose as an explanation of the behavior observed in our experiment follows the second approach. Moreover, it draws on the theory of iterative reasoning, which is applicable in games in which iterative dominance is prevalent.[5] The equilibrium result in Akerlof's lemons market requires the players to compute an infinite number of iterative steps to eliminate dominated strategies. A boundedly rational decision-maker, however, is able to perform only a limited number of iterations.

The idea of iterative reasoning has been tested in numerous experiments.[6]

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[1] Akerlof (1970).

[2] A corresponding result was shown by Bazerman/Samuelson (1983) in their "acquire-a-company problem."

[3] See Conslik (1996) for an overview.

[4] An example that belongs to the first category of bounded rationality approaches is the experiment of Beard/Beil (1994): If player 1 holds a belief that player 2 is not sufficiently rational, then the weakly dominated Nash equilibrium of this game is played. The main findings of this experiment were reproduced by Goeree/Holt (2001). An example of the second source of Stahl/Wilson's explanations for deviations from rational choice theory is that "subjects simplify the problem," as explained by Camerer (1997, 185).

[5] Chapter 5 of Camerer (2003) provides an introduction to iterative dominance; Section 5.6 explains the "levels of reasoning" concept.

[6] See, e.g., Schotter/Weigelt/Wilson (1994).

The "centipede game" of Rosenthal (1981) has raised particular interest. In contrast to the theoretical prediction, McKelvey/Palfrey (1992) have discovered that players rarely leave the centipede game at early stages. However, the probability of termination is increasing in the number of nodes played. This behavior could be explained by a limited ability for iterated reasoning.

Nagel (1995) also draws on stepwise elimination of dominated strategies and describes a guessing game experiment which has been executed with thousands of participants worldwide.[7] The vast majority of the participants in her experiment do not play the Nash equilibrium strategy. Nagel explains the deviation from prediction by the assumption that real-world players make only a limited number of iteration steps, which appears at first glance to be very similar to our experiment.

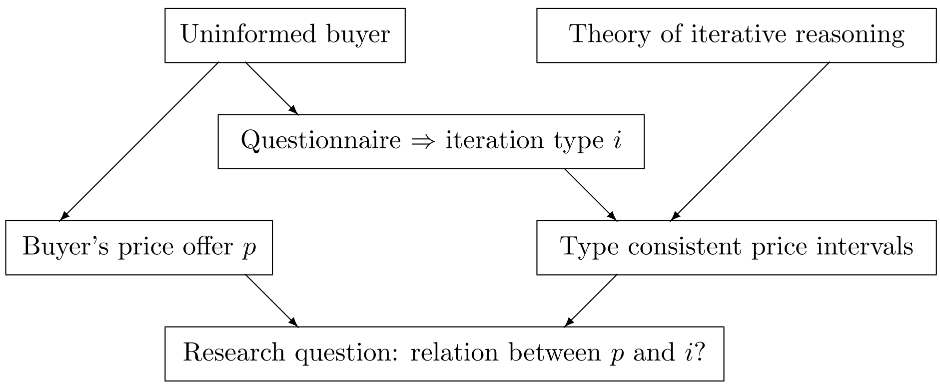
However, Nagel follows the first rather than the second approach introduced by Stahl/Wilson (1995). In her theory, the player under scrutiny is implicitly assumed to be unlimited in his ability to act rationally, i.e., to find best responses. She rather assumes that players have false assumptions concerning the types of their peers. According to Nagel's results, players are either "type" 1, 2, 3, or infinity. This terminology reflects that subjects assume their peers to perform either 0, 1, or 2 iteration steps and, consequently, try to be exactly one step ahead. Or, they assume that the others are perfectly rational (i.e., they expect others to perform an infinite number of iteration steps) and then choose the Nash equilibrium strategy. Our approach should carefully be distinguished from Nagel's in that we do not concentrate on the subjects' beliefs about other players' types. We rather focus on the subjects' capability of repeatedly applying the concept of iterative dominance, i.e., on their ability to find best responses.

There is another important difference between our paper and the experiments of Beard/Beil (1994) and Nagel (1995): In the latter papers, the explanation for observed behavior (i.e., the beliefs about the others' types) is based on the observations themselves. Our contrasting research program is depicted in Figure 1. We have evaluated two distinct data series which were generated

[7] See Thaler (1997), Nagel et al. (1999), and Selten/Nagel (1998).

independently from each other. The one variable consists of the observed prices offered by the uninformed buyers in the lemons market, denoted by p. The source of the other variable is a questionnaire filled out by the buyers after each round.[8] We have used these written statements to categorize the participants into "iteration types" (denoted by i).[9] We have observed that players are either extremely limited (type-0 or 1) or elaborate (type-2 and greater). Therefore, we distinguish only these three categories of iteration types.

Figure 1: Iteration Types of Buyers and Observed Prices



Applying the theory of iterative reasoning to our lemons market, we can derive price intervals from which we expect a buyer of type i to choose his price offer. In the final step, we compare the observed prices with the type-consistent price intervals to answer our research question: Is there a relation between iteration types and observed prices? We have found a significant negative correlation between these data series. Thus, the concept of limited iterative reasoning does not only theoretically explain the observed behavior; this explanation is also supported by the data.

[8]Statements given by the buyer subjects after their decision in an experiment run the risk of retrospectively serving as a rationalization of the actual behavior. In our case, this problem can safely be neglected for two reasons: Subjects either have the ability to perform more than one iteration step or they do not, and this cannot be faked. Moreover, the subjects filled out the questionnaire before they learned of the actual outcome resulting from their decisions.

[9]In, e.g., Kübler/Weizsäcker (2002), the subjects' iteration types were estimated from the data.

In Section 2, we introduce two versions of a lemons market. Under the assumption of perfect rationality the predicted outcomes in the two markets are complete and partial market collapse, respectively. We then introduce our notion of iterative reasoning and derive the predicted behavior for different degrees of bounded rationality.

In Section 3, we describe our experiment. In the one-shot version of both parameter settings (Sections 3.1 to 3.2), just as predicted by our bounded rationality approach, the participants completed many more transactions than would be expected of perfectly rational players. Higher iteration types (revealed by the written statements) offer significantly lower prices.

As described in Section 3.3, participants repeatedly played one of the two market designs. We observe that the offered prices declined with the number of rounds played, but remained significantly above the price that was predicted for perfectly rational players. This can also be explained by limited iterative reasoning.

Section 4 concludes the article with a discussion of the possible implications for economic policy, in particular for the regulation of lemons markets.

2 Adverse Selection

2.1 Setup

This section presents two versions of a lemons market model that we have tested in a series of experiments. In one parameter setting, the market is expected to collapse completely. In the other setting some trade is predicted to take place. However, efficiency would require all units in both markets to be traded.

Consider a market in which an unspecified good is traded. We assume its quality to be uniformly distributed over the interval $[0, 1]$ and denote the actual quality of a specific unit as Q. Two groups of agents are active in this market:

- Sellers, each of whom owns one unit of the good and knows its true quality. The sellers' valuation is denoted as $a(Q)$, with $a(Q) = \beta Q$ $(\beta > 0)$.

- Buyers, who cannot observe the true quality of a certain unit of the good, but know the distribution of quality. Their valuation is denoted as $n(Q) = \gamma + \delta Q$.

We assume $\gamma \geq 0$ and $\delta \geq \beta$: the buyers' valuation for each quality level $Q > 0$ exceeds the sellers'.[10] We also assume the following interaction structure: Each buyer makes a price offer. The offer is randomly assigned to a specific seller, who then decides whether to accept the offer or not. If the seller accepts, then the unit is traded. If the seller refuses the offer, then no transaction takes place. Let the possible reactions of the seller be represented by $\tau = 0$ if he refuses the offer, and by $\tau = 1$ if he accepts.

Denote the initial monetary endowment of the players as $V_i \geq 0$ with $i = b, s$ for buyers and sellers. If a seller receives a certain price offer p, then his payoff is $V_s + (1-\tau)\beta Q + \tau p = V_s + \beta Q + \tau(p - \beta Q)$. The latter part of this expression is the seller's expected gain from trade, which we denote as $\Pi_s = \tau(p - \beta Q)$, whereas βQ represents the seller's valuation of this initial endowment with quality.

