



**Iterative Reasoning in an
Experimental „Lemons" Market**

Roland Kirstein • Annette Kirstein

FEMM Working Paper No. 14, March 2007

F E M M

Faculty of Economics and Management Magdeburg

Working Paper Series

Iterative Reasoning in an Experimental “Lemons” Market.[†]

Roland Kirstein* Annette Kirstein**

28 - March 2007

Abstract

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

We examine to which extent the theory of iterated reasoning contributes to the explanation of these observations. Perfectly rational behavior requires a player 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.

JEL classification: *D8, C7, B4*

Encyclopedia of Law and Economics: *0710, 5110*

Keywords: *bounded rationality, market failure, adverse selection, regulatory failure, paternalistic regulation*

[†]We are grateful to Max Albert, George Akerlof, Ted Bergstrom, Friedel Bolle, Vincent Crawford, Maher Dwik, Mathias Erlei, Ralph Friedmann, Rod Garrat, Hans Gerhard, Wolfgang Kerber, Manfred Königstein, Clemens Krauß, Rosemarie Lavaty, Göran Skogh, Dieter Schmidtchen, Jean-Robert Tyran and other seminar and conference participants in Hamburg, Karlsruhe, Kassel, Saarbrücken, Santa Barbara and Zürich for valuable comments (the usual disclaimer applies). Part of this research was done while we enjoyed the hospitality of the University of California in Berkeley (Law School) and Santa Barbara (Economics Department). The Deutsche Forschungsgemeinschaft provided financial means to run the experiments.

*Corresponding author. Professorship of Business Economics, Faculty of Economics and Management, Otto-von-Guericke-University, D-39106 Magdeburg, Germany, md@rolandkirstein.de, phone +49-391-67-18729, fax +49-391-67-11764. I am indebted to the Thyssen Stiftung for the generous financial support of my research trip.

**SFB 504 “Concepts of Rationality, Decision Making, and Economic Modeling,” University of Mannheim, and Institut für Wirtschaftstheorie and Operations Research, University of Karlsruhe, D-76128 Karlsruhe, Germany, Kirstein@wiwi.uni-karlsruhe.de.

1 Introduction

Akerlof (1970) has identified asymmetric information as a source of inefficient market outcomes and even market collapse. In experimental as well as in real world “lemons markets,” however, the empirical extent of market failure is smaller than predicted by rational choice theory.¹ We have run two experiments in which the participants had to trade under asymmetric information. 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. A theoretical explanation for this deviation from perfectly rational behavior can be drawn from the theory of iterative reasoning.

Iterative reasoning is applicable in games in which iterative dominance is prevalent.² The idea of iterative reasoning has been explored in numerous experiments.³ Perfectly rational behavior in a lemons market requires the players to eliminate dominated strategies in an infinite number of iteration steps. As boundedly rational decision-makers are able to perform only a limited number of iterations, this theory leads us to predict that they will bid higher prices. The outcome of a lemons market with boundedly rational buyers is, therefore, less inefficient than the market result if only perfectly rational buyers are present. In our experiment, we have examined to which extent the price offers of an uninformed buyer can be explained by his “iteration type”⁴, i.e., the number of iteration steps he performs when eliminating dominated strategies. Our experimental data shows a negative correlation between the buyers’ iteration types and their price offers. However, this negative correlation can only be confirmed for those subjects who perform a positive number of iteration steps. In the course of the experiments, many decisions appear to have been made without any elimination of dominated strategies. These subjects have rather picked their prices randomly. Just as the rational choice theory, the theory of iterative reasoning has little predictive power with regard to players who act randomly. However, an explorative analysis of our experimental data indicates that this

¹An early example is the “acquire-a-company” experiment by Bazerman/Samuelson (1983).

²Section 5.6 of Camerer (2003) explains the “levels of reasoning” concept.

³See, e.g., Schotter/Weigelt/Wilson (1994).

⁴See Costa-Gomes/Broseta/Crawford (2001).

buyer type, just as the boundedly rational type, has chosen higher prices than those subjects who were identified as perfectly rational.

The main contribution of our paper lies in the fact that we have determined the buyers' iteration types independently of the observable behavior which the types are supposed to explain. Existing studies on iterative reasoning have inferred the iteration types from the observed behavior. A famous example is the "guessing game" experiment in Nagel (1995).⁵ For two reasons, we have chosen a different approach: First, if the iteration type is directly derived from the observed prices, the former cannot be used as an explanation for the latter. Secondly, the direct derivation method would categorize any buyer as rational who offers a very low price. However, this behavior could as well be caused by the failure to perform any iteration steps at all. Our method allows to distinguish between perfectly rational buyers and players who just act randomly.

Another difference between our experiment and Nagel's is the focus of iterative reasoning. Deviation from the behavior that is predicted under common knowledge of rationality can be explained by her theory even without discarding the assumption that all players are fully rational. It is sufficient to assume that a player falsely believes that some of the peers perform only a limited number of iteration steps, and then reacts optimally to this belief by staying exactly one iteration step ahead.⁶ Hence, it is not a cognitive limitation of the player under scrutiny that makes him perform only a finite number of iteration steps.⁷ Our model does not focus on the beliefs of the player under scrutiny. If he deviates from perfectly rational behavior, this is explained by his performing a finite number of iteration steps, which is caused by his limited cognitive ability.⁸

Our research program is depicted in Figure 1. We have evaluated two distinct

⁵See also Thaler (1997), Nagel et al. (1999), Selten/Nagel (1998), and Ho/Camerer/Weigelt (1998). Other examples are Beard/Beil (1994), Eyster/Rabin (2005), and Kübler/Weizsäcker (2004).

