SONDERFORSCHUNGSBEREICH 504

Rationalitätskonzepte,
Entscheidungsverhalten und
ökonomische Modellierung

No. 07-03

Satisficing in sales competition: experimental evidence

Siegfried K. Berninghaus*
and Werner Gueth**
and M. Vittoria Levati***
and Jianying Qiu****

May 2007

Financial support from the Deutsche Forschungsgemeinschaft, SFB 504, at the University of Mannheim, is gratefully acknowledged.

*Universität Karlsruhe , email: sbe@vwl3.wiwi.uni-karlsruhe.de

**Max Planck Institute for Research into Economic Systems, Strategic Interaction Group, email: gueth@mpiew-jena.mpg.de

***Max Planck Institute of Economics, Strategic Interaction Group, email: levati@econ.mpg.de

****Max Planck Institute of Economics, Strategic Interaction Group, email:

Universität Mannheim
L 13,15
68131 Mannheim

Satisficing in sales competition: experimental evidence

Siegfried Berninghaus[a], Werner Güth[b],

M. Vittoria Levati[b]*, Jianying Qiu[b]

[a] *Institute for Economics and Operations Research, University of Karlsruhe, D-76128 Karlsruhe, Germany*

[b] *Max Planck Institute of Economics, D-07745 Jena, Germany*

Abstract

In a duopoly market, aspirations express how much sellers want to earn given their expectations about the other's behavior. We define individually and mutually satisficing sales behavior for given individual beliefs and aspirations. In a first experimental phase, whenever satisficing is not possible, beliefs, aspirations, or sales have to be adapted. In a second phase, testing the absorption of satisficing, participants are free to select non-satisficing sales profiles. The results reveal that most people are satisficers who, either mandatorily or deliberately, tend to adjust aspiration levels if they cannot be satisfied.

JEL classification: C92; C72; D43

Keywords: Satisficing behavior; Bounded rationality; Duopoly; Theory absorption

* *Corresponding author.* Max Planck Institute of Economics, Strategic Interaction Group, Kahlaische Str. 10, D-07745 Jena, Germany. Tel.: +49-(0)3641-686629; fax: +49-(0)3641-686667. E-mail address: levati@econ.mpg.de (M. V. Levati).

1. Introduction

Fifty years ago, Herbert A. Simon [18] published a paper that became a basis for the theory of choice. Due to the informational and computational limits of human rationality, Simon suggested a theory of bounded rationality based on "satisficing". More generally, the process begins with stating desired outcomes (aspiration formation), continues with searching for actions that guarantee them (satisficing), and ends up adapting aspirations in the light of experience (aspiration adaptation). Satisficing with its three constituent sub-processes conforms more to actual human behavior than descriptions built upon classical rationality.

Though the literature drawing on the notions of 'bounded rationality' and 'satisficing' in order to explain phenomena at odds with the classical concepts of perfect rationality is by now voluminous,[1] only recently experimental economists have started investigating satisficing behavior in laboratory. Some such experiments try to detect aspiration levels and their adjustment by statistically analyzing search data (see, e.g., Zwick et al. [24]); others render the satisficing approach applicable by directly eliciting aspirations (see Güth [4], and the references therein).

Our study differs from former experiments in two aspects. First, we consider a duopoly market, i.e., a setting with strategic interaction, where beliefs about the other's behavior play a central role. Furthermore, within such a market, we address the appealing (and hitherto neglected) question of whether satisficing individuals change their aspirations whenever they cannot be satisficed or revise other aspects of their mental model for deriving decisions.

The notion of "adjustment", as it has been commonly used in theoretical models of boundedly rational behavior, allows agents to revise one of the ele-

[1] In organization theory, for instance, there have been attempts to build theories of the business firm incorporating bounded rationality assumptions since the 70s (see, e.g., Leibenstein [11], Radner [16, 17], and, more recently, Noreen and Burgstahler [15]). An empirical test of how an optimizing search compares to a satisficing search has been conducted by, e.g., Markovitch and Rosdeutscher [13].

ments of the decision problem at hand. For instance, in search theory, people adapt their aspiration levels from one period to the next (see, e.g., Radner [17]). In recent game theoretical models with satisficing players, aspirations are dynamically updated (Kim [10]) or actions can be revised over time (Napel [14]). However, the fundamental question of which aspect of their boundedly rational mental representation of the decision task individuals *actually* revise when their aspiration level cannot be met has hardly ever been addressed.[2] The experiment reported here is designed to expressly investigate this issue.

