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

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

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Abstract

We have experimentally tested a theory of bounded rational behavior in a "lemon market". It provides an explanation for the observation that real world players successfully conclude transactions when perfect rationality predicts a market collapse. We analyzed two different market designs: complete and partial market collapse. Our empirical observations deviate substantially from these theoretical predictions. In both markets, the participants traded more than theoretically predicted. Thus, the actual outcome is closer to efficiency than the theoretical prediction. Even after 20 repetitions of the first market constellation, the number of transactions did not drop to zero.

Our bounded rationality approach to explain these observations starts with the insight that perfect rationality would require the players to perform an infinite number of iterative reasoning steps. Bounded 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 iteration types and observed price offers.

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1 Introduction

Asymmetric information can cause inefficient market outcomes. This is the main insight of Akerlof (1970).[1] Akerlof's famous example was a highly stylized market for used cars in which cars of two different qualities exist: some cars have high quality, others are "lemons". Efficiency requires all cars to be traded. However, under the assumption that the sellers know the quality of their car, whereas the buyers are unable to observe the true quality of a specific car, an adverse selection effect may cause the market to collapse entirely (under the worst circumstances). Real-world players, however, usually tend to successfully complete at least some transactions in lemon markets.

We have run a series of experiments in which the participants had to trade in a lemon market. The prices offered by the uninformed buyers were much higher than those predicted by the theory. Therefore, the amount of traded goods exceeded the theoretical prediction as well. Thus, the empirical extent of the market failure was smaller than expected.

One way to explain such behavior requires relaxing the assumption that players are perfectly rational. Many models of bounded rationality exist.[2] Stahl/Wilson (1995, 128) have defined and tested five bounded rational archetypes of players that can be distinguished with respect to their "model of other players and their ability to identify optimal choices given their priors". They point out that two ways exist how 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.

The concept of bounded rationality that we propose as an explanation of the observed behavior in our experiment follows the latter approach. Moreover, it draws on the theory of iterative reasoning.[3] The equilibrium result in Akerlof's lemon market requires the players to compute an infinite number of iterative steps. Bounded rationality, however, allows a decision-maker to perform only a limited number of iterations.

Note that our approach should be distinguished from the one in Nagel (1995). Her paper describes a guessing game experiment which has been executed with thousands of participants worldwide.[4] Participants are asked to write down (in private) a figure between 0 and 100. These figures are collected, the average is computed, and the participant whose figure is closest to a fraction of the average receives a prize. In the unique Nash equilibrium all participants write down zero.[5] As in our experiment, the derivation of this Nash equilibrium

[1] This seminal paper has inspired an enormous body of literature, see e.g. Wilson (1989) for an introduction and overview.

[2] See, e.g., Conslik (1996) for an overview.

[3] Camerer (2003), chapter 5 provides an introduction into iterative dominance; section 5.6 explains the "levels of reasoning" concept.

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

[5] Nagel (1995, 1314). The famous "beauty contest" of Keynes (1936, 156) implicitly assumed a factor equal to one. This case clearly leads to multiple Nash equilibria. For a factor greater than one, there are two Nash equilibria, see Nagel (1995, 1314) for details.

also rests on an infinite number of iteration steps, and the vast majority of the participants in that experiment does not play the Nash equilibrium strategy.

Nagel explains that observation with the assumption that real world players make only a limited number of iteration steps, which appears to be very similar to our experiment on the first glance. However, her paper follows the first rather than the second approach introduced by Stahl/Wilson (1995). In her theory, the player under scrutiny is not assumed to be limited in his abilities to act rationally. She rather assumes that players have false assumptions concerning the type of their peers. If a player thinks that all other players perform only two iteration steps, then it is the perfectly rational choice to limit oneself to three steps.

While Nagel's theory refers to beliefs about other players' types, our theory deals with the abilities of the individual player under scrutiny. Thus, her theory does not describe the respective player as being bounded rational. However, there is one similarity between these two approaches. According to Nagel's results, players are either "type" 1, 2, 3, or infinity.[6] This terminology reflects that people assume their peers to perform either 0, 1, or 2 iteration steps (and try to be one step ahead), or they assume that the others are perfectly rational (infinite number of steps). The latter behavior is typical for participants who have enjoyed some training in game theory. In our experiment, we also find that players are either extremely limited (type 0 or 1) or elaborate (type 2 or greater), an observation that induced us to distinguish only these three categories of iteration types.

Another example that belongs into the first category of bounded rationality approaches is the experiment of Beard/Beil (1994): player 1 can choose L and gain 9.75 (his opponent receives 3). Alternatively, he can choose R and put player 2 on the move. If 2 now acts rationally, then he chooses r, which brings him 5 (and 10 for player 1). If he fails to do so, he only receives 3 (and player 1 gets only 4.75). The subgame perfect Nash equilibrium is played only if 1 is convinced that 2 will indeed act selfishly. If 1 holds a belief that 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).

There is another difference between our paper on the one hand, and the experiments of Nagel (1995) and Beard/Beil (1994) on the other: in these papers, data evaluation is limited to the behavior observed. The driving force of their approach, i.e, the beliefs of the player under scrutiny with regard to his opponents' rationality, has to be determined from the observed behavior of the participants. We have evaluated two distinct data sets which were generated independently from each other. The one set consists of the observable behavior, i.e., the offered prices and traded quantities. The source of the other set is a questionnaire. We asked the participants to describe their line of reasoning briefly in words after each round. The evaluation of these written statements led to a categorization of the participants into "iteration types". We have found a

[6] This explains the title of the paper by Nagel et. al. (1999).

correlation between the iteration types and the offered prices. Thus, the concept of limited iterative reasoning does not only theoretically explain the observed behavior; this theory is also supported by the data.

The idea of iterative reasoning has been tested in numerous experiments.[7] The "centipede game" of Rosenthal (1981) has raised particular interest. It is subgame perfect to finish the game already at the first node, but when both players stay in the game for further rounds, this increases the mutual payoff. McKelvey/Palfrey (1992) have discovered that players rarely leave the game at early stages. However, the probability is increasing with the number of nodes played. This behavior could be explained by a limited ability for iterated reasoning. As in our experiment, perfect rationality requires a player to perform a high (if not infinite) number of reasoning steps, but each additional step of iterative reasoning decreases the payoff.

If the agents in a lemon market are bounded rational, then the predicted outcome would not be as inefficient as under the assumption of perfect rationality. Bounded rational participants thus generate a greater cooperation rent than in the Nash equilibrium predicted under the assumption of perfect rationality. One should, however, be aware that these transactions do not necessarily have to be bilaterally beneficial. If an uninformed buyer in a lemon market concludes a transaction on the basis of false expectations, then he may well be worse off than without the transaction. If such a transaction is "welfare enhancing", then this term refers to Kaldor-Hicks improvements rather than to Pareto improvements.

The remainder of this paper is organized as follows: in section 2, we introduce two versions of the Akerlof model. Under the assumption of perfect rationality, the predicted outcome is a complete market collapse in the first parameter setting, whereas in the second only some units of low quality are predicted to be traded. Players of bounded rationality, according to our concept, are predicted to conclude a greater number of transactions under both of the two parameter settings. The lower the reasoning type of a buyer (as derived from the written self-description in the questionnaire), the higher the offered price. The lower the degree of rationality among the buyers, the higher is the number of transactions we expect to take place.

In section 3, we describe our experiment. In the parameter constellation for which a complete collapse was predicted, the number of transactions was smaller than in the market with partial collapse. Thus, a "lemon" effect was still observable. However, under both parameter constellations the participants have completed much more transactions than the perfect rationality-based model predicts. However, the number of concluded transactions was still inefficient.

Our bounded rationality approach - based on the theory of iterative reasoning - would predict such a behavior if buyers are active who perform only a limited number of reasoning steps. We have determined the participants' iterative reasoning types from their written statements. Then, we have compared these types with the observable prices. We have found a significant correlation between iteration types and observed price offers. This first part of the

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

experiment is described in sections 3.1 to 3.3.

We have run an additional experiment, the results of which are presented in section 3.4, to test whether the transactions observed are due to a first-round effect (in other words: whether experienced players learn to let the market collapse). Participants who did not take part in the first part of the experiment repeatedly played one of the two market constellations. According to our observations, the offer prices declined with the number of rounds played, but remained significantly above the price that was predicted for perfectly rational players.

Section 4 concludes the article with a discussion of the possible implication of our results for economic policy, in particular for the regulation of lemon markets.

2 Adverse Selection

2.1 Setup

This section presents the two versions of the Akerlof model that we have tested in a series of experiments. The results of these experiments are reported in the subsequent section. The two versions of the model are parameterized in a way that, under the assumption of perfect rationality, two different equilibrium outcomes are derived: in one setting, the market is expected to collapse completely; in the other setting some trade is predicted to take place. Both equilibria are inefficient, since efficiency would require all units in the market to be traded.