⁶A generalization has been presented by Camerer/Ho/Chong (2001) and (2004): In their theory, a type 0 chooses randomly, while a type $k > 0$ assumes that other players are of type 0 through $k - 1$, and responds optimally to this belief.

⁷A related concept is the "cursed equilibrium" in Eyster/Rabin (1995): A "cursed" player assumes his opponents to choose their type-contingent optimal behavior with a probability smaller than one. With the counter-probability, he expects them to choose average behavior, and reacts optimally to this belief.

⁸Stahl/Wilson (1995, 128) discuss the different types of bounded rationality models.

data sets which were generated 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 in each round by the buyers directly after having submitted their price offers. We are fully aware that relying on verbal statements given by participants following their decisions bears a risk – the statements may retrospectively serve as a rationalization of the own behavior. In our case, however, this problem can safely be neglected for two reasons: First, if a subject has the ability to perform just one iteration step, he is unable to imitate a higher type. Secondly, the subjects had to fill out the questionnaire before they learned the actual outcome resulting from their decisions. Hence, there was no information given between the decision and the verbal statement that might have been used for an update.

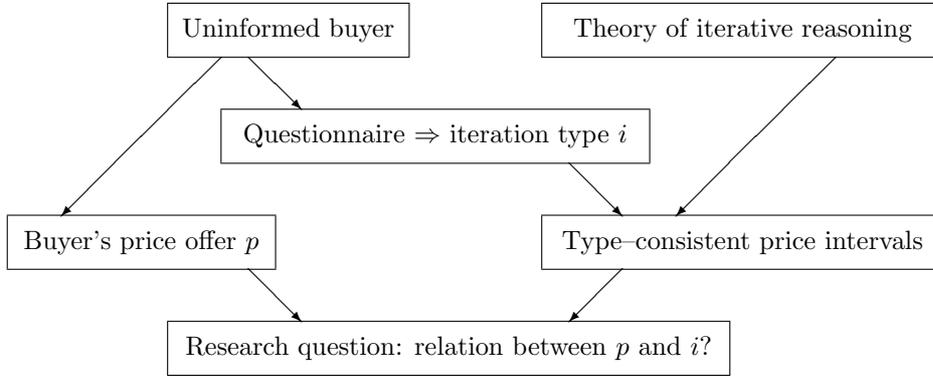
We asked the buyers to briefly describe their line of reasoning, and we have used these written statements to categorize the participants into iteration types (denoted by i).⁹ Their self-descriptions indicate that some buyers have randomly chosen their price offers (type-0), while others have performed just one iteration step (type-1) or decided in a rather elaborate fashion (type-2 and higher). We therefore distinguish only these three categories of iteration types. We have applied the theory of iterative reasoning to our lemons market model and derived price intervals from which we predict a buyer of type i to choose his price offer.

In the final step, we compared the type-consistent price intervals with the observed prices p to answer our research question: Does a negative relation exist between iteration types and observed prices? We have found two main results:

- The verbal statements of most of the subjects do not allow for the interpretation that they have performed iterative elimination of dominated strategies. These participants seem to have acted rather randomly.
- A significant negative correlation between type and price offer exists for those types who have performed iteration steps. Moreover, we have observed that most of these types' price offers were actually taken from the

⁹Nagel (1995, 1318) mentions that written comments of the subjects in her experiment seem to support her results, but she has not derived the subjects' types from these statements.

Figure 1: Iteration Types of Buyers and Observed Prices



type-consistent price intervals.

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 experiments. In the first experiment, the subjects play each market setting just once (sections 3.1 to 3.2). In Section 3.3, the second experiment is reported, in which the participants repeatedly played one of the two market designs. 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 $a(Q) = \beta Q$.
- 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 $\delta \geq \beta > 0$. Thus, for each quality level $Q > 0$, the buyers' valuation 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.

Denote the initial monetary endowment of the players as $V_i \geq 0$ and the (ex post) gain from trade as Pi_i , with $i = b, s$ for buyers and sellers. If a seller accepts a certain price offer p , then his payoff is $V_s + p$. If he rejects the offer, his payoff is $V_s + \beta Q$. His gain from trade, therefore, amounts to $p - \beta Q$. It is rational for a seller to accept a price offer only if it exceeds his valuation of the good ($\Pi_s > 0$ 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.

If a price offer p is accepted by a seller, then the buyer's payoff amounts to $V_b + \gamma + \delta Q - p$. If it is rejected, he is left with V_b . Ex post, his gain from trade is $\gamma + \delta Q - p$. An uninformed buyer faces a much more complicated decision problem than a seller. When perfectly rational, he tries to maximize the

¹⁰Under 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.

expected gain from successfully closing a transaction by choosing an appropriate price offer p , but he is unaware of the true quality.

2.2 Perfectly Rational Buyers

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

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

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*

¹¹Price 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.

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

- 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,*
- 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 perfectly rational 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 Boundedly Rational Buyers

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 $n_k = n(EQ_k)$; $k \in \mathbb{N}$.