To this aim, in a first experimental phase (consisting of 12 periods), we *enforce* satisficing choices. In a duopoly market with various states of demand, participants not only have to specify their own state-dependent sales behavior, but also to predict their opponent's behavior and form state-specific profit aspirations. If their action profile is not satisficing, in the sense of not allowing the achievement of the desired period-profit in *each* state, subjects *must* revise their beliefs, search for new sales strategies, and/or adapt their aspirations until the latter can be (potentially) met. In such a way, we can investigate what is mostly revised by individuals (beliefs, aspirations, or sales behavior) when the satisficing requirement does not hold, and engage with the following questions: Will actors be willing to adjust their aspirations to given expectations and own actions? Or will they stick to their aspirations, thereby modifying beliefs and/or own actions?

Of course, we are also interested in whether or not individuals voluntarily satisfice, i.e., if satisficing is absorbed after having been exposed to it.[3] Note that the question of whether satisficing is absorbed presupposes that participants are aware of what satisficing means. The latter is induced by phase 1 whereas phase 2 is meant to test the absorption of satisficing. In the second

[2]Tietz [20] and Tietz et al. [21] have imposed structured aspiration ladders for negotiators and confirmed aspiration balancing (both parties concede equally often in aspiration steps) in bargaining experiments, without eliciting beliefs or asking for action profiles.

[3]See Güth and Kliemt [5] for a conceptual discussion of theory absorption, and Güth et al. [6] for an experimental analysis.

phase (consisting, for the sake of consistency, of 12 periods too), we still inform our seller participants of whether or not their sales strategy is satisficing given their elicited beliefs, but allow them to freely choose their sales quantity. By this means, we can assess the absorbability of the satisficing approach for decision problems with strategic interaction.

The paper proceeds as follows. Section 2 introduces the experimental duopoly market and the satisficing approach. Section 3 illustrates the experimental procedures in detail. Section 4 presents the experimental results, and Section 5 concludes.

2. The stochastic market and theoretical analysis

We study a homogeneous duopoly market with stochastic linear demand. For the sake of simplicity, especially to render the experimental scenario simple enough, we abstract from (production) costs so that revenues equal profits. The stochastic aggregate inverse demand function is[4]

$$p_i = \max\{D_i - x_i^a - x_i^b, 0\}.$$

Here, p_i is the price as well as the unit profit in state i of the homogeneous market when sellers a and b supply the amounts x_i^a and x_i^b, respectively. D_i is a stochastic variable with discrete realizations $0 < D_1 < D_2 < \ldots < D_n$. To limit the effect of probability transformations (Kahneman and Tversky, [9]), we assume that all n (≥ 2) realizations of the stochastic variable D_i are equally probable. When selling x_i^j in state i, seller j ($j = a, b$) earns

$$\pi_i^j = p_i x_i^j. \tag{1}$$

The equilibrium solution for this market is straightforward to derive and is given by $x_i^j = D_i/3$, for $j = a, b$ and $i = 1, \ldots, n$, yielding the same state-dependent equilibrium profit of $(D_i/3)^2$ for both sellers. The symmet-

[4]Every (piecewise) linear demand can be reduced to this form by an appropriate choice of the unit amount if the stochastic effect is a parallel shift of the demand curve. By imposing $p_i \geq 0$, we avoid specific rules for the case of losses during the experiment.

ric equilibrium strategy profiles are $\mathbf{x}^a = \mathbf{x}^b = (D_1, \ldots, D_n)/3$. Denoting by $\hat{\mathbf{x}}^j = (\hat{x}_1^j, \ldots, \hat{x}_n^j)$ seller j's beliefs about her competitor's sales profile, true beliefs can be expressed in the form $\hat{\mathbf{x}}^a = \mathbf{x}^b$ and $\hat{\mathbf{x}}^b = \mathbf{x}^a$. Boundedly rational sellers will not be able to predict their competitor's strategy profile perfectly, although they may learn to do so.