Consider a market in which a good is traded that may assume different qualities. We assume the quality to be uniformly distributed over the interval $[0, 1]$, and we denote the actual quality of a specific unit as Q. The actual quality is relevant for the agents' valuation of the car. Two groups of agents are active in this market:

- (Potential) sellers, each of whom owns one unit of the good and knows the true quality of this unit. The valuation of the sellers is denoted as $a(Q)$, with $a(Q) = \beta Q$ $(\beta > 0)$.
- (Potential) buyers who do not own the good. They are unable to observe the true quality of a certain car, but they know the distribution of the quality. Their valuation is denoted as $n(Q) = \gamma + \delta Q$.

We assume $\gamma \geq 0$ and $\delta > \beta$: the buyers' valuation for each quality level $Q > 0$ exceeds the sellers'. In a situation of symmetric information, the efficient outcome could easily be achieved. Assume that both market sides are fully informed about the quality of a respective unit. 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. Assume, on the other hand, that both market sides are uninformed, but do know the distribution of the quality. Then each buyer and seller would agree to buy a specific unit for a price between their valuation of the average quality (which is 0.5).

However, this result is not predicted under asymmetric information about the goods' quality. We 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 a contract is concluded and the unit of the commodity is traded. If the seller refuses the offer, then no transaction takes place. Denote the possible reactions of the seller as $\tau = 0$ if he refuses the buyer's offer, and $\tau = 1$ if he accepts.

Now we derive the payoffs of the two parties, written as Π_i, with $i = b$ for buyers and $i = s$ for sellers. The initial endowment of the players is $V_i \geq 0$. If a certain buyer submits a price offer p, which is randomly allocated to a certain seller, then the seller receives $\Pi_s = V_s + (1-\tau)\beta Q + \tau p$, which equals $V_s + \beta Q + \tau(p - \beta Q)$. Obviously, it is rational to accept for a seller if, and only if, $p > \beta Q$. The decision problem of a seller, if faced with a price offer p by a certain buyer, is rather simple.

The buyer's payoff accrues to $\Pi_b = V_b + \tau(\gamma + \delta Q - p)$ if the transaction is concluded. An uninformed buyer faces a much more complicated decision problem. He should maximize the expected gain from successfully closing a transaction, namely $\gamma + \delta Q - p$ by choosing an appropriate price offer p, however without knowing the true quality Q.

2.2 Perfect rationality

Any price offer $p \leq \beta$ divides the support of the quality Q into three subsets:[8]

- $Q < n^{-1}(p)$: the offer is accepted, i.e. $\tau(p) = 1$, but the resulting payoff leads to a loss for the submitting buyer;
- $n^{-1}(p) < Q < a^{-1}(p)$: the offer is accepted and brings a profit for the buyer;
- $Q > a^{-1}(p)$: the offer is rejected, or $\tau(p) = 0$.

The assumption $a(Q) = \beta Q$ implies $a^{-1}(p) = p/\beta$. The buyer's expected payoff, conditional on his submitted price offer, accrues to

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

A perfectly rational buyer chooses his price offer in order to maximize $E\Pi_b(p)$. In the subsequent analysis, as well as in the experiment, we distinguish two different parameter constellations regarding $n(Q)$:

1. $n(Q) = \delta Q$ (hence $\gamma = 0$) and $\delta > \beta$,

[8] 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.

2. $n(Q) = \gamma + \delta Q$ with $\gamma > 0$ and $\delta = \beta$.

In case 1, the valuations of both the sellers and the buyers start in the origin, and the buyers' valuation has greater slope. Case 2 is characterized by parallel valuation curves with a constant distance. The following proposition derives the optimal price offer, denoted p^*, made by a perfectly rational decision maker.[9]

> **Proposition:** *Assume a lemon 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 $\delta \geq \beta > 0$. Then*
>
> 1. *if $\delta \leq 2\beta$ is true, the optimal price offer under parameter constellation 1 ($\gamma = 0$ and $\delta > \beta$) is $p^* = 0$,*
> 2. *if $\delta \leq 2\beta$ is true, the optimal price offer under parameter constellation 2 ($\gamma > 0$ and $\delta = \beta$) is $p^* = \gamma$,*
> 3. *if $\delta \geq 2\beta$, the optimal price offer is $p^* = \beta$.*

The result $p^* = 0$ implies a complete market collapse: even though it would be efficient to trade all units in the market, asymmetric information makes the buyers abstain from positive offers, so no units are traded at all. In the other 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

The optimal choice demonstrated above can equivalently be derived by an iterative reasoning process. Iterative reasoning, however, has the advantage that it allows for modeling bounded rationality. Within the framework of this theory, a perfectly rational decision-maker performs an infinite number of reasoning steps, whereas a bounded rational decision-maker is able to carry out only a limited number of steps.

Let us first consider a buyer who does not analyze the situation at all. He picks his price offer just by pure chance. To put it formally: this buyer performs zero iteration steps. Another buyer might evaluate the situation a more elaborate way: he knows that the unknown, true quality of the car he offers a price for is uniformly distributed between 0 and 1. Thus, he would calculate with an expected quality of 1/2. Such a buyer would offer a price from the interval between the sellers' and his own valuation of this expected value. This buyer performs the first step of the iterative reasoning process.

The next buyer under scrutiny may realize that, even if he offers the highest possible value, i.e. his own valuation of the expected quality, there might be some sellers who would refuse his offer. Unfortunately, these are the sellers

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

who own the highest qualities. 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, which means bidding a lower price. A buyer who stops here has performed two steps of iterative reasoning.

In the next reasoning step, the buyer may still be hesitant to actually make the offer he has derived yet. The reason for this reluctance can be derived out of a similar reasoning: 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. It is determined by the expected quality EQ_k.

2.3.2 Complete market collapse

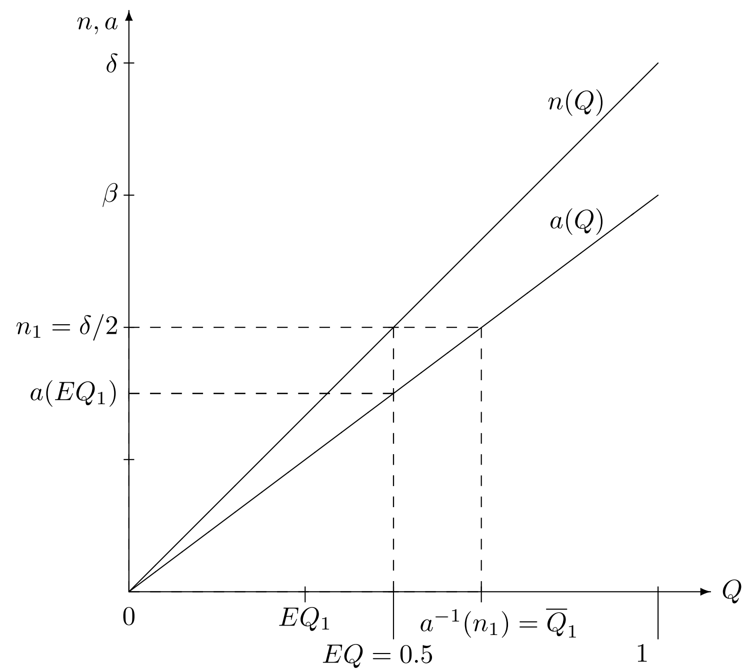
Let us examine the parameter constellation 1 (i.e., $\gamma = 0$ and $\delta > \beta$). In case of a buyer who performs only one step of iterative reasoning, the maximum willingness to pay is $n_1 = n(EQ_1) = \delta/2$. For a transaction to occur, a buyer should make an offer that exceeds the sellers' valuation of the expected quality. We denote the minimum offer of this buyer as a_1, with $a_1 = a(EQ_1) = \beta/2$. We limit our focus to cases where $n_1 < \beta$, which means $\delta < 2\beta$ in the present parameter setting. This assumption implies that sellers with positive probability exist who own a unit of high quality and can be expected to reject even the highest offer the buyer (after one step of reasoning) is willing to make. All sellers who offer quality greater than

$$\overline{Q}_1 = a^{-1}(n_1) = \frac{\delta}{2\beta}$$

will prefer to refuse the offer and leave the market. They keep their item for themselves. Index 1 indicates that this is the maximum quality attracted by the offer of the buyer who is in step 1 of the iterative process. Figure 1 visualizes EQ, $n(EQ)$, $\overline{Q}_1$, and EQ_1. The quality is shown on the horizontal axis, the valuations by sellers and buyers, respectively, are shown on the vertical axis. The upper diagonal curve represents the buyers' valuation, $n(Q)$, the lower one represents the sellers' valuation, $a(Q)$.