It is rational for a seller to accept a price offer if it exceeds his valuation of the good, that is, if, and only if, $\Pi_s > 0$ or, equivalently, $p > \beta Q$. The simplicity of the sellers' decisions later allows us to focus on the buyers' reasoning process only, and the buyers' priors about the sellers' perfect rationality can be taken for granted.

Having submitted a price p, the buyer's payoff amounts to $V_b + \Pi_b = V_b + \tau(\gamma + \delta Q - p)$, where Π_b represents the buyer's expected gain from trade. An uninformed buyer faces a much more complicated decision problem than a seller. When perfectly rational, he tries to maximize the expected gain from successfully closing a transaction by choosing an appropriate price offer p, but he is unaware of the true quality.

[10] Under symmetric information, the efficient outcome could easily be achieved. For each quality level, there is a buyer whose willingness to pay exceeds the respective seller's willingness to accept, and the market will be cleared. If both market sides are uninformed, but do know the distribution of quality, then each buyer and seller would agree to trade a specific unit for a price between their valuations of the average quality.

2.2 Perfect Rationality

Any price offer $p \leq \beta$ divides the interval of possible qualities into three subsets:[11]

- $Q < n^{-1}(p)$: the offer is accepted ($\tau = 1$), but the buyer suffers a loss;
- $n^{-1}(p) < Q < a^{-1}(p)$: the offer is accepted ($\tau = 1$) with a profit for the buyer;
- $Q > a^{-1}(p)$: the offer is rejected ($\tau = 0$).

The assumption $a(Q) = \beta Q$ implies $a^{-1}(p) = p/\beta$. The buyer's expected gain from trade, conditional on his submitted price offer, is given by

$$E\Pi_b(p) = \int_0^{p/\beta} [n(Q) - p] dQ = \int_0^{p/\beta} [\gamma + \delta Q] dQ - \frac{p^2}{\beta}.$$

A perfectly rational buyer chooses his price offer to maximize $E\Pi_b(p)$. We distinguish two different parameter settings regarding $n(Q) = \gamma + \delta Q$:

1. $\gamma = 0$ and $\delta > \beta$.
2. $\gamma > 0$ and $\delta = \beta$.

In case 1, the valuations of both the sellers and the buyers start at the origin, and the buyers' valuation has greater slope. Case 2 is characterized by parallel valuation lines. The following proposition derives the optimal price offer, denoted by p^*, made by a perfectly rational decision maker.[12]

> **Proposition:** *Assume a market in which the buyers' valuation of quality Q is $n(Q) = \gamma + \delta(Q)$, and the sellers' valuation is $a(Q) = \beta Q$, with $\gamma \geq 0$ and $\delta \geq \beta > 0$. If*
>
> *i) $\delta < 2\beta$, then the optimal price offer under the first parameter setting ($\gamma = 0$ and $\delta > \beta$) is $p^* = 0$, and the average traded quality is 0,*

[11] Price offers greater than β are strictly dominated and can, therefore, be neglected: with $p = \beta$, the price offer would attract all possible qualities up to $Q = 1$. Hence, a higher price offer cannot make the buyer better off.

[12] The proof of this proposition is confined to the appendix.

ii) $\delta < 2\beta$*, then the optimal price offer under the second parameter setting (*$\gamma > 0$ *and* $\delta = \beta$*) is* $p^* = \gamma$*, and the average traded quality equals* $\gamma/2\beta$*,*

iii) $\delta \geq 2\beta$*, then the optimal price offer is* $p^* = \beta$*, and the average traded quality is 1/2.*

An optimal price $p^* = 0$ implies that the market collapses completely. Even though it is efficient to trade all units in the market, asymmetric information makes the buyers abstain from positive offers, so no units are traded. In the second case, the market collapses only partially: units with $Q \leq a^{-1}(\gamma) = \gamma/\beta$ are traded.

2.3 Bounded Rationality

2.3.1 Iterative Reasoning

Now we present a more general model which is based on iterative thinking. It allows for modelling both boundedly and perfectly rational players. We start with a buyer who does not analyze the situation at all. He picks his price offer randomly. We call this type of behavior "performing zero iteration steps." If another buyer acknowledges that the quality is uniformly distributed between 0 and 1, he would base his decision on the expected quality of 1/2. Such a buyer would then offer a price ranging between the sellers' and his own valuation of the expected $Q = 1/2$. This buyer performs the first step of the iterative reasoning process. His maximal willingness to pay is $n(1/2)$.

A third buyer may realize in this situation that, even if he offers his maximal willingness to pay, the sellers who own the highest qualities would refuse his offer. If the buyer understands this, then the expected quality of the good he will actually receive, conditional on his price offer, is smaller than the unconditional expected quality his price offer was based on after the first step of reasoning. Therefore, this buyer will update his offer and bid a lower price. A buyer who stops here has performed two steps of iterative reasoning. In the next reasoning steps, a buyer would realize that the lower the price offer, the smaller the maximum quality the buyer can expect to receive.

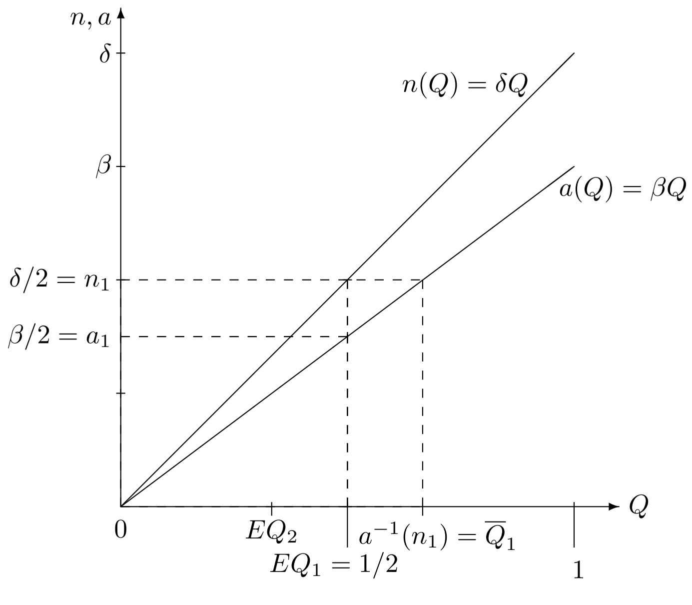
Let us denote the expected quality for a buyer who performs k steps of iterative reasoning as EQ_k. We assume that such a player represents the distribution of the quality by this expected value. The buyers' maximum willingness to pay is denoted as $n_k = n(EQ_k)$.

2.3.2 Complete Market Collapse

In parameter setting 1 (i.e., $\gamma = 0$ and $\delta > \beta$), the maximum willingness to pay of a buyer who performs only one step of iterative reasoning is $n_1 = n(EQ_1) = \delta/2$. We limit our focus to cases where $\delta < 2\beta$, which implies $n_1 < \beta$. To conclude a transaction, this buyer should at least bid the sellers' valuation of the expected quality $a_1 = a(EQ_1) = \beta/2$.

At a price offered after one step of iterative reasoning, all sellers who offer a quality greater than $\overline{Q}_1 = a^{-1}(n_1) = \delta/2\beta$ will prefer to keep their item for themselves. It is due to the assumption $\delta < 2\beta$ that, even if the buyer offers his maxiumum willingness to pay, the sellers who own units of high quality can be expected to reject the offer, or: $\overline{Q}_1 < 1$.

Figure 2: Complete market collapse: first step of iterative reasoning



If a buyer performs a second reasoning step, he anticipates $\overline{Q}_1$ to be the highest possible quality in the market if he offers $p = n_1$. Therefore, the expected quality contingent on the maximal offer during the first step of iterative reasoning is $EQ_2 = 0.5\overline{Q}_1$. Therefore, such a buyer has a maximum willingness to pay, contingent on his beliefs, which amounts to $n_2 = n(EQ_2) = \delta\overline{Q}_1/2 = \delta^2/4\beta$. The assumption $\delta < 2\beta$ implies $EQ_2 < EQ_1$ and $n_2 < n_1$.