Let us, therefore, consider a seller $j = a, b$ with given, but not necessarily true beliefs $\hat{\mathbf{x}}^j$ regarding the other's behavior in the n states of nature. If $\mathbf{A}^j = (A_1^j, \ldots, A_n^j)$ is j's aspiration profile, which complies with the natural (even for boundedly rational sellers) monotonicity requirement $A_i^j \leq A_{i+1}^j$ for all $i < n$, then the action profile $\mathbf{x}^j = (x_1^j, \ldots, x_n^j)$ with $x_i^j \leq x_{i+1}^j$ for all $i < n$, satisfies the aspiration profile $\mathbf{A}^j$ of j if

$$[D_i - x_i^j - \hat{x}_i^j]x_i^j \geq A_i^j \quad \text{for all} \quad i = 1, \ldots, n. \tag{2}$$

We refer to (2) as seller j's *individually satisficing requirement.*[5] We say that a vector $\mathbf{x} = (\mathbf{x}^a, \mathbf{x}^b)$ of strategy profiles is *mutually satisficing* if (2) is fulfilled for both sellers a and b.

After sufficient trials, both sellers may entertain true beliefs. In this case, a more stringent version of condition (2) holds, where mutual satisficing is based on true beliefs $\mathbf{x} = (\mathbf{x}^a, \mathbf{x}^b) = \hat{\mathbf{x}} = (\hat{\mathbf{x}}^b, \hat{\mathbf{x}}^a)$. Since rational expectations and optimality characterize strategic equilibria (see Aumann and Brandenburger [1]), optimal mutual satisficing, based on true beliefs, is equivalent to equilibrium behavior.[6]

3. Experimental protocol

The computerized experiment was conducted at the laboratory of the Max Planck Institute in Jena (Germany) in October 2006. The experiment was

[5]Note that (2) requires sellers to choose satisfactory actions in *all* n states of nature. This captures an important feature of Simon's theory: simultaneously doing more than one cognitively demanding task weakens human capabilities and induces real difficulties in handling even very simple choice problems (on this topic, see also Simon [19], and Lilly [12]).

[6]See, e.g., Lilly [12] and van Witteloostuijn [23] for earlier studies demonstrating that maximizing and satisficing can lead to comparable results.

programmed using the z-Tree software (Fischbacher [2]). Overall, we ran four sessions with a total of 128 participants, all being students from various fields at the University of Jena.

Each experimental session consisted of two subsequent phases, with 12 periods each.[7] In each period, the 32 participants of a session were divided into 16 groups á two sellers, so as to form 16 duopoly markets. New groups were randomly formed in each of the 24 repetitions (strangers design).[8] To collect more than one independent observation per session, subjects were rematched within matching groups of 8 players, guaranteeing 4 independent observations per session and 16 independent observations in total. In order to discourage repeated game effects, participants were not informed that random re-matching of the groups had been restricted in such a way.

In the instructions, subjects were told that they would act as a firm which, together with another firm, serves one market, and that in each period both were to choose, independently, how much to produce and sell. Quantities had to be integer numbers between 0 and 20. Participants were informed that their period-profit would be determined via function (1) and, therefore, depend on the realization of the state of demand and on the total quantity chosen by the two firms in the market.

The variable D_i could assume three equally probable values: $D_1 = 12$, $D_2 = 24$, and $D_3 = 48$. Hence, the symmetric equilibrium requires the duopolists to sell 4 in the worst state 1, 8 in the intermediate state 2, and 16 in the best state 3. The implied state-dependent equilibrium profits are: $\pi_1^* = 16$, $\pi_2^* = 64$, $\pi_3^* = 256$.

To investigate our first major research question (i.e., whether satisficing is

[7] The instructions distributed at the beginning explained the rules of the first experimental phase only. Written instructions on the second phase were distributed at the end of the first one (a translation of the German instructions for the two phases can be found in the Appendix).

[8] This should avoid the possibility of tacit collusion. See Holt [7] and Huck et al. [8] for experimental studies showing collusion in partners design where the same subjects interact repeatedly.

achieved by revising beliefs, adapting aspirations, or searching for new own sales strategies), in the first phase (period 1–12), we forced subjects, via a so-called decision aid, to comply with satisficing requirement (2). In every period and each duopoly market, besides choosing her own sales profile $\mathbf{x}^j = (x_1^j, x_2^j, x_3^j)$, each seller had to predict the sales profile $\hat{\mathbf{x}}^j = (\hat{x}_1^j, \hat{x}_2^j, \hat{x}_3^j)$ of her competitor as well as form her own aspirations profile $\mathbf{A}^j = (A_1^j, A_2^j, A_3^j)$. Therefore, in every period, participants had to fulfil three tasks and provide a total of 9 decisions: (*i*) the quantity they wanted to produce and sell in each of the three states, (*ii*) the quantity they expected the other to produce and sell in each state, and (*iii*) the period-profit they aspired to in each state.