Note that $\overline{Q}_1$ is smaller than 1, which is due to the assumption $\delta < 2\beta$. This maximum quality is, simultaneously, the starting point for the second reasoning step of a buyer. In this second step of the iterative reasoning process, a buyer expects $\overline{Q}_1$ to be the highest quality that can actually be achieved in the market. Therefore, the expected quality contingent on the maximal offer during the first step of iterative reasoning is $0.5\overline{Q}_1$ (which is smaller than 0.5). Thus, the buyer has a maximum willingness to pay, contingent on his beliefs, that amounts to

Figure 1: Complete market collapse: first step of iterative reasoning



$$n_2 = \delta \overline{Q}_1 = \frac{\delta^2}{2\beta}$$

Due to the assumption $\delta < 2\beta$, this is smaller than n_1. Obviously, $\overline{Q}_k$ as well as n_k decrease with the number of iteration steps $k > 0, k \in \mathbb{N}$. Therefore, this iterative reasoning leads to lower price offers, the higher the number of reasoning steps. For an infinite number of steps, the buyer reaches the equilibrium solution: perfect rational buyers offer a zero price and no unit is traded. This is the outcome of maximum inefficiency as compared to a situation with complete information. In the asymmetric information equilibrium, the players realize zero cooperation rent.

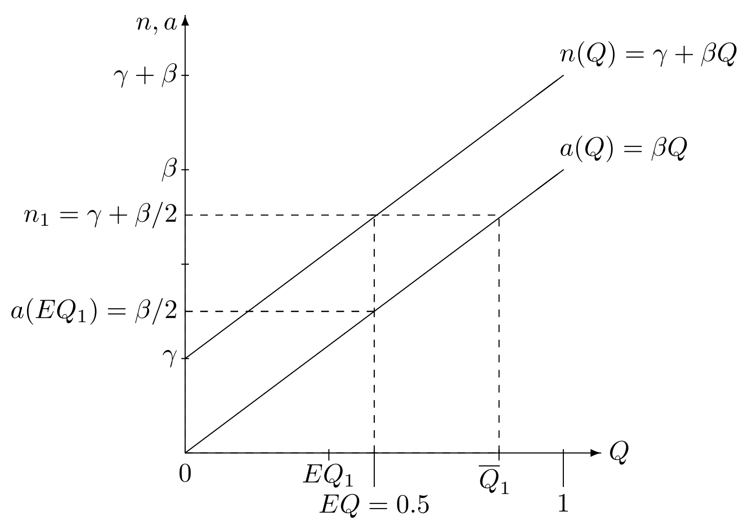
Bounded rational players, on the contrary, make only a limited number of steps. The observation of a positive price offer may reveal the respective seller's reasoning level. For any number of reasoning steps $k > 0$ a player performs, we can define an interval $[a(EQ_{k-1}), n_k]$ from which this player should choose his price offer. If he would offer a price greater than n_k, he would prefer its rejection; if he bids a price below the corresponding valuation of the seller $a^{-1}(EQ_k)$, the buyer cannot expect this offer to be accepted. Only an offer within this interval will - from the buyer's point of view - be accepted and simultaneously benefit him.

Thus, as long as the intervals for different levels of reasoning do not intersect, we can derive a buyer's level from his price offer. Note that the intervals tend to overlap for higher values of k. Thus, this idea serves well to identify the lower number of reasoning.

2.3.3 Partial market collapse

We now examine the second parameter constellation: $\gamma > 0$ and $\delta = \beta$. Figure 2 demonstrates the situation of a decision-maker who performs one step of iterative reasoning. Such a buyer assumes an expected quality $EQ = 1/2$. Thus, he should offer a price between $a(EQ)$ and $n(EQ) = n_1$.

Figure 2: Partial market collapse



In the second step, a buyer would realize that, even if he bids the highest possible price for this expected quality, namely $n(EQ_1)$, some sellers holding a unit of high quality would reject his offer. The highest possible quality during the first reasoning step which a buyer may actually achieve is $\overline{Q}_1 = a^{-1}(n_1) = (\gamma + \beta)/2\beta$. Thus, in the second reasoning step, the buyer expected a quality that equals $\overline{Q}_1/2 = (\gamma + \beta)/4\beta$.

As derived above, a perfectly rational and expected payoff-maximizing buyer would offer $p = \gamma$. In this case, only qualities below $1/3$ would be traded. Thus, the iterative process stops at a positive price offer even if the number of steps is infinite.

3 The experiment

3.1 Experimental Design

In the following, the parameter constellation with complete market collapse is labeled as (comp), and the one with partial collapse is named (part). In the (comp) market, we assigned $n(Q) = 4Q$ as the buyers' valuation, and in the (part) market the buyers valued quality with $n(Q) = 1 + 3Q$. The buyers' valuation was fixed as $a(Q) = 3Q$.

We chose four different treatments that were run in 2002 and 2003 at Karlsruhe University, Germany:

- treatment A: [part1, comp2],
- treatment B: [comp1, part2],
- treatment C: [20 times comp],
- treatment D: [20 times part].

In treatments A and B, subjects played each (part) and (comp) for one round, where the numbers 1 and 2 indicate the respective round each design was played. In treatments C and D, to avoid the possibility of mere first round effects, 20 rounds of (comp) and (part) were played.[10]

248 students of Karlsruhe University participated in 18 experimental sessions (five sessions for treatments A and B each, and four sessions for C and D each). 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.

Treatments A and B were conducted in a **non-computerized** way, i.e. we used paper and pencil. Each experiment group was split in halves and randomly assigned to two different rooms. The participants in each of the rooms first acted as buyers (submitted price offers to the other room), and then acted as sellers (received price offers from the other room). Subjects took over both roles because sellers only had to make the simple decision whether or not a certain price offer exceeded the valuation of their unit of the good.[11]

In principle, we even could have let computers decide, but we wanted our subjects to interact with real people.

The subjects were seated in separate sections of the rooms, facing the wall, which made it impossible to gather information from their peers. The participants were not permitted to communicate with each other. The written instruc-

[10] The instructions for treatments A and B are included in Appendix B. The highly similar instructions for the last two treatments are available on request.

[11] Note, that in the first session of treatments A and B, subjects were assigned the role of either buyer or seller. For the sake of a larger database, we then changed to the above mentioned procedure.

tions were distributed and read aloud. Questions were asked and answered only in private.

Each buyer received an initial endowment of 4 Euros per round, which made sure that their willingness to pay did not exceed the ability to pay. Each seller in both rounds was endowed with one unit of the good, and additionally received a show-up fee of 3 Euros at the end of the experiment to compensate for the possibility of bad luck concerning the qualities of the good.

The experiment started with the first market design of the respective treatment. Each buyer made a decision for a price offer and wrote it down on a prepared form. In each of the two rooms, a separate administrator collected all the price offers. After this, the administrator endowed the players in his room with one unit of the good.[12] Finally, the price offers were randomly allocated to the participants in the respective other room. The subjects then acted as sellers and decided whether to accept or to reject the offer received. Every subject learned his outcome of the first round in private.

Before the second round started, the buyers were asked to write down in their own words their line of reasoning that lead to their respective price offer. Then, the second design was carried out the same way as the first, and again subjects verbally described their line of reasoning with respect to the second-round price offer.[13] After the two rounds, the subjects were paid their earnings in cash. The chosen parameters realized an average payment of about 8 Euros; the experiment lasted approximately 50 minutes.

Treatments C and D were conducted in a **computerized** way. Each subject played 20 repetitions of only one market design, i.e. (comp) or (part). The subjects were seated and instructed the same way as under treatments A and B. Each participant typed his decisions into his computer terminal. The designs (comp) and (part) were exactly the same as under treatments A and B. The procedures differed only slightly since the subjects stayed in the randomly assigned role of either buyer or seller during all 20 rounds.[14] The buyers were endowed with 4 ECU (experimental currency unit) per round, the sellers received one unit of the good (new quality in each round), and 2 ECU per round to compensate for possibly low qualities of the good. In every round, each buyer was randomly and anonymously matched with one of the sellers. After each round,

[12] This guaranteed that the quality of the own unit in the role of a seller did not influence the own price offer in the role of a buyer.

[13] To make things easier, the second-round good given to the sellers was of the same quality as in round one. This was not known to the buyers in the other room. Nevertheless, it is possible that subjects concluded that the other room faced the same procedure. Therefore, there is a slight chance that those subjects who traded in round one realized that they already knew one of the 8 to 10 (depending on session size) possible qualities, i.e. the one they bought in round one. These subjects then could have updated the expected quality they were facing in round two. We consider this rather unlikely, or at least negligible, and therefore disregard this fact in the following.