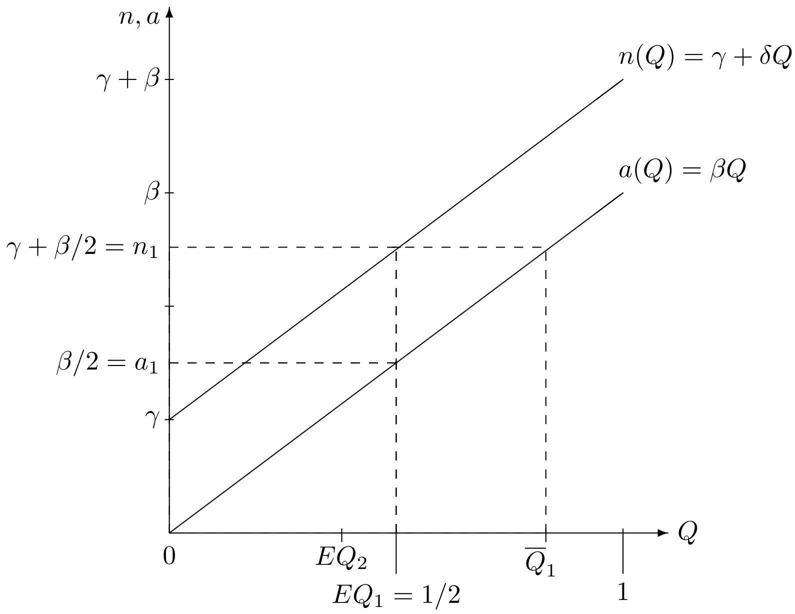
Figure 2 displays EQ_1, a_1, n_1, $\overline{Q}_1$, and EQ_2. Quality is shown on the horizontal axis, the valuations of both sellers and buyers on the vertical axis. The upper diagonal line represents the buyers' valuation, $n(Q)$, and the lower one represents the sellers' valuation, $a(Q)$. Clearly, $\overline{Q}_k$ as well as n_k decrease as the number of iteration steps k increases; $k \in \mathbb{N}$. Iterative reasoning leads to lower price offers, the greater the number of reasoning steps carried out. For an infinite number of steps, the buyer reaches the price offer predicted for perfectly rational buyers: he offers zero, and no unit is traded. Boundedly rational players, however, make only a limited number of steps. A positive price offer may reveal a buyer's reasoning level. For any number of reasoning steps k a player performs, we can derive an interval $[a_k, n_k]$ from which this theory predicts the player to choose his price offer.

2.3.3 Partial Market Collapse

For the second parameter setting ($\gamma > 0$ and $\delta = \beta$), Figure 3 demonstrates the situation of a decision-maker who performs one step of iterative reasoning. Such a buyer assumes an expected quality $EQ_1 = 1/2$. Thus, he should offer a price between $a_1 = a(EQ_1) = \beta/2$ and $n_1 = n(EQ_1) = \gamma + \beta/2$.

If a buyer carries out a second step, he would realize that, even if he bids n_1, the sellers holding a unit of the highest quality would reject his offer. The highest possible quality which a buyer actually expects to achieve during the first step of reasoning is $\overline{Q}_1 = a^{-1}(n_1) = (2\gamma + \beta)/2\beta$. Thus, this buyer expects a quality that equals $\overline{Q}_1/2 = (2\gamma + \beta)/4\beta$. After an infinite number of iteration steps, a perfectly rational buyer offers $p = \gamma$, and qualities below $1/3$ are traded.

Figure 3: Partial market collapse



3 The Experiment

3.1 Experimental Design

The experimental parameter settings with complete and partial market collapse are labeled as (comp), and (part), respectively. In the (part) market, we chose $\delta = 3$, and $\gamma = 1$. Hence, the buyers' valuation was $n(Q) = 1 + 3Q$. In the (comp) market, we chose $\delta = 4$ and $\gamma = 0$, leading to $n(Q) = 4Q$. In both designs, the sellers' valuation was fixed as $a(Q) = 3Q$ (thus $\beta = 3$). We conducted four treatments:

- treatment A: first (part), then (comp);
- treatment B: first (comp), then (part);
- treatment C: 20 rounds (comp);
- treatment D: 20 rounds (part).

In treatments A and B, each subject played (part) and (comp) once. We added treatments C and D in order to examine whether the observations of the first two treatments had merely been first-round effects. Here, 20 rounds of (comp) and (part) were played.[13] The experiments were conducted with 248 students of Karlsruhe University (Germany) who participated in 18 experimental sessions (five sessions each for treatments A and B, and four sessions each for C and D). The group size ranged from 16 to 20 participants per session. Each of the subjects participated in only one session. Most of the participants were studying Business Engineering at the undergraduate level. At the time of the experiment, none of them had enjoyed any formal training in contract theory.

In each session, the group was split in half and randomly assigned to two different rooms. The participants were not permitted to communicate with each other. The written instructions were distributed and read aloud. Questions were asked and answered only in private.

Treatments A and B were not computerized, i.e., paper and pencil were used. The participants in each of the rooms first acted as buyers (they submitted price offers to the other room), and then acted as sellers (they received price offers from the other room). We let subjects take over both roles because sellers only had to make the simple decision of whether or not a certain price offer exceeded the valuation of their unit of the good.[14] Every buyer wrote a price offer on a prepared form. An administrator in each room first collected all the price offers. Then he endowed the players in his room with one unit of the good.[15] The price offers were randomly allocated to the participants in the other room, and the sellers' decisions were made.

Before the end of each round, the buyers were asked to write down, in their own words, the line of reasoning that led to the corresponding price offer. Finally, the subjects learned their individual outcomes in private. Only those

[13]The instructions for (part) in treatments A and B are included in Appendix B. The highly similar instructions for (comp) as well as for the last two treatments are available on request.

[14]In the first session of both treatments A and B, the subjects played only one role, either that of buyer or seller. From the second session on, we changed to the above procedure. In principle, we even could have let a computer make the sellers' decisions, but we wanted our subjects to interact with real people.

[15]This guaranteed that the quality of participants' units (as sellers) did not affect their price offers (as buyers).

buyers whose offers were accepted learned about the quality their partner was endowed with. Then, the second round was carried out in the same way as the first, but with a different market design.

While acting as buyers, participants received an initial endowment of 4 Euros per round, which ensured that their willingness to pay did not exceed their ability to pay. As sellers, the subjects received an additional show-up fee of 3 Euros which compensated for the possibility of being endowed with a poor-quality good. After the two rounds, the subjects were paid their earnings in cash. The chosen parameters resulted in an average payment of about 8 Euros, and the experiment lasted approximately 50 minutes.

Treatments C and D were **computerized**. Each subject played 20 repetitions of only one of the above market designs, i.e., (comp) or (part). The subjects were seated and instructed the same way as under treatments A and B.[16] The buyers were endowed with 4 ECU (experimental currency units) per round. The sellers received one unit of the good (the quality of which could be different in each round), and 2 ECU per round to compensate for the possibility of receiving low qualities of the good. In every round, each buyer was randomly and anonymously matched anew with one of the sellers. After each round, the buyers were asked to write down their reasoning regarding the prices they offered in a questionnaire. Then the subjects were informed about their own outcome from the preceding round. After 20 rounds, subjects were paid their earnings in cash. 10 ECU amounted to 1.25 Euros. The sessions lasted about one hour, and the participants were paid about 10 Euros on average.

3.2 Predictions and Results in Treatments A and B

3.2.1 Description of Individual Data

Figures 4 and 5 give an overview of all price offers made in both rounds of each design. Treatment A, i.e., (part) in the first round and (comp) in the second,

[16] The procedures differed only slightly from treatments A and B in that the subjects stayed in the randomly assigned role of either buyer or seller during all 20 rounds. Even though the sellers' situation was of the same simplicity as under treatments A and B, it appeared reasonable not to switch roles. This experiment was computerized, and we wanted to avoid the possibility of subjects mixing up the two roles if confronted with different computer screens in rapid sequence.

contains 50 observations. Treatment B (first (comp), then (part)) consists of 51 observations per round. The bold symbols represent rejected offers (no trade), and the open ones represent accepted prices (trade). The dots depict the first round of play, i.e., (part1) in figure 4, and (comp1) in Figure 5, and the triangles represent the second round of play, i.e., (part2) and (comp2). The line represents the sellers' valuation of their quality. For all decisions to be rational, no bold symbol should appear above the line as the offered price exceeded the seller's valuation. Moreover, no open symbol should appear beneath the line since the price is short of the valuation. Only a negligible number of the sellers' decisions appear irrational.