2.3.2 Complete Market Collapse

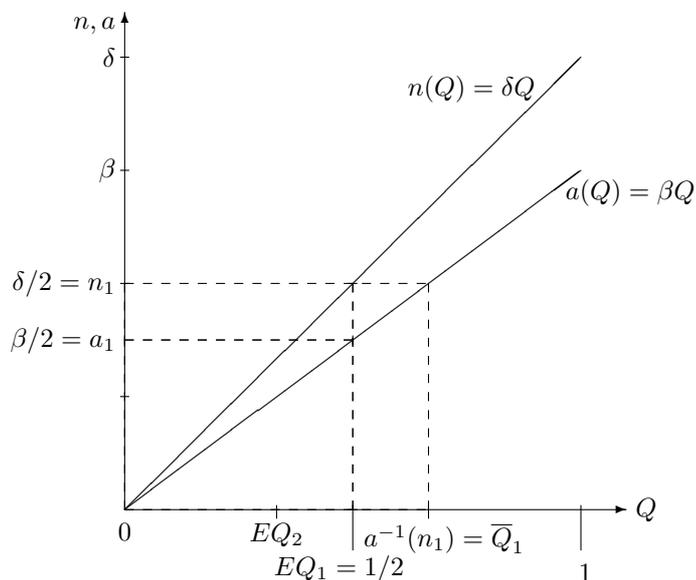
In parameter setting 1 (i.e., $\gamma = 0$ and $\delta > \beta$), the maximum willingness to pay of a buyer who performs only one step of iterative reasoning is $n_1 = n(EQ_1) = \delta/2$. We limit our focus to cases where $\delta < 2\beta$, which implies $n_1 < \beta$. To conclude a transaction, this 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 $\bar{Q}_1 = a^{-1}(n_1) = \delta/2\beta$ will prefer to keep their item for themselves. It is due to the assumption $\delta < 2\beta$ that, even if the buyer offers his maximum willingness to pay, the sellers who own units of high quality can be expected to reject the offer, or: $\bar{Q}_1 < 1$.

If a buyer performs a second reasoning step, he anticipates \bar{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 $EQ_2 = 0.5\bar{Q}_1$. Therefore, such a buyer has a maximum willingness to pay, contingent on his beliefs, which amounts to $n_2 = n(EQ_2) = \delta\bar{Q}_1/2 = \delta^2/4\beta$. The assumption $\delta < 2\beta$ implies $EQ_2 < EQ_1$ and $n_2 < n_1$.

Figure 2 displays EQ_1 , a_1 , n_1 , \bar{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, \bar{Q}_k as well as n_k decrease as the number of iteration steps k increases. 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

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



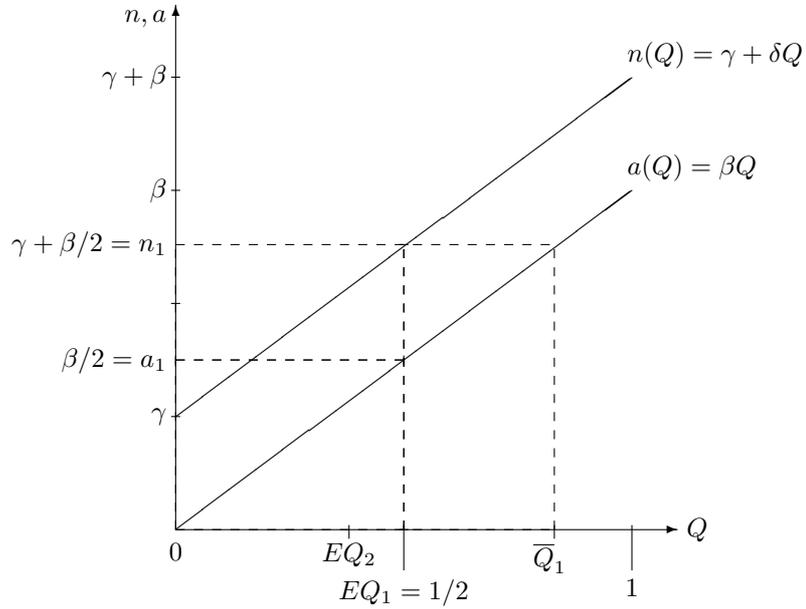
rational buyers: He offers zero, and no unit is traded. Boundedly rational players, however, carry out only a limited number of steps. For any number of reasoning steps k a player performs, we can derive an interval $[a_k, n_k]$ from which this theory predicts the player to choose his price offer.

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 $\bar{Q}_1 = a^{-1}(n_1) = (2\gamma + \beta)/2\beta$. Thus, this buyer expects a quality that equals $\bar{Q}_1/2 = (2\gamma + \beta)/4\beta$. 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 two experiments with two treatments each.

Experiment 1:

- treatment A: first (part), then (comp);
- treatment B: first (comp), then (part).

Experiment 2:

- 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.

The first experiment was 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.

After having submitted their price offers in each round, and before having learned the actual results, the buyers were asked to write down, in their own

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

¹⁴In 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 switched to the above procedure.

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

words, the line of reasoning that led to the corresponding price offer.¹⁶ Finally, the subjects learned their individual outcomes in private. Only those buyers whose offers were accepted learned about the quality their anonymous partner was endowed with. 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.

The second experiment was 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.¹⁷ 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 (we used the same wording as in treatments A and B). 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.

¹⁶The exact wording of the question was, now translated into English, “*Please briefly describe the reasoning that led to your particular price offer.*”

¹⁷The 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.

3.2 One-shot Play 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, 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.¹⁸

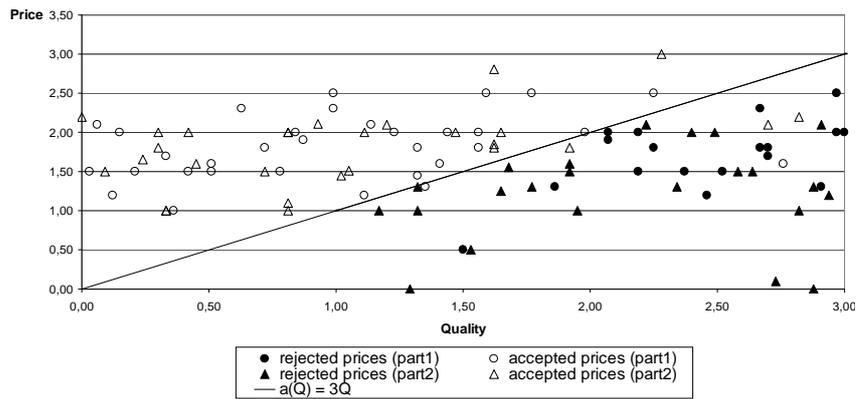


Figure 4: Price Offers in (part)

¹⁸In Figure 4, we observe 0 rejected offers that should have been accepted, i.e., no bold symbol appears above the line, and 5 accepted offers that should have been rejected, i.e., 5 open symbols appear below the line. In Figure 5, only 1 rejected offer should have been accepted, and 2 accepted offers were better rejected.