[14] Even though the sellers' situation was of the same simplicity as under treatments A and B, this appeared reasonable since this experiment was conducted in a computerized way, and we were afraid of subjects mixing up the two roles if confronted with different computer screens in fast sequence.

subjects were informed about their own outcome of the precedent round, and the buyers were asked to write down their reasoning as to prices offered in a questionnaire.[15] After 20 rounds, subjects were paid their earnings in cash. Thereby, 10 ECU amounted to 1.25 Euros. The sessions lasted approximately one hour and paid about 10 Euros.

3.2 Predictions for Treatments A and B

3.2.1 Rational Choice Approach

This section summarizes the hypotheses drawn from rational choice theory. The basic theory of Akerlof, as applied to our experimental setting, allows to derive the following two null hypotheses:

H1: In the $n = 4Q$ market, only $p = 0$ is offered (and no trade occurs).

H2: In the $n = 1 + 3Q$ market, only $p = 1$ is offered (and units with $Q < 1/3$ are traded, thus $E(Q) = 0.17$).[16]

In a rather explorative way, we investigate whether the respective ordering of (comp) and (part) significantly influences the subjects' behavior:

H3: Prices on markets of the same type, i.e. prices on (comp) or on (part), do not differ when offered in the first round compared to the second round.

3.2.2 Iterative Reasoning

The above null hypotheses are based on the idea that people perform an infinite number of iteration steps. Our theory of bounded rationality starts with the assumption that people tend to make only an infinite number of iteration steps when choosing their behavior. When deriving the hypotheses for iterative reasoning behavior, we refer to the alternative hypotheses of H1 and H2 that state our conjectures about prices larger than 0, and larger than 1, as well as about the respective qualities. Additionally, we expect the (part) and (comp) designs to differ significantly in prices and traded qualities, and we therefore derive the following null hypothesis:

H4.1: Offered prices do not differ in the (comp) design compared to the (part) design.

H4.2: Traded qualities do not differ in the (comp) design compared to the (part) design.

[15] In these treatments, we also let the sellers fill in a similar questionnaire to keep them busy during the time it took the buyers to fill in their forms.

[16] Note that, if qualities between 0 an 1/3 are expected to be traded following the prediction according to the rationality approach, then the mean observed traded quality should be 0.17 since qualities are uniformly distributed.

Concerning the process of iterative reasoning which we asked our participants to describe in a written statement after each round, we formulate the next null hypothesis.

H5: The price offers are not correlated with the iteration type (according to the verbal statements).

3.3 Results for Treatments A and B

3.3.1 Rational Choice Approach

We first describe the data[17], and then present the statistical results[18] of treatments A, i.e. [part1, comp2], and of treatment B, i.e. [comp1, part2].

First of all, in figures 3 and 4 appear all price offers in both rounds of treatment A, and figures 5 and 6 show the prices offered under treatment B.

The bold symbols represent offers rejected by the respective seller (no trade), the hollow ones symbolize accepted prices (trade). The line represents the sellers' valuation of their respective quality. For all decisions to be rational, there should be no bold symbol above the line (this subject did not trade although the offered price exceeded the value of the own good), and no hollow one beneath the line (sales price smaller than valuation). As can be seen in figures 3 to 6 only negligibly few decisions are irrational ones.

Tables 1 and 2 present an overview of the main results of the two treatments.[19] We see minimum, maximum, and mean qualities, and price offers, as well as buyer payoffs, and seller payoffs under each treatment.

Table 1: Overview of Main Results of Treatment A

		Q	traded Q	p	Π_b	Π_s
(part1)	min	.01	.01	.50	2.96	1.00
	mean	.51	.34	1.78	4.12	2.05
	max	1.00	.92	2.50	6.16	3.00
(comp2)	min	.01	.01	.00	2.29	.51
	mean	.51	.30	1.30	3.86	1.28
	max	1.00	.92	2.20	6.18	3.00

Let us first have a look at the (comp) design. In (comp1) under treatment B, and in (comp2) under treatment A mean prices amount to 1.32 Euros, and

[17]The sellers' payoffs Π_s do not include the 3 Euros show-up fee. Prices are shown in Euros.

[18]We have used SigmaStat version 2.0, a statistical software package from SPSS Inc., to evaluate the data. All statistical tests were conducted to a 5 percent significance level. We use means to describe the data, but refer to medians to test differences in central tendency. We thereby use a non-parametric Rank Sum Test, the Mann-Whitney U-Test.

[19]Note that the number of price-offers is not exactly half of the number of participants in the respective treatment since, as mentioned above, in the very first groups the subjects acted either as buyers or sellers instead of taking over both of these roles as was the case later on.

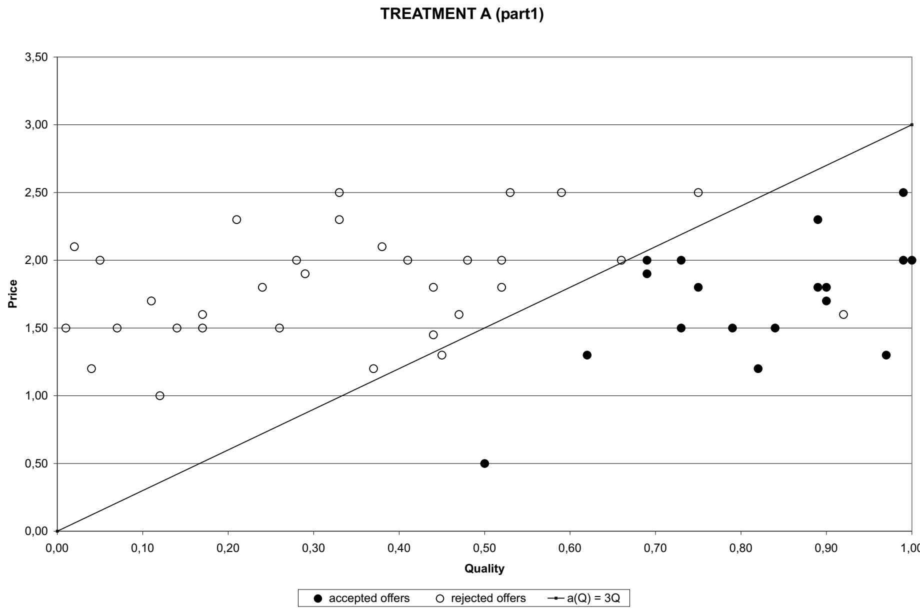


Figure 3: Price Offers in (part1)

1.30 Euros respectively. In (comp1), 41% of all prices offered are accepted, an the mean traded quality is .27. Under (comp2), the acceptance rate is 50% and a mean quality of .30 is traded. Thus, traded qualities and offered prices are by far greater than the predicted zero[20], and, obviously, the market does not collapse completely under the (comp) design.

Under (part1), 64% of the price offers are accepted, and the mean price of 1.78 is significantly greater than the predicted $p = 1$.[21] The mean traded quality

[20] A significance test is not necessary here, since the deviations from the predicted outcome are obvious.

[21] The observed median in (part1) equals 1.8, the theoretically predicted median (theo) is $p = 1$, T = 1350 with $N(part1) = N(theo) = 50$.

Table 2: Overview of Main Results of Treatment B

		Q	traded Q	p	Π_b	Π_s
(comp1)	min	.00	.00	.00	2.36	.30
	mean	.51	.27	1.32	3.72	1.94
	max	.98	.54	3.40	4.29	3.40
(part2)	min	.00	.00	.00	2.80	1.00
	mean	.51	.35	1.55	4.12	1.97
	max	.98	.94	3.00	5.62	3.00

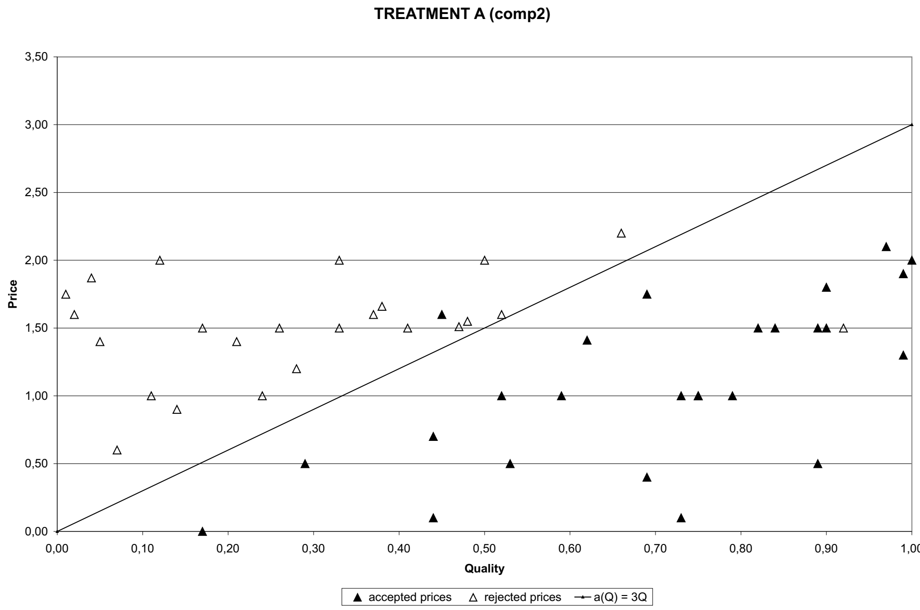


Figure 4: Price Offers in (comp2)

of 0.34 is nearly twice as high as the theoretical prediction of 0.17. In (part2), the observed results are very similar. The acceptance rate is 55%, the mean price-offer accrues to 1.55 and differs significantly[22] from the predicted value. Mean traded quality amounts to 0.35.