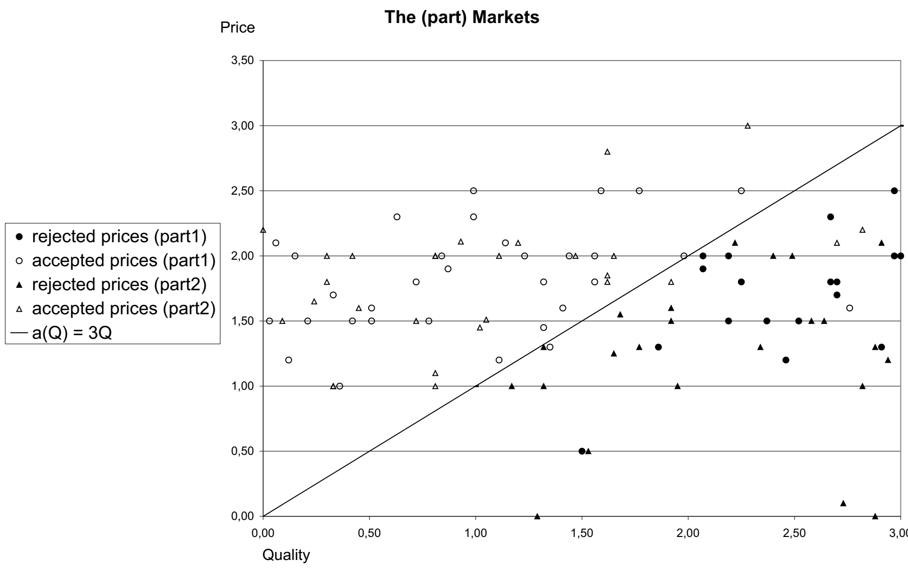


Figure 4: Price Offers in (part)

3.2.2 Does the Ordering of the Designs Matter?

The first step in evaluating the experimental data relates to the question of whether the ordering of the two market designs in treatments A and B has a significant influence on the offered prices. Thus, the first null hypotheses are:

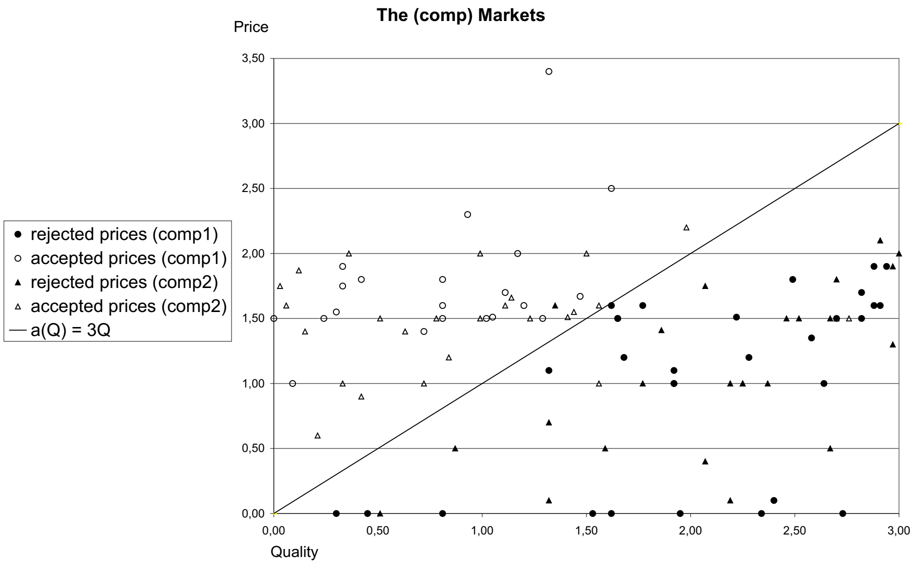


Figure 5: Price Offers in (comp)

Ha: The prices in first-round play of the (comp) market design do not differ from those in second-round play.

Hb: The prices in first-round play of the (part) market design do not differ from those in second-round play.

A Wilcoxon test[17] shows for each market design that the prices offered in the first round did not differ significantly from the observed prices in the second round.[18] Thus, neither of the null hypotheses can be rejected.

Result 1: The observed price offers are independent of the order in which the market designs were played.

[17] We have used SysStat version 8.0, a statistical software package from SPSS Inc., to evaluate the data. All statistical tests were conducted at a 5 percent significance level.

[18] We compared two samples each, i.e. rounds 1 and 2 of each market design by using a Wilcoxon test controlled for ties. The pairwise comparison of (part1), and (part2) reveals that in 20 cases the second round price is larger than the corresponding first round price. In 26 cases, the reverse is true. The Z for our test is -1.640 with a (two-sided) probability 0.101. In the (comp) markets, the second round price is larger than the first round price in 19 cases, and vice versa in 23 cases. The Z is 0.050 with a (two-sided) probability of 0.95.

This result encouraged us to evaluate the data generated for each market design without regard to whether it was generated in the first or the second round.[19]

3.2.3 Do Buyers Offer Rational Prices?

The proposition in Section 2.2 and the theoretical analysis in 2.3 show that fully rational buyers in each of the two market designs need to perform an infinite number of iterative reasoning steps. Many recent experimental studies, however, reveal that iterative reasoning seems to stop after very few steps, if it starts at all. Thus, we conjecture a considerable number of subjects to be boundedly rational when formulating the following null hypotheses:

Hc: In the (comp) market, only $p = 0$ is offered.

Hd: In the (part) market, only $p = 1$ is offered.

If the above null hypotheses are true, the average traded quality in (comp) should be zero, whereas in the (part) market it is expected to be 1/6 (see the Proposition in Section 2.2). The descriptive aggregate data of both (comp) and (part) are provided in Table 1.[20] It shows the minimum, maximum, and average values of the price offers, qualities, and traded qualities, as well as the buyers' and sellers' gains from trade in each market design.[21]

In (part), 60% of the price offers are accepted, and the average price of 1.66 is significantly greater than the predicted $p = 1$.[22] The average traded quality of 0.34 is nearly twice as high as the theoretical prediction of 0.17.

In (comp), 46% of all prices offered are accepted. The average price offer amounts to 1.31 Euros, and the average traded quality is 0.29, both of which are obviously far greater than zero. Clearly, the market does not collapse completely under the (comp) design, and we reject both hypotheses.

[19] We have also evaluated the data of the two rounds separately, which leads to conclusions that are identical to those subsequently derived.

[20] As mentioned above, the subjects acted either as buyers or sellers in the first session. Therefore, the number of observations is not exactly the half of the number of participants.

[21] The table only shows the gains and losses from trade (the sellers' show-up fee, their endowments with the good, and the buyers' monetary endowment are excluded).

[22] The two-sided one-sample t-test shows that the empirical average is significantly greater than the theoretical average of 1 in the null hypothesis Hd. The test results are as follows: average = 1.664, t = 12.351, and p = 0.000.

Table 1: Basic Data per Round *(in Euros, endowments excluded)*

		p	Q	traded Q	(Π_b)	(Π_s)
	min	0.00	0.00	0.00	-1.20	-1.16
(part)	average	1.66	0.51	0.34	0.12	0.47
101 observations	max	3.00	1.00	0.94	2.16	2.20
	min	0.00	0.00	0.00	-1.71	-1.26
(comp)	average	1.31	0.51	0.29	-0.21	0.34
101 observations	max	3.40	1.00	0.94	2.18	2.08

Result 2: In both market designs, observed prices are higher than is predicted for perfectly rational players.

Since some goods are traded, buyers in the (part) design earn an average payoff of 0.12 Euros but make an average loss of 0.21 in the (comp) market. Sellers in (part) earn 0.47, whereas in (comp) they only earn 0.34 Euros per round on average.