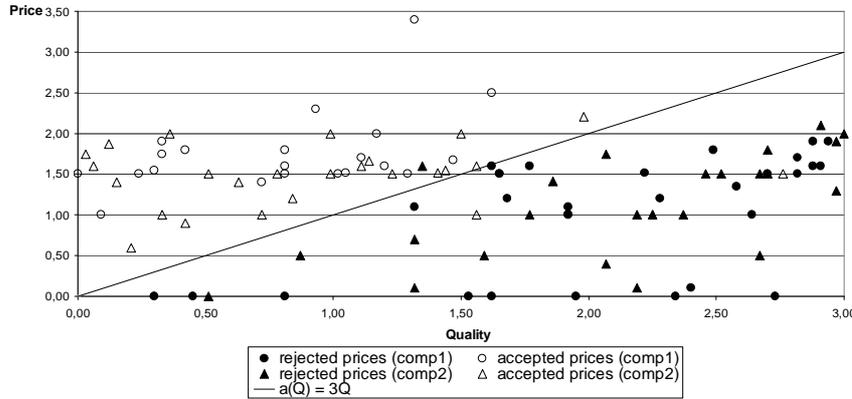


Figure 5: Price Offers in (comp)

3.2.2 Does the Ordering of the Market 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.¹⁹ Thus, our first null hypothesis is:

In both market designs, the offered prices in first-round play do not differ from those in second-round play.

A Wilcoxon test 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.²⁰ Thus, the null hypothesis cannot be rejected for both of the market designs, and we have derived our first result.

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

¹⁹We have used SPSS version 13.0 and SysStat 8.0, two statistical software packages from SPSS Inc., to evaluate the data. All tests were conducted at a 5 percent significance level.

²⁰For each market design, we compared the results of the first and second round play 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 value 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 value 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.²¹

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 hypothesis:

In the (comp) market, only $p = 0$ is offered, while in the (part) market, only $p = 1$ is offered.

According to the Proposition in Section 2.2, the average traded quality in (comp) should be zero, whereas in the (part) market it is expected to be $1/6$, if the above null hypothesis is true. The descriptive aggregate data of both (comp) and (part) are provided in Table 1.²² 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.²³

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

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

²¹We have also evaluated the data of the two rounds separately, which leads to conclusions that are identical to those subsequently derived.

²²As 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.

²³The 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).

In (part), 60% of the price offers are accepted, and the average price of 1.66 is significantly greater than the predicted $p = 1$.²⁴ 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, so we can reject the null hypothesis also for this market design.

Result 2: In both market designs, observed prices are higher than 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 Does Limited Iterative Reasoning Explain the Price Offers?

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 a subject apparently has carried out according to his self-description, 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 derive the predicted, i.e., the type-consistent price interval for each type- i .

²⁴The two-sided one-sample t-test shows that the empirical average is significantly greater than the theoretical average of 1. The test results are as follows: average = 1.664, $t = 12.351$, and $p = 0.000$.

3. We then observe the actual price offer p .
4. Finally, we are interested to see whether a negative correlation exists between the type- i of a participant and his actual price offer. Moreover, we explore whether the observed price offer has been chosen from the type-consistent price interval. If not, then the theory of iterative reasoning would have no explanatory power with regard to the observed behavior.

We have sorted the self-descriptions into three type- i categories.²⁵ If a self-description did not contain an expected quality of $1/2$ nor any further systematic evaluation of the market situation, we categorized this subject into type-0.²⁶ Participants who expressly mentioned they were calculating with an expected quality of $1/2$ were encoded as type-1.²⁷ All individuals who performed more iterative reasoning steps were grouped into the last category, called type-2+.²⁸ Most of the written statements indicate that players either perform 0, 1, 2, or an infinite number of iteration steps.²⁹

Table 2 displays the price interval from which a certain iteration type would consistently choose his price offer, as we have demonstrated with our theoretical analysis in Section 2.3). We have encountered three specifics:

- A subject of type-0 is expected to offer prices from 0 to 4 in both market designs. Hence, any price offer would be type-consistent. Thus, our theory does not provide falsifiable hypotheses with regard to type-0.

²⁵In Appendix C, we present an overview of some typical verbal statements of each type. The encoding of the verbal statements was done without any knowledge of the offered prices. The filled in questionnaires are available on request.

²⁶For instance, typical lines of reasoning that we categorized as type-0 subjects were “*I chose p such that quality gets better*”, or “*I had no idea, I just gambled*”, or “*I analyzed what the seller’s quality must be, compared to my price offer.*” The third statement could as well be made by a subject who understood the market mechanism well, but was unable or unwilling to describe this in more detail. However, this statement is too ambiguous to be anything else than type-0. Overall, we have been rather hesitant when categorizing a statement into type-1 or type-2+.

²⁷Subjects of type-1 could easily be identified. Typical examples for a type-1 statement are “ *$E(Q) = 1/2$ and $a(Q) = 1.5$, thus my offer is 1.51*”, or “*I calculated $E(Q) = 1/2$ and wanted to make some profits.*”

²⁸The subjects’ self-descriptions did not allow us to distinguish, e.g., type-5 from type-6. A typical type-2+ statement was, e.g., “*The possible loss is always higher than the possible gain, thus on average there is always a loss.*”

²⁹Thus, our observations are in accordance with studies such as Nagel (1995), or Kübler/Weizsäcker (2004).