Based on this, we have derived our first empirical result that prices, and traded qualities are higher than predicted by rational choice theory:

Result 1: The hypotheses H1 and H2 can be rejected.

Moreover, we see that in both (part) designs the buyers earn an average payoff of 4.12 Euros. Buyers in (comp)-markets, however, make average losses from trading which amount to 0.28 and 0.14 Euros, respectively, in comparison to the 4 Euros endowment.

As to hypothesis H3, we now compare the two treatments and both market designs with respect to differences induced by the ordering of market designs. In treatment A, i.e. [part1, comp2], the average price drops from 1.78 in the first to 1.30 in the second-round play. The ordering [comp1, part2] under treatment B exhibits an increase in the average price from 1.32 to 1.55. These observations are qualitatively in line with the theoretical prediction, according to which the prices are higher under (part) than under (comp). Moreover, mean prices under design (part) (1.78 in treatment A, and 1.55 in treatment B), as well as prices

[22] T = 3544.5 with N(part2) = N(theo) = 51.

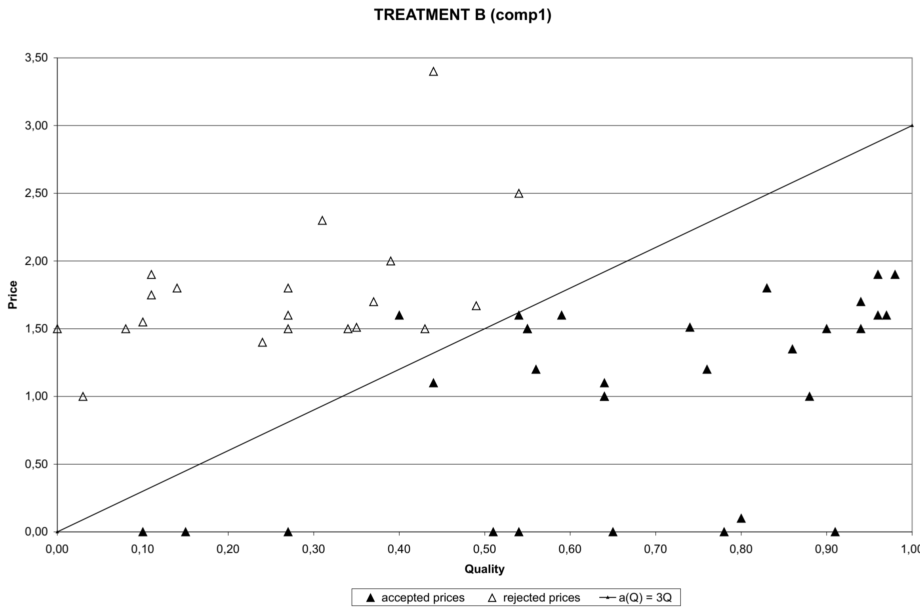


Figure 5: Price Offers in (comp1)

under design (comp) (1.30 and 1.32) do not differ significantly.[23]

However, note that the difference in prices between (part1) and (part2) is weakly significant at a 10%-level. This indicates that the experience of the (comp) design in period 1 induces the participants to act more cautiously thereafter. A closer look at the 20 repetitions of (comp) and (part) in section 3.4 will allow for deeper insight.

Overall, we state that the respective ordering of the market designs does not inhibit significant differences with respect to price offer behavior.

Result 2: The hypothesis H3 cannot be rejected.

3.3.2 Iterative Reasoning

As was presented above, observed prices and traded qualities in both market designs are significantly higher than theoretically predicted (see Result 1 and the data in section 3.3.1).

Moreover, design (part) reveals significantly higher prices than (comp) in both periods. Comparing the two first-round designs, that is (part1) to (comp1), as well as both of the second-round designs, we observe a significant difference

[23]Median(part1) = 1.8, median(part2) = 1.55; T = 2805 with N(part1) = 50, N(part2) = 51, P = 0,084; median (comp1) = median(comp2) = 1.5; T = 2479 with N(comp1) = 51, N(comp2) = 50, and P = 0,632.

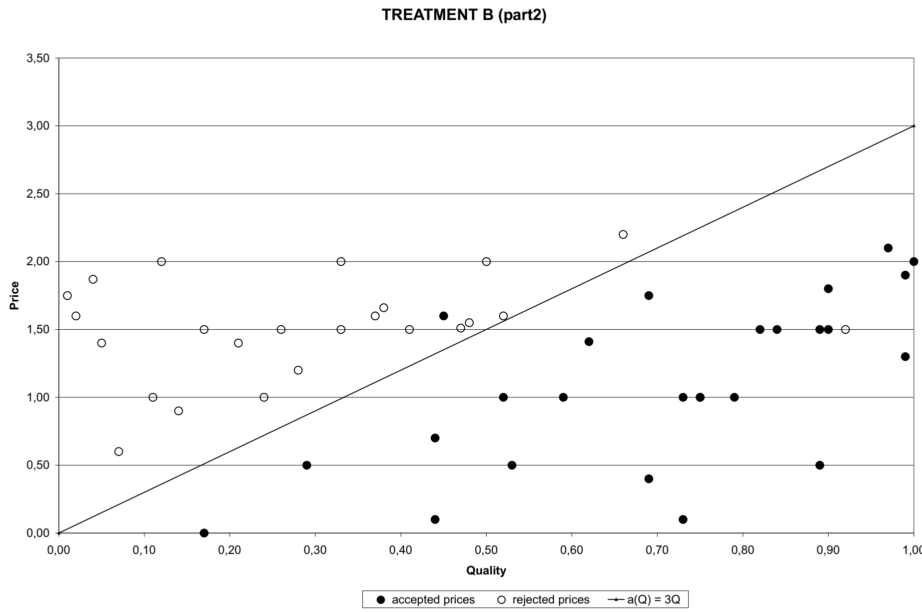


Figure 6: Price Offers in (part2)

in prices in both cases.[24] Tables 1 and 2 show the qualities traded in (comp2) and (part2) which are 0.30 and 0.35. These values are not significantly different from each other. The same holds true for the mean quality of 0.34 in (part1), and 0.27 in (comp1).[25] Thus, traded qualities in comp and part do not differ, and:

Result 3: H4.1 is rejected, but H4.2 cannot be rejected.

Let us now further examine the iterative reasoning process. By drawing on the subjects' own description of their way of reasoning, we have derived each subject's type k, where k indicates the amount of performed steps of iterative reasoning.

We sorted the self-descriptions into three categories of types (see Appendix C for some typical verbal statements of the respective types)[26]:

- Type 0 describes that he expects a quality out of the interval [0, 1] without further evaluation of the market situation.

[24] The median price (part1) is 1.8, median price (comp1) is 1.5, T = 3091, N(part1) = 50, N(comp1) = 51, P = 0,001. Median price (part2) is 1.55, median price (comp2) is 1.5, T = 2226, N(part2) = 51, N(comp2) = 50, P = 0,028.

[25] The median quality (part1) is 0.33, median quality (comp1) is 0.27, T = 510.5, N(part1) = 32, N(comp1) = 21, P = 0,309. Median quality (part2) is 0.29, median quality (comp2) is 0.28, T = 639.5, N(part2) = 28, N(comp2) = 25, P = 0,533.