3.2.4 Are Higher Prices Explicable by Limited Iterative Reasoning?

In this section we examine the data with regard to our claim that iterative thinking may provide an explanation for the observation that prices and traded qualities are higher than predicted by rational choice theory. The argument proceeds in four steps:

1. We have determined the participants' iteration types independently from their submitted price offers. After each round, the subjects gave descriptions of their own reasoning. We denote the number of iterative reasoning steps the subject apparently has carried out as "i" and call the subject "type-i."

2. According to the theory of iterative reasoning and the valuations a_i, n_i presented in Section 2.3, we derived the predicted price interval for each type-i.

3. We then observed the actual price offer p.

4. Finally, we were interested to see whether an actual price offer of a participant of type-i was drawn from the corresponding interval. This would establish a relation between the observed behavior and the type-i derived from the questionnaires.

We have sorted the self-descriptions into three type-i categories.[23] If a self-description contained an expectation of some quality out of the interval [0, 1] without further evaluation of the market situation, we categorized this subject into type-0. Participants who expressly mentioned they were calculating with an expected quality of 1/2 were encoded as type-1. All individuals who performed more iterative reasoning steps were grouped into the last category, called type-2+, because the subjects' self-descriptions were not elaborate enough to clearly distinguish, e.g., type-5 from type-6. Most of the written statements indicate that players either perform 0, 1, 2, or an infinite number of iteration steps.[24]

Table 2: Types-i and Type-i-consistent Price Offer Intervals

	buyer's type-i	min offer	max offer
	0	0.00	4.00
comp	1	1.50	2.00
	2+	0.00	1.49
	0	0.00	4.00
part	1	1.50	2.50
	2+	0.00	1.49

Table 2 displays the price intervals which a specific type would consistently choose his price offer from. We have encountered three problems:

- A subject of type-0 is expected to offer prices from 0 to 4 in both market designs. Hence, this type cannot be distinguished from the others.
- According to our theoretical analysis in Section 2.3 regarding the (comp)

[23]In Appendix C, we present some typical verbal statements of each type. The encoding of the verbal statements was done without any knowledge of the offered prices.

[24]Thus, our observations are in accordance with studies such as Nagel (1995), or Kübler/Weizsäcker (2002). However, these studies inferred from the observed prices that the majority of subjects show a tendency to perform only a low number of iteration steps. The difference from our work is that we are able to determine each subject's level of reasoning independently from the observed price offer.

market design, prices from 1.33 to 1.5 (which occurred only twice) cannot be related to a specific type-i. We have assigned prices below 1.5 to the interval for type-2+.

- The predicted price intervals in (part) overlap. Prices between 1.5 and 2.25 are in line with type-1 and type-2. Nevertheless, any price below 1.5 is consistent only with type-2+. We decided to locate the price interval which is consistent with type-2+ at prices between 0 and 1.5, while prices between 1.5 and 2.25 were assigned to type-1.[25]

The null hypotheses we tested are:

He: For $i = 1, 2+$, the observed price offers in (comp) are equally distributed over the two corresponding price offer intervals.

Hf: For $i = 1, 2+$, the observed price offers in (part) are equally distributed over the two corresponding price offer intervals.

If these null hypotheses are rejected, the observations provide empirical evidence that our theory of iterative thinking may serve as an explanation for the observed deviations from perfect rationality. Tables 3 and 4 show the frequencies of chosen prices. The first column lists the price offer intervals as presented above in Table 2.

Table 3: (comp) by Type-i. *101 possible observations, 4 descriptions missing*

	type-			
price offer interval	0	1	2+	Sum
$p > 2$	5	0	0	5
$1.5 \leq p \leq 2$	30	**22**	**1**	53
$p < 1.5$	22	**7**	**10**	39
Sum	57	29	11	97

59% of the subjects in the (comp) and 64% in the (part) market design have described themselves as type-0. Thereof, the majority have chosen the second

[25]Hence, the (part) design is less useful than the (comp) design for identifying significant correlations between types and their price offers.

Table 4: (part) by Type-i: *101 observations, 4 descriptions missing*

	type-			
price offer interval	0	1	2+	Sum
$p > 2.5$	4	3	0	7
$1.5 \leq p \leq 2.5$	38	**21**	**4**	63
$p < 1.5$	20	**1**	**6**	27
Sum	62	25	10	97

price interval. Extremely high prices, i.e., prices located in the first interval, have solely been chosen by types-0 in the (comp) market, and by types-0 and 1 in (part). Apparently, the likelihood of a low-price offer increases with higher type-i. In (comp), as well as in (part), types-2+ chose significantly lower prices than types 1.[26] Thus, we can reject the null hypotheses and draw the following conclusion:

Result 3: The iteration types 1 and 2+ derived from the subjects' self-descriptions are negatively correlated with the observed price offers.

This result implies that the iteration types derived from the participants' self-descriptions may contribute an explanation for the observed behavior.

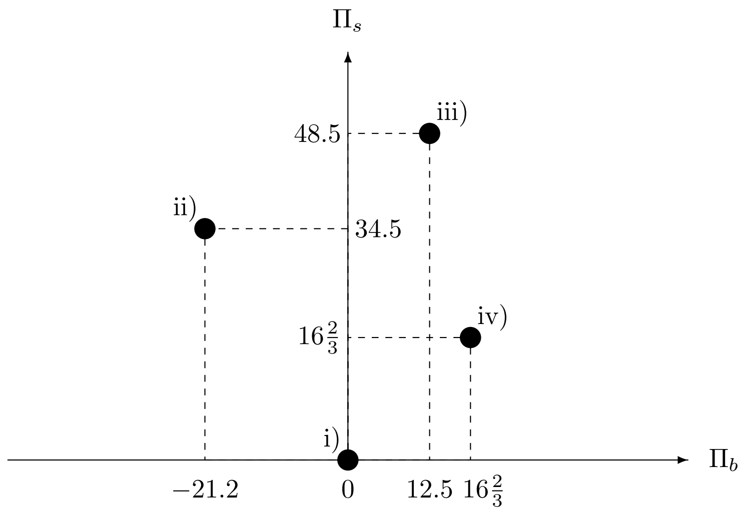
3.2.5 Is Limited Iterative Reasoning Efficiency-enhancing?

In the previous sections, we derived the conclusion that bounded rationality on the buyers' side prevents one-shot lemons markets from a complete or partial collapse. Figure 6 shows which market side profited or lost from trade in treatments A and B.

The point labeled "i)" represents the situation without trade as well as the outcome which rational choice theory predicts for the (comp) market. Point ii) represents the observed outcome under the (comp) design: the total gains from trade amount to 34.5 Euros for the sellers, and to -21.2 Euros for the buyers. Trade has earned the group of sellers a remarkable gain which even exceeds the loss suffered by the group of buyers. Defining welfare as the sum

[26] The relevant entries are printed in bold numbers in Tables 3 and 4. We used a Chi-Square test. Under (comp), the χ^2-value is 14.55, and p = 0,0001; under (part), the χ^2-value amounts to 12.371, and p = 0,0004.

Figure 6: Total Gains from Trade



of the parties' outcomes, trade has increased welfare, but only in the Kaldor-Hicks sense. Voluntary trade does not lead to a Pareto-improvement. Hence, boundedly rational buyers would prefer prohibition over free trade if this were the only means to protect them from their losses.

The analysis comes to different results for the (part) design. Again, point i) represents the outcomes without trade. The theoretical prediction, assuming perfect rationality, is represented by point iv): if the buyers offer a price $p = 1$, then only units with quality $Q < 1/3$ are traded. A traded unit generates a welfare gain of 1. With a uniform distribution of quality and 101 buyers, the expected welfare gain is 33 2/3. The price $p = 1$ distributes this welfare gain evenly among the two market sides, so both sides receive 16 2/3. The actual outcome, however, is shown at point iii): 47.6 in total for the sellers and a total of 12.4 Euros for the buyers. Welfare is higher than under perfect rationality, but – as in the (comp) market – at the buyers' expense. The sellers profit from the existence of bounded rationality among the buyers, while the boundedly rational buyers are (on average) worse off than perfectly rational buyers would be. However, in the (comp) market, both sides gain from trade. Voluntary trade induces a Pareto-improvement, and no justification for prohibition could be drawn from this study.[27]

3.3 Repeated Play in Treatments C and D

In section 3.2.4, we saw that many subjects seem to have performed only a limited number of iterative reasoning steps. This resulted in significantly higher price offers than predicted by rational choice theory. It is possible that these results are due to the fact that only one round per market design was played. The subjects might have learned to perform more iterative steps when playing several repetitions of the game. Therefore, we let subjects (who did not take part in treatments A or B) play 20 rounds of either the (comp) design – subsequently denoted as treatment C – or the (part) design – treatment D. We conjecture that:

1. Prices and traded qualities do not decline to the level predicted by rational choice theory (see Section 3.3.1),
2. The subjects' types may change over time (see Section 3.3.2),
3. A correlation exists between types-i and observed prices over 20 rounds (see Section 3.3.3).