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

	buyer's type- i	min offer	max offer
comp	0	0.00	4.00
	1	1.50	2.00
	2+	0.00	1.33
part	0	0.00	4.00
	1	1.50	2.50
	2+	0.00	2.25

- In the (comp) market design, prices between 1.33 and 1.5 can neither be related to type-1, nor to type-2+. Such prices were offered only twice.
- The predicted price intervals in (part) overlap. Prices between 1.5 and 2.25 would be consistent with type-1 and type-2. Nevertheless, any price below 1.5 is consistent only with type-2+.

Tables 3 and 4 show the frequencies of chosen prices³⁰, where the first column lists the price offer intervals as presented in Table 2 and discussed above. In the bottom two rows, the types' average and median prices are depicted.

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

Price offer interval	Type-			Sum
	0	1	2+	
$p > 2$	5	0	0	5
$1.5 \leq p \leq 2$	30	22	1	53
$1.33 < p < 1.5$	2	2	0	4
$p \leq 1.33$	20	5	10	35
Sum	57	29	11	97
Average price by type	1.45	1.47	0.29	–
Median price by type	1.50	1.50	0.00	–

59% of the subjects in the (comp) and 64% in the (part) market design have described themselves as type-0. Extremely high prices, i.e., prices located in the first interval, have seldom but solely been chosen by types-0. Since

³⁰In both markets, four descriptions are missing, as four subjects did not fill in the questionnaire.

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

Price offer interval	Type-			Sum
	0	1	2+	
$p > 2.5$	2	0	0	2
$2.25 < p \leq 2.5$	4	4	0	8
$1.5 \leq p \leq 2.25$	36	20	4	60
$p < 1.5$	20	1	6	27
Sum	62	25	10	97
Average price by type	1.66	1.91	1.17	–
Median price by type	1.63	2.00	1.00	–

type-0 chooses a price randomly, any price offer is consistent with type-0 (type-consistent choices are printed bold in Tables 3 and 4). In (comp), 76% of types-1 and 91% of types-2 offer type-consistent prices. In (part), the percentages amount to 96% and 100%, respectively. Thus, regarding the descriptives, our observations are to a large extent in line with the theory.³¹ As our theory generates restricted price offer intervals only for type-1 and type-2+, we initially conjecture a negative relation between offered prices and type- i for $i = 1, 2+$. Thus we test the (converse) null hypothesis for type-1 and 2+:

The higher the type, the higher the price in both market designs.

The highly significant³² rank order correlations amount to -0.57 in (comp), and to -0.65 in (part). Tables 3, and 4 have shown that the negative relations of types and prices are based on a large number of type-consistent price choices. We draw the following conclusion:

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

Though restricted price intervals are theoretically derived only for type-1 and type-2+, we can explore differences in median price offers among all three types

³¹A χ^2 -test would clearly support this result, but its application faces the problem that too many entries in Tables 3 and 4 equal zero.

³²The tests each reveal a (one-sided) p -level of 0.000. We used the prices and self-descriptions generated by types-1 and 2+ in each market to conduct the tests.

in each market (see Tables 3 and 4 for the median prices).³³ The Kruskal-Wallis ANOVA on ranks in (comp) reveals that the three groups differ significantly in median prices ($H = 19.811$, $df = 2$, $p < 0.001$). Also in (part), the differences in median prices are significant among the three types ($H = 13.522$, $df = 2$, $p = 0.001$).

The pairwise comparisons (Dunn’s method)³⁴ show that, in both market designs, types-2+ chose significantly lower prices than types-1, which confirms the above stated result 3. What is more, types-2+ have submitted lower price offers than types-0, which, however, is significant only in (comp). The comparison between types-0 and types-1 exhibits no significant difference in both markets. Overall, there is no evidence that lower iteration types have chosen lower prices than higher types. Hence, this explorative analysis sustains the idea that iterative thinking may contribute to explaining the observed deviations from perfect rationality.

3.2.5 Is Limited Iterative Reasoning Efficiency-enhancing?

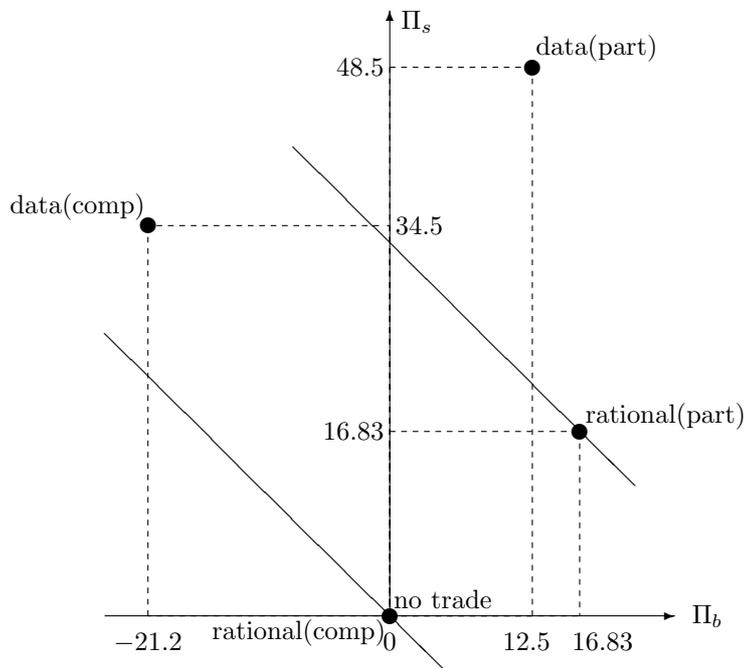
In the previous sections, we derived the conclusion that bounded rationality on the buyers’ side prevents one-shot lemons markets from a complete or partial collapse. Figure 6 shows which market side profited or lost from trade in treatments A and B.