After having completed these tasks, it was checked by the software whether satisficing requirement (2) held for all three possible states. Each participant was then informed whether or not her stated profit aspirations could be achieved in each state of nature, given her beliefs and her own sales choices in that state. If this was not possible for some state, the participant *had to* go back and revise one or more components of her decisions. Revisions were also allowed in case of compliance with (2), though. Only when (2) was fulfilled for all three states, the participant could confirm her specification and move to the next period. Thus, in the first phase, when both seller participants have confirmed, it is commonly known that the condition of mutual satisficing has been fulfilled, although expected and actual choices may differ.

To assess our second major research question (i.e., whether individuals voluntarily use the decision aid, as required by absorption of satisficing), in the second phase (period 13–24), we allowed participants to confirm their sales profile even though, owing to their elicited beliefs, it was not satisficing.

To incentivize expectations as well as aspiration choices we paid participants either according to their stated beliefs or according to their aspirations, with both possibilities being equally likely. This method of paying should motivate participants both to predict the other's behavior as accurately as possible and

to submit 'true' aspirations. When payments were based on stated beliefs, the payoff of seller participant j $(j = a, b)$ in selected state i $(i = 1, 2, 3)$ was given by:

$$W_i^j = 100 - |x_i^j - \hat{x}_i^j|.$$

We did not inform participants about the exact content of the above rule. We just explained them that the closer their predictions were to the actual quantity chosen by the other firm, the higher their earnings.

When payments depended on aspirations, participant j earned her aspiration A_i^j for the selected state i if the actual profits sufficed to satisfy A_i^j, i.e., if

$$\pi_i^j = [D_i - x_i^j - x_i^k]x_i^j \geq A_i^j \tag{3}$$

with $k = a, b$, $k \neq j$. We refer to condition (3) as *actually satisficing* by seller j in state i. If condition (3) was not met, seller j earned the highest aspiration A_l^j with $\pi_i^j \geq A_l^j$. Paying aspirations rather than actual profits implements the usual interpretation of aspiration levels, namely that one primarily cares for achieving aspired period-profits.

At the end of each period, participants got individual feedback about both duopolists' sales profile $\mathbf{x}^a$ and $\mathbf{x}^b$, the selected state of nature, the implied profits, the dimension on which they were paid, and the resulting period-earnings.

4. Experimental results

In reporting our results, we proceed as follows. First, we present an overview of elicited aspiration levels and sales behavior. Then we turn to our main questions, and investigate what is mostly revised by our participants (beliefs, aspirations, or sales choices) whenever satisficing is not fulfilled, and whether people voluntarily maintain satisficing in phase 2 after having been 'obliged' to follow it in the first 12 periods.

4.1. General results

Table 1 provides descriptive statistics on profits, choices, expectations and aspirations over all periods, separately for the first (period 1–12) and the second phase (periods 13–24) of the experiment.

[Table 1 about here]

Profits in the two phases are not significantly different (two-sided Wilcoxon signed rank test, $p = 0.980$).[9] As regards own sales choices, whatever the phase, x_1 and x_2 do not significantly differ from the game-theoretical predictions requiring participants to sell 4 and 8 in the worst and intermediate state, respectively ($p > 0.05$ for both states in both phases, one-sided Wilcoxon signed rank test). In contrast, in the best state 3, participants undersell as compared to the benchmark solution of 16 ($p = 0.029$ in both phases).

Beliefs about the competitor's sales amount, in general, are not accurate, but systematically below actual choices (in phase 1: $p < 0.001$ in all three states; in phase 2: $p < 0.02$ in all states; one-sided Wilcoxon signed rank test). Subjects best respond to the expected quantity of the other firm in the intermediate state 2, whatever the phase, and in the worst state 1 in phase 2 ($p > 0.28$ always; Wilcoxon signed rank test comparing computed best replies to actual choices). However, the best state 3 and the worst state 1 in phase 1 trigger choices that are significantly lower than the quantities best responding to expectations ($p < 0.005$ for all three comparisons). Such finding already suggests that our participants are not always able to make optimizing choices.