[26] Note that subjects can not only develop from type k to type k+1, but also backward, from e.g. type 2+ to type 0, if so described by themselves. Moreover, we coded the verbal statements without looking at, i.e. **independent** of, the offered prices

- Type 1 expressly mentions to have calculated with an expected quality equal to 0.5.
- Type 2+ expresses a deeper analysis of the strategic situation on the market. The pure Type 2 is aware of the fact that, when assuming $E(Q) = 0.5$, no quality higher than $a^{-1}(n(0.5))$ will be offered on the market. Thus, the "updated" expected quality is $0.5(a^{-1}(n(0.5))$. This type consequently offers a lower price. Type 3 even performs one more of these iteration steps, and so forth. Since most of the subjects' self-descriptions were not elaborate enough to clearly distinguish, e.g., Type 5 from Type 6, we summarize all these types into one category called Type 2+.

The following table 3 shows the relation between type and the respective price interval a specific type is expected to choose his offer from. This table only refers to the (comp) market design, that is to $n(Q) = 4Q$. Note that the (part) market design (i.e., the one with $n(Q) = 1 + 3Q$) is less useful for identifying types, since price intervals start overlapping right from type 1 on. For that reason, we analyze the types only with respect to the (comp) design. As was analyzed in more detail in section 2.3, type k expects the quality EQ_k on the market. He, therefore, offers at minimum the sellers' valuation of EQ_k, that is $a^{-1}(EQ_k)$, and at maximum his own valuation $n(EQ_k)$.

Table 3: Types and Type-consistent Price Offer Intervals

seller's type k	min offer $a^{-1}(EQ_k)$	max offer $n(EQ_k)$
1	1.50	2.00
2	1,00	1,33
3	0.66	0.88
4	0.14	0.29
5	0.09	0.19
6	0.06	0.13
∞	0	0

From type 4 on, the intervals start to overlap. Thus, a clear assignment of type is only possible for $k < 3$, or for price offers greater than 0.66. Since many experimental observations indicate that players either perform 1, 2, 3 or an infinite number of iteration steps, the setting is sufficient to identify the relevant types.

To sum up, if price offers are chosen consistently with the own verbal description of the reasoning process types in the (comp) design would offer as follows:

- Type 0 is expected to offer prices from 0 to 4, since any of these price offers is consistent with a self-description pointing to this type.

- Type 1 should choose prices between $a(0.5) = 1.5$ and $n(0.5) = 2$, since he calculates with an expected quality equal to 0.5.
- Type 2+ performs at least 2 steps of iterative reasoning and, therefore, we expect the offered prices to range from 0 to 1.

Tables 4 and 5 show the prices chosen by types 0 to 2+, where the indicated price offer intervals correspond to the intervals derived in table 3. Thus, a price $p > 2$ - if chosen consistent to the own verbal statement - can only be chosen by a type 0, and never by subjects who describe themselves as types 1 or 2+. Note that, on the other hand, type 0 to be consistent with his written descriptions can choose any price between 0 and 4. Type-consistent prices between 1.5 and 2 indicate a type 1, and prices smaller than 1.5 reveal type 2+ if prices were chosen consistently.

Table 4: (comp1) by type: 51 observations, 4 descriptions missing

	type			
price offer interval	0	1	2+	Sum
$p > 2$	3	0	0	3
$1.5 \leq p \leq 2$	17	**10**	**1**	28
$p < 1.5$	7	**2**	**7**	16
Sum	27	12	8	47

Table 5: (comp2) by type: 50 observations, 0 descriptions missing

	type			
price offer interval	0	1	2+	Sum
$p > 2$	2	0	0	2
$1.5 \leq p \leq 2$	13	**12**	**0**	25
$p < 1.5$	15	**5**	**3**	23
Sum	30	17	3	50

We can see that the likelihood of a low-price offer increases with the type revealed by the written statements. As to statistical testing, since type 0 is consistent with any price between 0 and 4, and types 1 and 2+ in our experiment never chose to offer a price that exceeded 2 Euros we reduced the statistical test to types 1 and 2+, and prices smaller than 2, i.e. to the bold numbers in tables 4 and 5. It turns out that in (comp1), types 2+ chose significantly lower prices than types 1; under (comp2) the data point to the same direction and the difference is significant, too.[27] Thus, the data allow to draw the conclusion:

[27] Under (comp1), the Chi-square value is 9.731, and p = 0,002; under (comp2), the Chi-square value amounts to 6.107, and p = 0,013.

Result 4: H5 can be rejected.

3.3.3 Efficiency Considerations

In section 3.3.2, we presented the conclusion that bounded rational behavior on the two different lemon markets prevented their complete or partial collapse. In the following, table 6 summarizes who profited or lost from trade.

Table 6: Efficiency, or Gains from Trade in Euros

design	max	**b**uyers	**s**ellers	**b + s**	theory
(part1)	50.0	6.1	25.9	32.0	16.7
(comp2)	25.5	-6.9	14.5	7.6	0.0
(comp1)	26.3	-14.3	20.0	5.7	0.0
(part2)	51.0	6.4	22.6	28.0	17.0

The first column "max" in table 6 shows maximum possible efficiency if every unit of the good had been sold. Columns "buyers" and "sellers" describe the totalled gains from trade in Euros of buyers and sellers under each design. The buyers' gains under each design amount to $\Sigma(n(Q)-p)$, i.e. to their totalled single valuations of the bought quality minus the prices they paid. The respective sellers in total gained $\Sigma(p-a(Q))$ from the sold units. Column "b + s" gives the sum of net realized gains from trade under each design, i.e. the sum of "buyers" + "sellers". Finally, the last column indicates the efficiency that should have been realized according to the predictions from rational choice theory. Since under (comp) no trade is predicted, the gains from trade theoretically expected equal zero. In (part) markets, the efficiency gain per transaction is 1 Euro, i.e. buyer's minus seller's valuation. In theory, under uniform distribution of quality, the players achieve this gain with probability 1/3. Therefore, expected gains should amount to 33% of maximum possible efficiency.

Table 6 shows that the realized efficiency, i.e. the sum of net realized gains from trade, amounts to 64% of the maximum possible under (part1), and to 55% in (part2). And, as can be seen, both sellers and buyers overall profited from trade under (part). As to the (comp) market, the data also reveal that sellers and buyers profited in an overall perspective. But, in contrast to the moderate (part) design, net profits arise at the buyers' expenses who, as a whole, lose an amount of 6.9 Euros under (comp2), and of 14.3 Euros under (comp1). The realized percentage of efficiency ranges low from 30% to 22%. We, therefore, can conclude that the (comp) design might justify regulation and consumers' protection (i.e. buyers' protection) in real world markets.

3.4 Repeated Play in Treatments C and D

In the experiment described in section 3.3, the lemon markets did not collapse as predicted. In the (comp) design, a positive number of transactions was observed, and in the (part) design, more transactions than predicted took place, too. We have explained this deviation from the perfect rationality predictions by a theory of bounded rationality that is based on iterative thinking.

To a great extent, the subjects seem to have performed only a limited number of iterative steps and, therefore, they offered prices that were significantly larger than predicted by rational choice theory. This leaves the question unanswered whether our results in section 3.3 are caused by the limitation to only one round per market design, and whether subjects learn to perform more than one iterative step when playing several repetitions. After all, it is widely known in Experimental Economics that repeated play usually shows a tendency toward the theoretical equilibrium behavior.

Hence, we conducted two more treatments in which we let subjects play 20 rounds of either the (comp) design - called treatment C - or the (part) design - subsequently denoted as treatment D. Since treatments C and D only serve the purpose of correctly interpreting the 2-round data of treatments A and B, we restrict the analysis in this section to the interpretation of the descriptive data.

Table 7 presents some basic data of treatments C and D with respect to qualities and prices, as well as to the payoffs of buyers Π_b and of sellers Π_s. The data is highly aggregate that is, table 7 shows 31 observations under treatment C and 30 observations under treatment D. One observation accounts for one seller offering prices in 20 rounds (and being 20 times randomly and anonymously matched with a seller). Under treatment C, 31% of price offers during all 20 rounds were accepted. Treatment D shows an acceptance rate of 53% of all prices offered. This observation clearly is in line with the data under treatments A and B presented above.

Table 7: Basic Data from 20 Rounds in Treatments C and D

		Q	p	Π_b	Π_s
	min	.00	.00	1.00	2.00
C	mean	.49	.93	3.81	3.75
	max	1.00	3.30	5.33	5.30
	min	.00	.00	2.32	2.21
D	mean	.50	1.58	4.09	3.93
	max	1.00	3.00	6.94	5.99

Figure 7 pictures the development of mean prices over 20 rounds. Even after 20 repetitions of the (comp), as well as of the (part) lemon market design, markets still do not collapse to the extent predicted by rational choice theory. On the (comp) market, the mean price finally oscillates around .60 during the last seven rounds which is by far more than the theoretically predicted zero price. Under the (part) design, the mean price seems quite stable at about 1.5 for the second half of the experiment. Again, this exceeds the predicted $p = 1$ even after many repetitions. Moreover, as was already visible under treatment B when testing hypothesis H3 in section 3.3.1, prices decline both more rapidly and to a larger extent under the (comp) than under the (part) design. Obviously, buyers act more reserved when facing the less favorable (comp) market.