The point labeled “no trade” or “rational(comp)” represents the situation without trade, as well as the outcome which rational choice theory predicts for the (comp) market. The lower diagonal indicates the iso-welfare line (for a utilitarian welfare function, which defines welfare as the sum of the parties’ outcomes) for the zero welfare level. Point “data(comp)” is 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

³³We do not test group differences in mean prices by using a one-way ANOVA, as the data in Treatments C and D did neither pass the normality tests nor the equal variance tests. Thus, the non-parametric alternative, i.e., the Kruskal-Wallis ANOVA on ranks is always applied. We used the prices and self-descriptions generated by types-0, 1 and 2+ in each market to conduct the tests.

³⁴Dunn’s method is used as a post hoc test and is conducted to a 5%-level of significance.

Figure 6: Total Gains from Trade



buyers. Trade has increased total welfare, but only in the Kaldor-Hicks sense. Voluntary trade does not lead to a Pareto-improvement. Boundedly rational buyers would prefer prohibition over free trade if this were the only way to protect them from their losses.

The analysis comes to different results for the (part) design. The theoretical prediction, assuming perfect rationality, is represented by the point “rational(part)”: If the buyers offer a price $p = 1$, then only units with quality $Q < 1/3$ are traded. Trading one unit generates a welfare gain of 1. With a uniform distribution of quality and 101 buyers, the expected welfare gain is 33.67. The price $p = 1$, which is predicted by rational choice theory, distributes this welfare gain evenly among the two market sides, so both sides receive 16.83. The upper diagonal represents the welfare level achieved in this outcome. The actual result, however, is shown at the point labeled “data(part)”: The earnings of the sellers accrue to a total of 47.6, while the buyers receive a total of

12.4 Euros. 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 voluntary trade, as it induces a Pareto-improvement. Hence, for this market design our study provides no justification for prohibition.³⁵

3.3 Repeated Play in Treatments C and D

According to section 3.2.4, many subjects seem to have performed only a limited number of iterative reasoning steps. This explains 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 may learn 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 explore the following questions:

1. In Section 3.3.1: Do prices and traded quantities decline to the level predicted by rational choice theory?
2. In Section 3.3.2: Are the subjects’ types- i stable, or do they change over time?
3. In Section 3.3.3: Does a negative relation exist between types- i and observed prices over 20 rounds?

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, and sellers behaved very rationally.³⁶

³⁵The similar analysis for treatments C and D does not yield additional insight.

³⁶As to the sellers’ behavior, in treatment C, we observed only 4 unprofitably accepted offers, and 17 disadvantageously rejected offers in 20 rounds of play. In treatment D, they

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

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

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 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. The overall average traded quality is 0.23 (see Table 5), which also substantially deviates from the prediction of zero. Under the (part) design, the average price ranges from 1.6 to 1.4 during the second half of the experiment. Even after many repetitions, the offered prices exceed the perfectly rational prediction of $p = 1$. In each round, the observed prices differ significantly from the theoretically predicted price.³⁷ The overall average traded quality of 0.29 (see Table 5) is almost twice the 0.17 which was predicted by rational choice theory. 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

amounted to 5, and 8, respectively.

³⁷We exemplarily give the two-sided one-sample t-test results for the last two rounds, testing for a mean of 1. Round 19: mean = 1.380; $t = 4.836$; $p = 0.000$; round 20: mean = 1.401; $t = 5.132$; $p = 0.000$.

do not decline to the level predicted by rational choice theory.

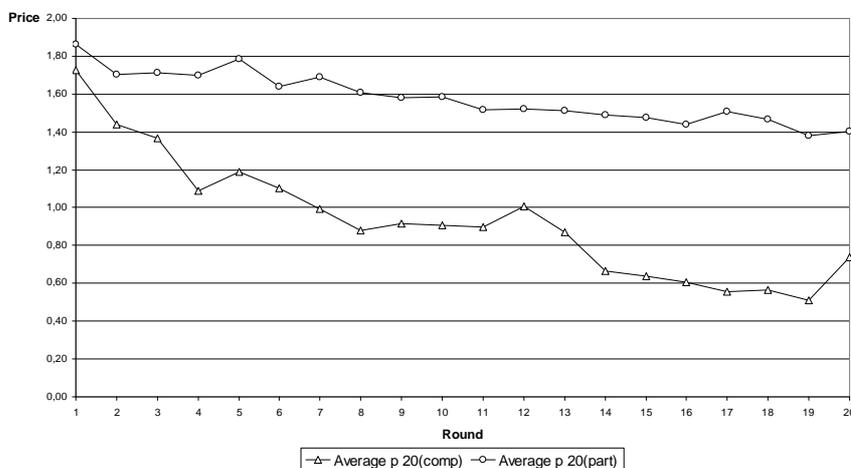


Figure 7: Price Offers in repeated (comp) and (part)

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.³⁸

During the whole 20 rounds of (comp) (see Figure 8), a stable percentage 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: In both market designs, the percentage of type-2+ grows over

³⁸Note 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.