3.3.1 Data Description

In the repeated (comp) market, 31% of price offers during all 20 rounds are accepted, while the acceptance rate in treatment D is 53%. As in the one-shot play, we observe higher acceptance rates in the (part) than the (comp) market.

Table 5 displays the prices and qualities, as well as the gains and losses from trade to the buyers and the sellers. The data aggregate 20 rounds with 31 observations per round under (comp) and 20 rounds with 32 observations per round under (part). Prices and payoffs show a tendency to be higher in the

[27] A similar overview could be provided for treatments C and B, however, without additional insight.

Table 5: Basic Data per Round *(in ECU, endowments excluded)*

		p	Q	traded Q	Π_b	Π_s
	min	0.00	0.00	0.00	-3.00	-0.56
20 times (comp)	average	0.93	0.49	0.23	-0.19	0.57
	max	3.30	1.00	0.95	1.33	3.00
	min	0.00	0.00	0.00	-1.68	-1.94
20 times (part)	average	1.58	0.50	0.29	0.09	0.44
	max	3.00	1.00	0.98	2.94	2.68

repeated (part) than in the repeated (comp) market. As in treatments A and B, some buyers face severe losses, especially in the (comp) design.

Figure 7 displays the development of average prices over 20 rounds. Even in round 20, both in the (comp) and the (part) design, the markets did not collapse to the extent predicted by rational choice theory. In the repeated (comp) market, the average price oscillates around 0.60 during the last seven rounds, which is far more than the theoretically predicted price of zero. Under the (part) design, the average price appears to be stable at about 1.5 during the second half of the experiment. Also, this exceeds the predicted $p = 1$ even after many repetitions. Moreover, prices decline both more rapidly and to a larger extent under the (comp) than under the (part) design. This implies our next result.

Result 4: Even after 20 rounds of repeated play, prices and traded qualities do not decline to the level predicted by rational choice theory.

3.3.2 The Development of the Types

The average prices show a tendency to decrease over time under both treatments. In light of our theory of bounded rationality, this should coincide with an increase in the level of reasoning, the more rounds are played. Figures 8 and 9 reveal the percentage of types-0 to 2+ in the two markets.[28]

During the whole 20 rounds of (comp) (see Figure 8), a stable percentage

[28] Note that types are not necessary stable over time. A certain subject's type-i may be adjusted upwards or downwards if the participant describes his reasoning accordingly. Moreover, an individual's development is not necessarily monotonic.

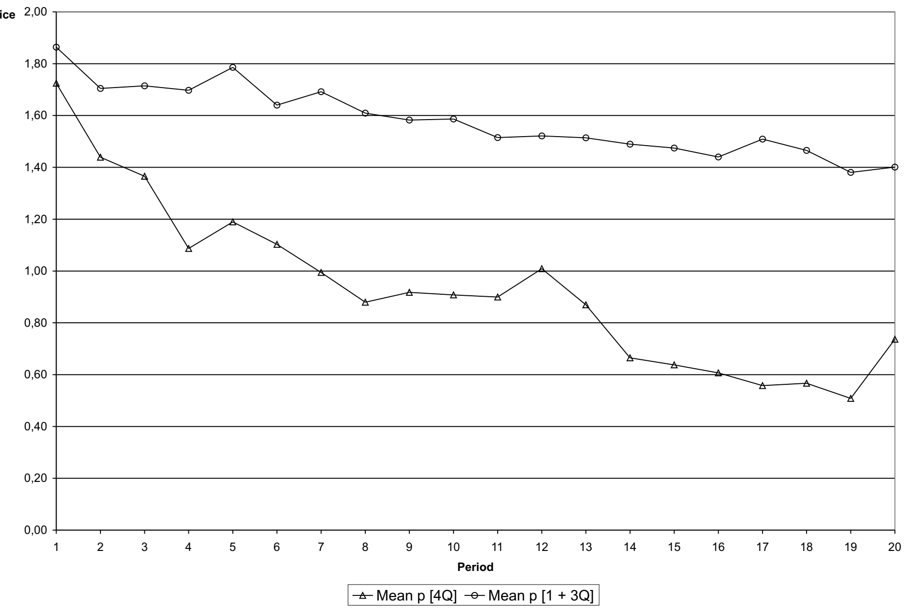


Figure 7: Price Offers in repeated (comp) and (part)

of about 60% to 70% of participants are type-0. Types-1 very quickly almost vanish from the market and, after round 11, constitute only a small share of 3%. The percentage of types-2+ varies between 3% and 30%. Figure 9 shows that only one half of the subjects are of type-0 in the repeated (part) market. The share of types-2+ is almost of the same size as in the repeated (comp) market. From round 5 on, the percentage of types-1 amounts to about 25%, which is much higher than under the (comp) design. Overall, the data allow us to draw the conclusion:

Result 5: The subjects' types-i change over time.

3.3.3 Correspondence of Types-i and Price Offers

The percentage of type-2+ grows to about 30% during the last third in both treatments. This is in line with the stable average prices we observe from period 14 on in Figure 7. But, we need to investigate whether the stable types-i and the stable average prices at the end of the game interact consistently.

Table 6 provides deeper insight. We tried to track each buyer individually

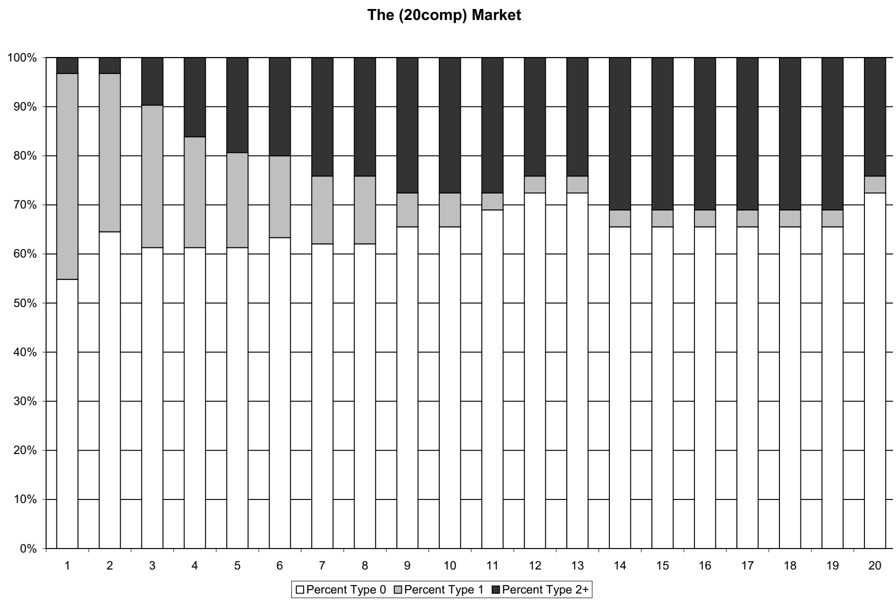


Figure 8: Percentage of Types in 20 rounds (comp)

with regard to his price offer and his self-described type-i. The columns display the relative frequency with which a subject described himself as the respective type. E.g., an individual of "type-0 $\geq 75\%$" described himself as type-0 in 15 out of 20 rounds. The rows cluster the consistency of the self-description as type-i with the actual price offer. A subject with "consistency of $\geq 90\%$" offered a price located in the corresponding type-consistent price offer interval (see Table 2) in at least 90% of the rounds in which he described himself as type-i. Note that a subject who "changed" his type during 20 rounds must have consistently changed price offers, too, in order to be "consistent." The entries show numbers of individuals.