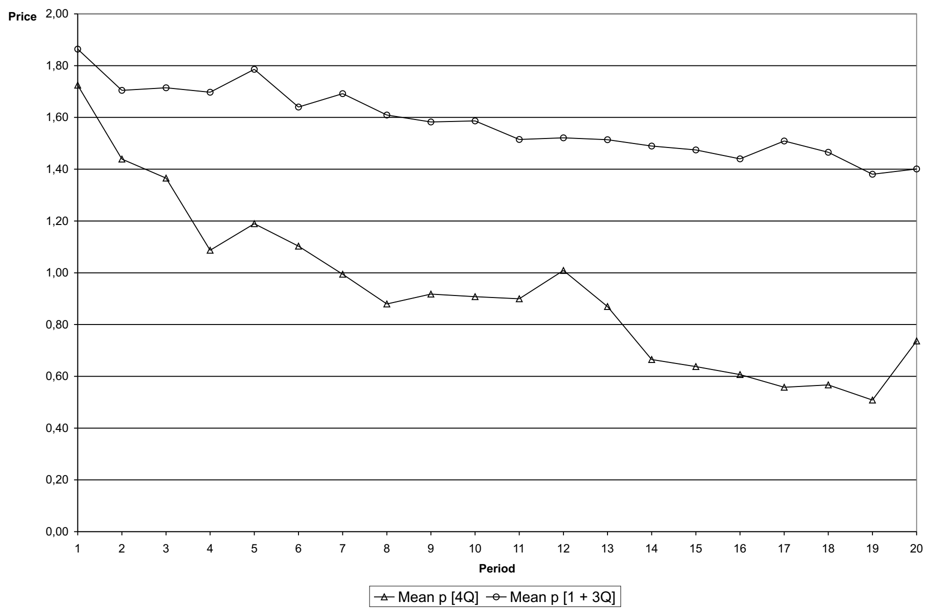


Figure 7: Price Offers in Treatments C and D

Overall, mean prices tend to decrease over time under both treatments, so the data suggest that the participants experience a learning effect. In the light of our theory of bounded rationality, this indicates an increase in the level of reasoning with the number of rounds played. We learn from figures 8 and 9 the percentage of types 0 to 2+ on the two markets.[28]

Indeed, type 2+ becomes more frequent from round to round in both markets. The percentage goes up to about 30% of types 2+ in the last third of the two treatments, which is in line with the quite stable mean prices from period 14 on in figure 7. Thus, a "learning effect" as to development in direction of type 2+ is clearly visible which most probably accounts for the decreasing prices.

Moreover, under treatment C, during the whole 20 rounds there is a stable percentage of about 60% to 70% of subjects of type 0. Types 1 very quickly almost vanish from the market and constitute only a small share of 5% from

[28]Please remember, that subjects can not only develop from type k to type k+1 over time, but also backward, from e.g. type 2+ to type 0, if so described by themselves. Of course, we coded the verbal statements without knowing, i.e. **independent** of, the offered prices.

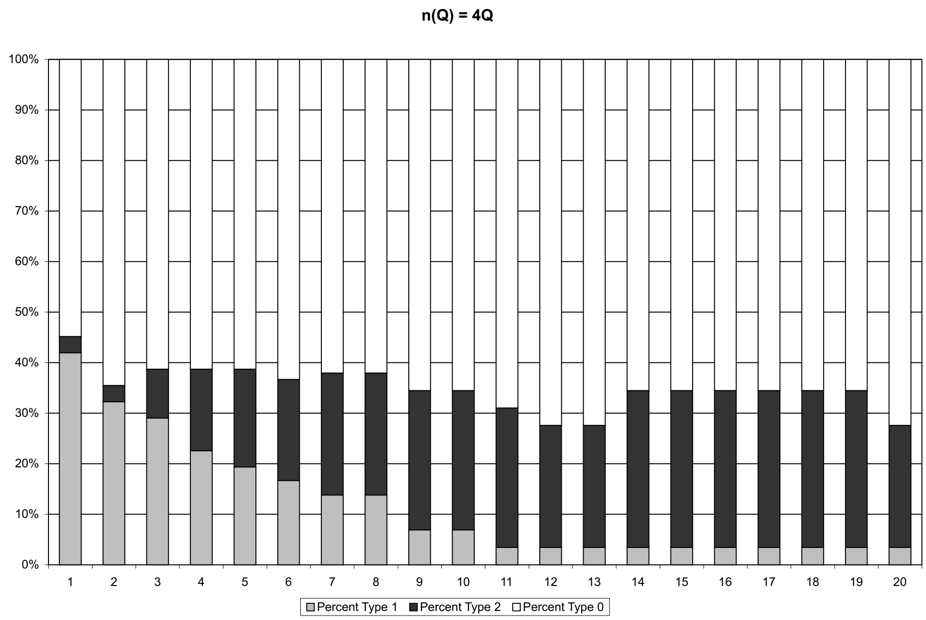


Figure 8: Percentage of Types on (comp) Market in 20 Rounds

round 11 on. Figure 9 of treatment D, finally, reveals that one half of the subjects on that market made up of type 0. The share of types 2+ is almost of the same size as in the (comp) market, but the percentage of types 1 at about 25% from round 5 on is astonishingly high, compared to (comp). This might be due to the fact that the buyers' losses are much more painful under (comp) than under the relatively moderate (part) design, where 1 ECU surplus per transaction is guaranteed even if the purchase is of zero quality. The results point to the fact that the higher pressure in (comp) markets forces the subjects to deeper thoughts. This results in types 1 changing to either type 2+ when the thinking process was successful, or - more often - in changing to type 0 and facing the gamble. Under (part), on the contrary, staying type 1 is not that painful with respect to losses from trade, and careful thinking is not as much enforced by bad experience as in the (comp) market.

4 Conclusion

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 of 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, effort into building of reputation...) based on

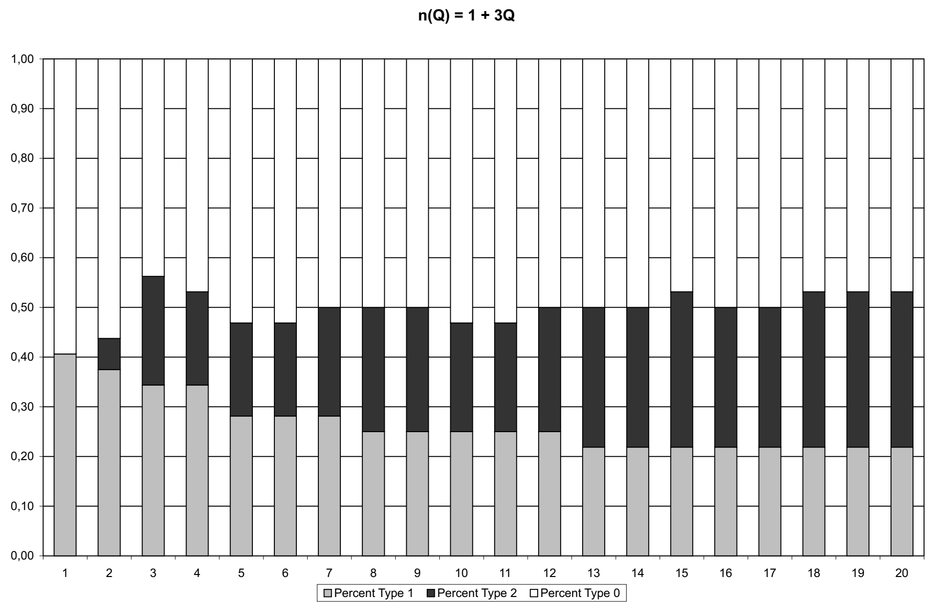


Figure 9: Percentage of Types on (part) Market in 20 Rounds

theory might go too far or be too costly, and may perhaps do even more harm than good.

This friendly policy implication of our results suffers, however, from a serious drawback: successfully completed transactions may inflict losses upon the respective buyers. After the completion of a transaction, the actual quality of the respective item is revealed. Some buyers may then realize that their valuation of the purchased item is lower than the price they had offered. 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 buyers, they would let the market collapse, avoiding such losses. Therefore, potential buyers who are boundedly rational might be interested in a regulation that protects them from completing harmful transactions in lemon markets.

Comparing the two market settings, we can - cautiously - interpret the (comp) design as a lemon market without warranty, while the (part) design is one with partial coverage. 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 partial warranty may lead to higher prices and a higher number of transactions as a means against asymmetric information. Note that this impact of insurance is not driven by a signaling effect, nor does it depend on risk-aversion on the side of the buyers.