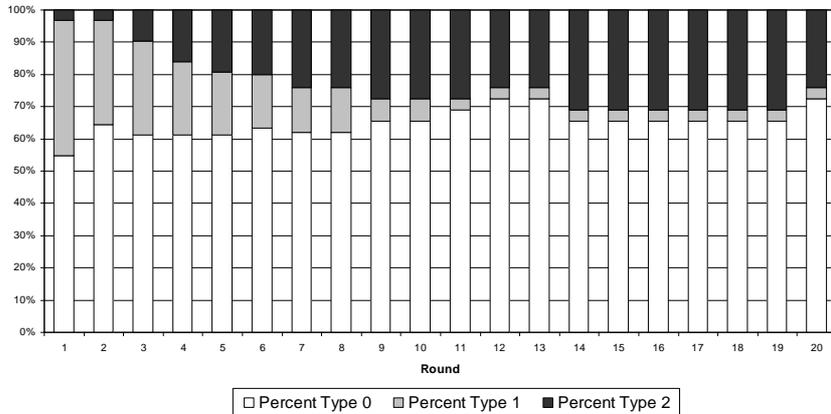


Figure 8: Percentage of Types in 20 rounds (comp)

time. Type-1 subjects almost vanish during the 20 rounds of (comp). In (part), the percentage of type-1 is almost stable. The number of types-0 slightly increases in the repeated (comp) market, and slightly decreases in the repeated (part) market.

Table 6: Overview of Self-descriptions through 20 periods

Subjects' Self-descriptions	20(comp)	20(part)
20 rounds type-0	11	8
20 rounds type-1	1	5
20 rounds type-2+	1	–
From type-0 to 1	–	2
From type-0 to 2+	3	3
From type-1 to 2+	1	3
From type-0 to 1 to 2+	–	1
From type-1 to 0	6	3
Forth and back	6	7
Missing	2	–
Sum	31	32

Table 6 provides an overview of the subjects' development. We track each buyer individually with regard to his self-described type- i through the 20 rounds. The first column indicates the observed developments. “Forth and back” at the

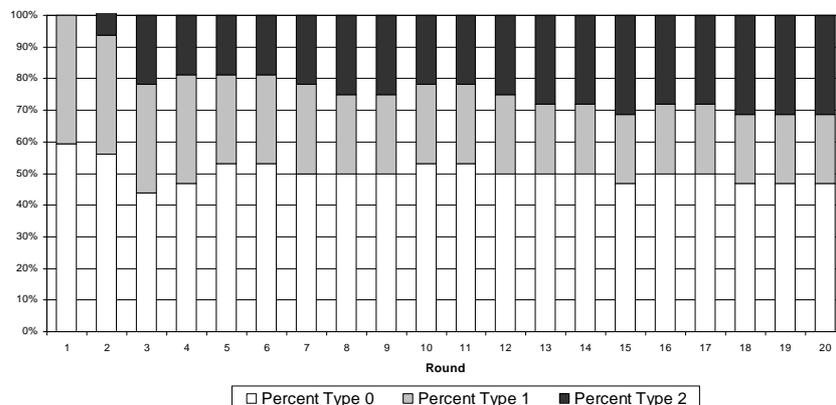


Figure 9: Percentage of Types in 20 rounds (part)

bottom of Table 6 labels subjects who – according to their self-description – changed from low to high type, and back.³⁹ The label “Missing” indicates subjects who did not (completely) fill out their questionnaires. The remaining nominations are self-explanatory. The entries display numbers of subjects, which add up to 32 in 20 rounds of (part), and to 31 in (comp), respectively.

About one third of subjects remain the same type throughout the 20 rounds. Another third shows a development from type-1 to type-0, or forth and back. The last third of the subjects moves from lower to higher types. Pure types-1 can be observed in the (part) market, but are almost nonexistent in the repeated (comp) market.

3.3.3 Correspondence of Types- i and Price Offers

The percentage of type-2+ grows from a very small percentage in the beginning to about 30% during the last third in both treatments. This would explain the observation that average prices decrease (see Figure 7). In this section, we investigate whether all types- i choose their price offers from the type-consistent

³⁹A development forth and back may happen if a subject starts with “trying”, then calculates $E(Q)$ and, in the following, explains in detail that high qualities vanish from the market, and finally turns to “gambling”. Such behavior would have been coded as a sequence “type-0, 1, 2, and back to 0”.

intervals throughout the 20 rounds.⁴⁰

We test our conjecture that price offers are type-consistent and, therefore, types-2+ should bid lower prices than types-1. If this were true also in the repeated game, the observed growing number of low types can be made responsible for the decreasing price. Analogously to the examinations of treatments A and B, Tables 7 and 8 display the frequencies of price offers in treatments C and D (type-consistent choices are printed bold). The bottom two rows depict the types' average and median price offers.

Table 7: (comp) by Type- i : 620 possible observations, 29 descriptions missing

price offer interval	type-			Sum
	0	1	2+	
$p > 2$	57	1	0	58
$1.5 \leq p \leq 2$	103	39	18	160
$1.33 < p < 1.5$	6	5	9	20
$p \leq 1.33$	218	27	108	353
Sum	384	72	135	591
Average price by type	1.09	1.14	0.50	–
Median price by type	1.03	1.50	0.04	–

Table 8: (part) by Type- i : 640 observations

price offer interval	type-			Sum
	0	1	2+	
$p > 2.5$	17	6	0	23
$2.25 < p \leq 2.5$	17	14	0	31
$1.5 \leq p \leq 2.25$	223	122	12	357
$p < 1.5$	65	28	136	229
Sum	322	170	148	640
Average price by type	1.75	1.73	1.04	–
Median price by type	1.75	1.60	1.00	–

Similar to the one-shot treatments A and B, the highly significant rank order

⁴⁰Because buyers and sellers were newly matched after each round, each of the $31 \cdot 20 = 620$ price offers under 20(comp), and of the $32 \cdot 20 = 640$ under 20(part) are treated as independent observations. In 20(comp), however, 2 subjects filled in the questionnaire only until round five, and round seven, respectively, hence 29 self-descriptions are missing.

correlations that relate types-1 and 2+ to their price offers reveal that, the higher the type, the lower the price. Spearman’s rho amounts to -0.82 in treatment C, and to -0.4 in treatment D.⁴¹ Tables 7, and 8 show that these relations of types and prices are based on a large number of type-consistent price choices. We, therefore, conclude:

Result 6: During 20 rounds of repeated play, the types- i contribute to explaining the observed prices, and the self-described iteration types 1 and 2+ are negatively correlated with the observed price offers.