Out of 31 subjects, 21 (68%) describe themselves as types-0 in at least 10 out of 20 periods in (comp), and 16 out of 32 (50%) in (part). In Table 6, many more highly consistent ($\geq 90\%$) than less consistent ($< 90\%$) entries are registered (see the first row of each treatment). We, therefore, conclude from the descriptive data:

Result 6: In repeated play, the types-i may contribute to explaining the

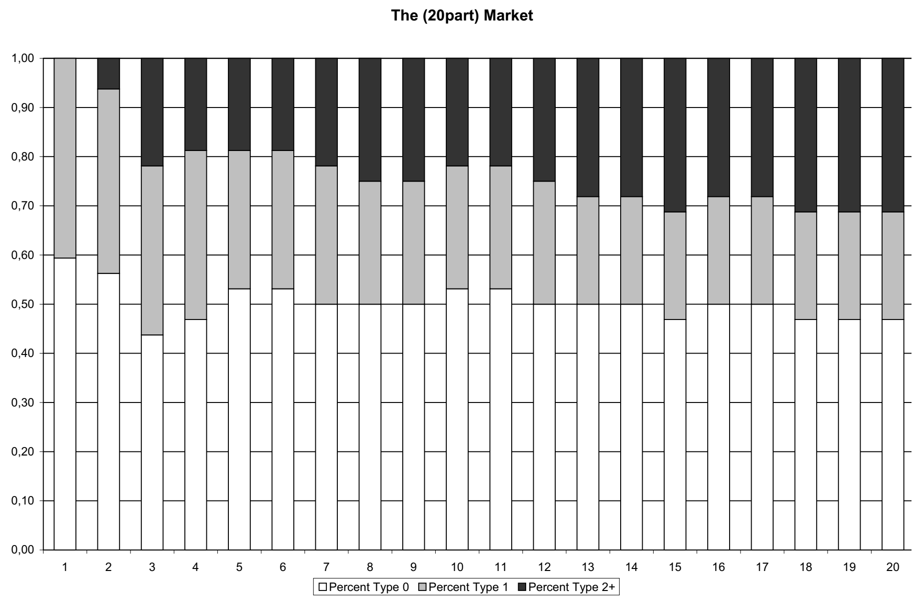


Figure 9: Percentage of Types in 20 rounds (part)

observed prices.

Surprisingly, a more or less pure type-1 is almost nonexistent in the repeated (comp) market, whereas in the repeated (part) market this type still occurs. These results might indicate that the higher pressure in (comp) markets forces the subjects to think more deeply, which induces some of the early-period types-1 switch to type-2+. Some of the written statements express that the subjects indeed faced a hard time during the decision process, and the alternative to

Table 6: Frequency of Type-i with Consistent Price Offers in 20 Rounds

		type-0		type-1		type-2+	
	consistency	$\geq 75\%$	$\geq 50\%$	$\geq 75\%$	$\geq 50\%$	$\geq 75\%$	$\geq 50\%$
20 (comp)	$\geq 90\%$	18	1	0	0	4	0
	$< 90\%$	0	2	1	0	1	4
20 (part)	$\geq 90\%$	14	1	3	1	5	3
	$< 90\%$	1	0	4	0	0	0

deeper reasoning seems to be a switch to type-0 by further taking the game as a gamble. In a (part) market, in contrast, staying type-1 until the end of the game is not as risky with respect to potential losses from trade. Thus, the need for more careful thinking is less pressing in the (part) than in the (comp) market.

4 Conclusion

We have run an experiment for two different lemons markets: under one design, labeled (comp), perfectly rational players are predicted to complete no transaction at all. Thus, the market is expected to collapse completely. Under the other design (part), perfectly rational players are expected to trade only some units of low quality. In both market designs under consideration, the observed price offers of uninformed buyers and the average traded qualities are higher than these predictions.

Our explanation of this behavior draws on the theory of iterative reasoning. Players who perform only a limited number of iteration steps are boundedly rational. We have compared the price offers with the respective buyers' iteration types, which were derived from their written self-descriptions independently of the price offers, and have found a negative correlation. This is empirical support for the hypothesis that limited iterative reasoning provides an explanation for the observed behavior of buyers in lemons markets.

Comparing the two market settings, we can cautiously interpret the (comp) design as a lemons market without warranty, while the (part) design is one in which the risk of breakdown is partially covered. Full insurance (like a quality-preserving warranty) implies that the buyer's net income from purchasing a car is constant, irrespective of its actual quality. The results show that a partial warranty may lead to higher prices and a higher number of transactions as a way to alleviate the effects of asymmetric information. Note that this impact of the warranty is not driven by a signaling effect, nor does it depend on risk-aversion on the part of buyers.

According to our design, the potential buyers were able to make a take-it or leave-it offer to their respective sellers. Under complete information, this would provide the buyers with a chance to capture the complete cooperation rent. Numerous experiments have demonstrated, however, that first-movers in ultimatum games do not exploit their position to the fullest, since they have to be aware of possible rejections (which, in principle, are irrational). In our experiment, the buyers were also unable to capture the cooperation rent, but here this was due to the asymmetry of information.[29] Boundedly rational buyers even faced expected losses that were captured by the sellers. Thus, the second movers turned out to have an extremely strong position in our experiment, due to their informational advantage. The chance to make a take-it or leave-it offer, which is usually clouded only by fear of rejection, can turn into a disadvantage if the first-mover is the uninformed party.

The collapse of markets that suffer from asymmetric information is an inspiring theoretical phenomenon. If, however, bounded rationality (in the form of limited iterative reasoning) of the uninformed market participants is taken into account, the inefficiency in the theoretical result might be greatly exaggerated. If market failure only occurs in theory, but not in reality, institutional means (such as mandatory insurance, warranties, building of reputation...) based on theory might go too far or be too costly, and may perhaps do even more harm than good.

This policy implication of our results, however, suffers from a serious drawback: successfully completed transactions may inflict losses upon the buyers. After the completion of a transaction, the actual quality of the item sold is revealed. Some buyers may then realize that their valuation of the purchased item is lower than the price they paid. They submitted their offer based on false (i.e., overly optimistic) expectations. In such a case, a concluded transaction is only a Kaldor-Hicks-improvement, but not a Pareto-improvement. If the buyers were perfectly rational, they would let the market collapse, avoiding such losses. Therefore, potential buyers who are boundedly rational might be interested in

[29] Note that in our ultimatum game, the first-mover did not demand a share of a given "cake." He rather demanded a slice from a cake, the size of which was unknown to him. In the ultimatum game with complete information, this distinction may be irrelevant, but under asymmetric information this seems to be crucial.

regulation that protects them from completing harmful transactions in lemons markets.

Appendix A

Proof of the Proposition

Let us first derive the condition for an optimal price in a general framework. Recall that sellers value quality Q with $a(Q) = \beta Q$, while the buyers value quality with $n(Q) = \gamma + \delta Q$. We assume $\gamma \geq 0$ and $\delta \geq \beta > 0$. We can disregard price offers $p > \beta$ since they are strictly dominated by $p = \beta$. For any price offer $p \in [0, \beta]$, the respective buyer's expected payoff is

$$\begin{aligned} V_b + E\pi_b(p) &= V_b + \int_0^{a^{-1}(p)} [n(Q) - p] dQ \\ &= V_b + \int_0^{p/\beta} n(Q) dQ - \frac{p^2}{\beta} \\ &= V_b + \frac{\gamma}{\beta} p + \frac{\delta}{2\beta^2} p^2 - \frac{p^2}{\beta} \\ &= V_b + \frac{\gamma}{\beta} p + \left[\frac{\delta - 2\beta}{2\beta^2} \right] p^2 \end{aligned}$$

The first derivative with respect to p is

$$\frac{\partial E\pi_b(p)}{\partial p} = \frac{\gamma}{\beta} + \left[\frac{\delta - 2\beta}{\beta^2} \right] p$$

and the second derivative is

$$\frac{\partial^2}{\partial p^2} = \left[\frac{\delta - 2\beta}{\beta^2} \right].$$

If $\delta \geq 2\beta$, then the corner solution $p = \beta$ maximizes the buyer's payoff, which proves our third result.