According to our design, the potential buyers were able to make a take-it or leave-it offer to the respective seller. 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 asymmetric information.[29] Even worse, under bounded rationality, the buyers even made expected losses that were captured by the sellers. Thus, the second movers turned out to have an extremely strong position in our experiment. The chance to make a take-it or leave-it offer that is usually clouded only by fear of rejection, can even turn into a disadvantage if the first-mover is the uninformed party.

Iterative thinking, the mixed implications of bounded rationality for economic policy, the effect of partial warranty on the willingness to conclude transactions, and finally the game-theoretic implications of asymmetric information for first-movers in ultimatum games deserve further exploration.

[29]Note that in our ultimatum game the first-mover did not demand a share of a given "cake". He rather demanded a slice of a given size 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.

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

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

The first derivative with respect to p is

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

and the second derivative is

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

The first derivative is positive if $\delta > 2\beta$. In such a parameter constellation, 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 may exist, as the second-order condition demonstrates. The first derivative equals zero if

1. $\gamma = 0$ and $p = 0$, or
2. $\gamma = 0$ and $\delta = 2\beta$, or
3. if $p = \dfrac{\beta\gamma}{2\beta - \delta}$.

The first case covers our parameter constellation 1: with $\gamma = 0$ 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 constellation.
The second case violates the second-order-condition for a maximum, $\delta < 2\beta$.

The third case relates to our second parameter constellation: $\gamma > 0$ and $\beta = \delta$. Here, the second-oder condition for a maximum is fulfilled, and the first-oder 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 for Buyers[30]

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

In the experiment, there are two types of players, "buyers" and "sellers". These roles are randomly assigned to the participants. You are a "**buyer**" and you will stay in this role during the whole experiment. In your room, there are only "buyers", in the other room there are only "sellers".[31] The experiment consists of 2 rounds. In each of the two rounds, one seller interacts with one buyer. In both rounds anew, buyers and sellers will be matched randomly. 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 equiprobable. 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 labelled Q.

Each **buyer** in each round starts with an amount of money of 4 Euros. The buyers value good quality higher 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**.[32] 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, each buyer learns about the real Q of his unit of X.

After each round, the buyers are credited a payoff following this rule:[33]

[30] When the sellers' instruction differs from the buyers' we use a footnote to show what was told to the sellers instead.

[31] Exchange "sellers" and "buyers".

[32] This function $n(Q)$ **is only known to the buyers** - you as a seller do not know $n(Q)$.

[33] If trade has taken place at price p the seller gets p Euros. If no trade has taken place

- 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 to the sellers, the function $a(Q) = 3Q$ denotes their value of good X in Euros: If X is not sold, the seller receives an amount of $a(Q)$ Euros. If, in contrast, a seller sells his X, he obtains the respective sales price.[34] 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 in his form (there are separate forms for each of the two rounds). All forms will then be collected by the experiment supervisor and will randomly be distributed to the sellers in the other room. Each seller gets exactly one form.
2. Each seller has been assigned a certain quality. Now, 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. In case of sale, 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 buyer. If a purchase has taken place, the buyer is informed about the real quality of the good X he bought.
4. By doing so, a round is finished.
5. After the two rounds, each player gets paid the totalled payoffs in cash.

Instructions Buyers, 1. round[35]

Your subject number is:
During this round, the situation on the X-market is as follows:

- Each buyer owns exactly 4 Euros, each seller owns exactly one unit 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.

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the seller gets $a(Q)$ Euros. Furthermore, each seller gets a show-up fee of **3 Euros for participating** in this experiment.

[34] The sellers' valuation of a certain quality in Euros is described by the function $a(Q) = 3Q$. If X is not sold the seller receives an amount of $a(Q)$ Euros at the end of that round. On the contrary, if he sells X he obtains the respective sales price.

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

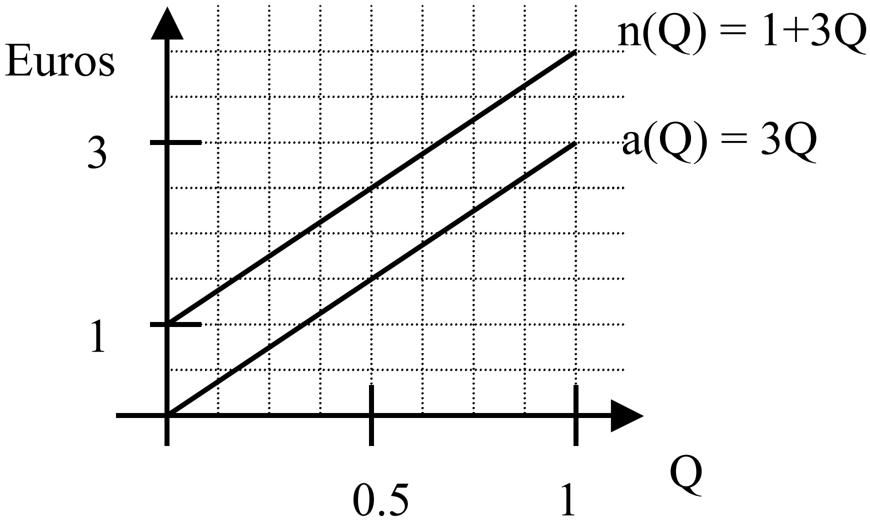

Figure 10:

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.

Instructions Sellers, both rounds

Your subject number is:
At the beginning of both rounds you own a unit of good X.
The quality of this good is: Q =
Your receive a price offer in each of the two rounds. Decide then, whether to decline (in this case you receive your valuation $a(Q) = 3Q$) or to accept the price.
Enter your decision in the offer form. In case of a sale, please enter your quality Q truthfully in the form (then you receive the sales price)
Example:
If a seller owns an X of quality $Q = 0.7$, and he does not sell it he gets 2.1 Euros.
If he sells his X at price $p = 3$ Euros he receives an amount of 3 Euros after that round.
If, in contrast, he sold X for 1.5 Euros he only gets 1.5 Euros.

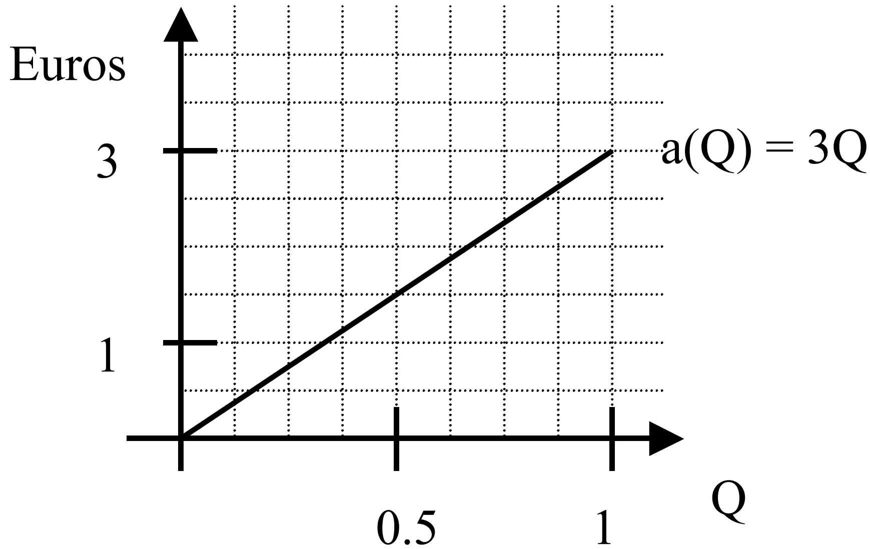

Figure 11:

Offer Form (Round 1)

The decision of a buyer
Your subject number is:
My price offer:
I want to buy one unit 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 X has the quality Q = .

The Questionnaire

Description of sellers' reasoning: Your subject number is:

Please, briefly describe the reasoning that led to your particular proposal of the sales price 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 with an expected quality of 1/2. 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 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 calculate explicitly with an expected quality of 1/2. Some examples are:

- "$E(Q) = 1/2$ and $a(Q) = 1.5$; thus, my offer is 1.51",
- "Since Q is uniformly distributed, I calculated with $Q < 1/2$ (risk-averse). Because $a(Q) = 3Q$, I chose $p = 1.5$",
- "With $E(Q) = .5$ a price $p = 1.5$ is accepted with probability 1/2",
- "I calculated with $E(Q) = .5$ 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 win 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 $p = 1.6$ seller sells $Q < 0.5$: with $Q = .5$ profits of 40 cents, with $Q = .4$ zero profits, with $Q = .3$ loss of 40 cents, and so on; thus, there is a negative expected profit",

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