Finally, though the theory predicts restricted price intervals only for type-1 and type-2+, we explore differences in median price offers among all three types in treatments C and D (see Tables 7, and 8 for the median prices).⁴² The Kruskal-Wallis ANOVA on ranks in the repeated markets reveals that the differences in median prices among all three types are significant, $H = 64.688$, $df = 2$, $p < 0.001$ in 20(comp), and $H = 266.941$, $df = 2$, $p < 0.001$ in 20(part). Pairwise comparisons (Dunn’s method)⁴³ show that, in both market settings, types-2+ offer significantly lower prices than types-1 or types-0, which confirms our Result 6.

4 Conclusion

We have run experiments to examine two different lemons market designs: Under one design, labeled (comp), perfectly rational players are predicted to conclude no transaction at all. Thus, the market is expected to collapse completely. Under the other market design, called (part), perfectly rational players are expected to trade only some units of low quality. In both market designs it would be efficient that all units be traded. According to the empirical results for both market designs, the average prices offered by the uninformed buyers and the average traded qualities are higher than the predictions for perfectly rational players.

⁴¹The tests each reveal a (one-sided) p -level of 0.000. We used the prices and self-descriptions generated by types-1 and 2+ in each market to conduct the tests.

⁴²As the data did neither pass the normality tests nor the equal variance tests, we use the non-parametric alternative, i.e., the Kruskal-Wallis ANOVA on ranks. We used the prices and self-descriptions generated by types-0, 1 and 2+ in each market to conduct the tests.

⁴³Dunn’s method is used as a post hoc test and is conducted to a 5%-level of significance.

A possible explanation of this behavior draws on the theory of iterative reasoning. Players who perform only a limited number of iteration steps to eliminate dominated strategies are boundedly rational. This theory includes perfectly rational behavior as a limit case: Such a decision-maker carries out an infinite number of iteration steps. For all iteration types, this theory allows us to derive a type-consistent price interval, from which an uninformed buyer of a certain type is predicted to choose his price offer.

During the experiments, we have determined each individual buyers' iteration type from written self-descriptions, independently of the observed price offers. Three types could be identified: The type-0 did not start an iteration, but picked his price offer randomly. Type-1 was able to carry out just one iteration step. Type-2+ decided rather elaborately, i.e., undertook at least two iteration steps.

For these types, we have compared the corresponding type-consistent price interval with the prices which were actually offered. The vast majority of prices were chosen from the type consistent price-interval. Moreover, for type-1 and type-2+, we observed a significant negative correlation between types and offered prices. This correlation did not vanish in the repeated play experiment. What is more, the data indicates that type-0 subjects have chosen significantly higher prices than type-2+ subjects. This empirical result supports the hypothesis that the theory of limited iterative reasoning contributes to explaining the behavior of buyers in lemons markets. The behavior of type-0, however, is not captured by this theory, just as the theory of perfect rationality does not say anything about such actors. However, using this method, we were able to identify each player's iteration type in each round without referring to their price offers. Furthermore, we could determine how many subjects actually have performed iterative reasoning at all.

The difference between the two market settings, (comp) and (part), can be interpreted as the existence of quality insurance (e.g., by a contractual or a mandatory warranty). With a full insurance, the valuation function of the buyers would be horizontal. Hence, the (part) market reflects partial insurance, while buyers in the (comp) market bear the full quality risk. The results of our experiments show that a partial warranty may induce the buyers to offer higher

prices and to conclude a higher number of transactions. Note that this effect of warranty is not caused by signaling, nor does it depend on risk-aversion on the part of buyers.

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 derived under the assumption of perfect rationality might be greatly exaggerated. Institutional means to prevent market failure, such as mandatory insurance, warranties, building of reputation, may therefore go too far and be too costly. They may perhaps do even more harm than good.

This policy implication of our experiment, however, suffers from a serious drawback: Successfully completed transactions may inflict losses upon the buyers. They may have submitted their offer based on overly optimistic expectations. In such a case, having concluded a transaction may not be a Pareto-improvement. In our (comp) market, boundedly rational buyers are even worse off than without trade. These consumers would be interested in regulation that protects them from participation in free trade. With regard to (comp) markets, such a regulation would not harm the perfectly rational buyers. Hence, it is an example of “asymmetric paternalism,” following Camerer et al. (2003).

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. round⁴⁴

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.

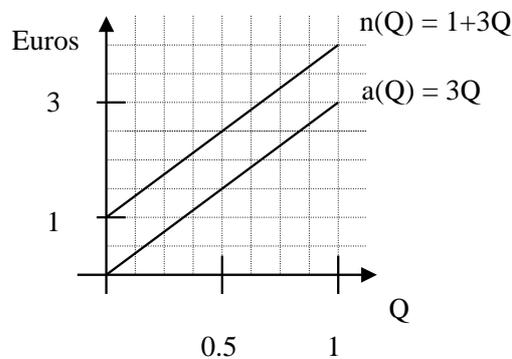


Figure 10:

Example:

⁴⁴The instructions for the second round are the same, except for the altered $n(Q)$ which then is $n(Q) = 4Q$.

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)⁴⁵

The decision of a **buyer**

Your subject number is:

My price offer:

I want to buy one unit of X at price $p = \dots$

.....

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 $Q = \dots$

The Questionnaire

Description of sellers' reasoning:

Your subject number is:

Please briefly describe - in each round - the reasoning that led to your particular sales price proposal in that round:

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,"

⁴⁵The form for Round 2 is similar.

- “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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