If, on the other hand, $\delta < 2\beta$, then an internal maximum exist, as the second-order condition demonstrates. The first derivative equals zero if

$$p = \frac{\beta\gamma}{2\beta - \delta}.$$

Thus, in our parameter setting 1 ($\gamma = 0$ and $\beta < \delta < 2\beta$) the maximum payoff is obtained with $p = 0$. This result establishes our prediction according to which the market collapses completely under this parameter setting.

In our second parameter setting ($\gamma > 0$ and $\beta = \delta$), the second-order condition for a maximum is satisfied, and the first-order condition can be simplified to

$$p = \frac{\beta\gamma}{2\beta - \beta} = \frac{\beta\gamma}{\beta} = \gamma.$$

This establishes our second result, according to which the market collapses only partially.

Appendix B

The Basic Instructions (*Treatment A*)

You are taking part in an economic experiment. Each participant makes his decisions in isolation from the others and enters them into an answer sheet. Communication between participants is not allowed. Male forms like "he" will be used to refer to anyone.

In the experiment, there are two types of players, "buyers" and "sellers," in the market for good X. **You take both** the role of a "**buyer**" and the role of a "**seller**." The subjects you interact with are **not** located in your room but in the room opposite to yours. There are as many subjects in your room as in the opposite one.

The experiment consists of 2 rounds. In each of the two rounds, one seller interacts with one buyer. In both rounds, buyers and sellers will be matched randomly anew. Thereby, a subject from this room in the role of a seller randomly interacts with a buyer from the opposite room. Likewise, a subject from the opposite room randomly interacts as seller with a buyer from this room. Therefore, in the role of a seller, you always sell your X to the other room. There is only a small chance that you as a buyer interact with a seller from the other room who simultaneously acts as buyer of your X. **In each of the two rounds**, it will be randomly allotted which buyer and seller interact. Even after the experiment, you will not be informed about who you traded with.

In each round, each seller is endowed with one unit of good X, and each buyer has 4 Euros at his disposal.

In each of the two rounds, the situation is as follows: The sellers offer their X. Each unit of good X has a certain quality that is only known to its seller. The qualities of X are uniformly distributed on the interval [0,1], that is each quality between 0 and 1 is equally probable. Thus, 0 indicates the worst and 1 the best quality. This probability distribution is known to both buyers and sellers. The actual quality of a unit of good X is labeled Q.

The **buyers** value good quality more highly than bad quality. The valuation of a certain quality in Euros is described by a function $n(Q)$. The exact shape of the function $n(Q)$ **will be explained later in the instructions**. No buyer can discover the real quality prior to his decision to buy; he only knows the probability distribution of quality. **Not until after a purchase** does each buyer learn about the real Q of his unit of X.

After each round, the buyers are credited a payoff following this rule:

- If trade has taken place at price p, the buyer gets $4 - p + n(Q)$ Euros,
- If no trade has taken place, the buyer gets 4 Euros.

As for the sellers, the function $a(Q) = 3Q$ denotes their value of good X in Euros: If X is not sold in one round, the seller receives $a(Q)$ Euros in that round. If, in contrast, a seller sells his X, he obtains the respective sales price. The totalled payoffs of the two rounds are the earnings of buyers and sellers.

Each round passes as follows:

1. First, the buyer makes his decision and enters his proposal for a sales price on his form (there are separate forms for each of the two rounds). All forms will then be collected by the experiment supervisor and randomly distributed to the sellers in the other room. Each seller gets exactly one form.
2. Each seller gets assigned a certain quality. Then he decides whether or not he wants to sell his unit X at the price proposed by the buyer. He enters this decision in the form. If a sale is made, he also enters the actual quality of the unit sold.
3. Again, the forms will be collected by the experiment supervisor and given back to the respective buyers. If a purchase has taken place, the buyer is informed about the real quality of the good X that he bought.
4. This completes one round.
5. After the two rounds, each player gets paid his total payoffs in cash.

Instructions Buyers, 1. round[30]

Your subject number is:
During this round, the situation on the X-market is as follows (also see Figure 10:

- Each buyer owns exactly 4 Euros, and each seller owns exactly one unit of X.
- The buyer's valuation of the quality of good X in the first round is $n(Q) = 1 + 3Q$. Thus, for example, one unit of good X with quality Q = 0.7 is worth $n(0.7) = 3.1$ Euros to each buyer.
- The sellers value X by $a(Q) = 3Q$. Therefore, the same unit is worth $a(0.7) = 2.1$ Euros to the seller.

Example:
We assume a buyer to purchase an X at price $p = 2.4$ Euros, and the real quality of that X to be $Q = 0.3$. Thus, $p > n(Q)$. Then, the buyer receives an amount of $(4 - 2.4 + 1.9) = 3.5$ Euros out of this round. If, in contrast, he buys this unit (with $Q = 0.3$) at price $p = 1.1$ Euros, then $p < n(Q)$. His earnings will then be (4 - 1.1 + 1.9) Euros = 4.8 Euros.

Offer Form (Round 1)[31]

The decision of a **buyer**

Your subject number is:

[30] The instructions for the second round are the same, except for the altered $n(Q)$ which then is $n(Q) = 4Q$.
[31] The form for Round 2 is similar.

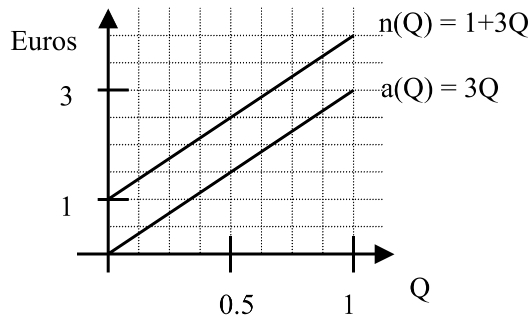


Figure 10:

My price offer:
I want to buy one unit of X at price p = ...

. . . .

The decision of a **seller**

Your subject number is (please fill in!): ...
My decision :

( ) I decline the offer.
( ) I accept. My unit of X is of quality Q = ...

The Questionnaire

Description of sellers' reasoning:
Your subject number is:
Please briefly describe the reasoning that led to your particular sales price proposal in each of the two rounds:
Round 1:
Round 2:

Appendix C

Here, we present some typical verbal statements of our participants.
Type-0 is supposed to not even calculate an expected quality. Some of the written statements that we coded as types-0 are, for example:

- "I chose p such that quality gets better,"
- "I had no idea, I just gambled,"

- "Seller only sells if $p > 3Q$; my choice was arbitrary – best choice would have been 1 Cent above $3Q$,"
- "Defensive behavior - better to be left with the good on my hands,"
- "I analyzed what the seller's quality must be, compared to my price offer,"
- "Profits rise with higher risk – no alternative seems to have decisive advantages, so I chose the middle course."

Type-1 is expected to explicitly use an expected quality of 1/2 in their calculations. Some examples are:

- "$E(Q) = 1/2$ and $a(Q) = 1.5$; thus, my offer is 1.51,"
- "Since Q is uniformly distributed, I used $Q < 1/2$ (risk-averse). Because $a(Q) = 3Q$, I chose $p = 1.5$,"
- "With $E(Q) = 0.5$ a price $p = 1.5$ is accepted with probability 1/2,"
- "I calculated $E(Q) = 0.5$ and wanted to make some profits."

Finally, type-2+ performs at least one more step of iterative reasoning than type-1. Therefore, type-2+ knows that the conditional expected quality clearly is smaller than 1/2 and a loss is to be expected with too high a price. Some examples (from the (part) market) are:

- "I compared possible gains and losses in a table; the chance to gain is 1:3 compared to the chance to lose; this is too risky,"
- "The possible loss is always higher than the possible gain; thus, on average there is always a loss,"
- "The expected gains are always smaller than 0; an offer is advantageous only if the slope of $n(Q)$ is at least twice as much as the slope of $a(Q)$,"
- "E.g., at $p = 1.6$ the seller sells if $Q < 0.5$: with $Q = 0.5$ profits are 40 cents, with $Q = 0.4$ profits are zero, with $Q = 0.3$ losses are 40 cents, and so on; thus, there is a negative expected profit."

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