Fig. 1 relies on independent observations to draw boxplots of aspirations across periods for each state in both phases. In phase 1, if we consider all 12 periods, aspirations exhibit a (slightly) increasing and significant time trend whatever the state of nature (Spearman's correlation coefficients between aspirations and "*periods 1–12*" are 0.267, 0.322 and 0.408 for states 1, 2 and 3, respectively; $p < 0.001$ always). Yet, for states 1 and 2 the aspiration trend

[9] Unless otherwise stated, all statistical tests are based on the 16 independent observations.

stays rather constant after the fourth period (Spearman's ρ between aspirations and "*periods 5–12*" are 0.047 and 0.001 for states 1, and 2; $p > 0.10$ always). As to phase 2, aspirations in states 1 and 2 increase to a very small degree over all periods ($\rho = 0.151$ for state 1, and $\rho = 0.126$ for state 2; both $p < 0.05$), whereas aspirations in state 3 are stable ($\rho = 0.016$, $p = 0.409$).[10] Furthermore, as suggested also by Table 1, for each state of nature, aspirations are significantly lower in phase 1 than in phase 2 ($p < 0.001$ for all three states; one-sided Wilcoxon test). Participants become "more demanding", in the sense of improving their aspired period-profit, in the second 12 periods.

[Fig. 1 about here]

Looking at the spread of aspiration levels over time, we find that the gap between profit aspirations in the best and worst state increases significantly over the 12 periods of phase 1 (denoting by $\overline{A}_i$ the average aspirations in state i, with averages over players for each matching group, Spearman's ρ between $\overline{A}_3 - \overline{A}_1$ and "*periods 1–12*", in phase 1, is 0.402, $p < 0.001$). The same applies to the development of the spread between aspirations in the intermediate state 2 and aspirations in either the best or the worst state in phase 1 ($\rho_{\overline{A}_3-\overline{A}_2} = 0.384$, $\rho_{\overline{A}_2-\overline{A}_1} = 0.306$; $p < 0.001$ in both cases). Over the last 8 periods, the gap between aspirations in the best state 3 and either other state still widens, though to a smaller degree (ρ between $\overline{A}_3 - \overline{A}_1$ and "*periods 5–12*" is 0.192; ρ between $\overline{A}_3 - \overline{A}_2$ and "*periods 5–12*" is 0.254; $p < 0.03$ in both cases); however, the increasing time trend in the spread between $\overline{A}_2$ and $\overline{A}_1$ vanishes ($\rho = 0.014$, $p = 0.870$). All considered spreads remain stable in the second phase ($\rho_{\overline{A}_3-\overline{A}_1} = 0.003$; $\rho_{\overline{A}_3-\overline{A}_2} = -0.034$; $\rho_{\overline{A}_2-\overline{A}_1} = 0.02$; $p > 0.05$).

4.2. Satisficing behavior

We now turn to our two main research questions. Subsection 4.2.1 presents an aggregate data analysis of satisficing behavior. Subsection 4.2.2 provides

[10] The picture does not change if we consider only periods 5 to 12.

details about individual behavior.

4.2.1. Aggregate data

What do participants revise more often when satisficing requirement (2) does not hold? To answer this question, we separate the data according to phase because compliance with satisficing is mandatory in phase 1 and voluntary in phase 2. Fig. 2 provides the number of changes in own choices, expectations and aspiration levels for each state of nature over all 12 periods of phase 1. Fig. 3 provides the same number for phase 2.

[Fig. 2 and 3 about here]

Starting from phase 1, out of all the 4608 individual observations (32 subjects $\times$ 3 states $\times$ 12 periods $\times$ 4 sessions), 3564 comply immediately with requirement (2), meaning that the three profiles of interest, $\hat{\mathbf{x}}^j$, $\mathbf{A}^j$, and $\mathbf{x}^j$, are satisficing at first attempt for the same individual. Most of these immediately satisficing profiles are confirmed, but a small number (134 or 3.76%) is revised, with most of the revisions (72%) concerning own aspirations, some (16%) expectations, and just a few (11%) own sales choices. The observation that participants adapt mostly their aspiration levels when satisficing is not fulfilled also applies to the remaining 1044 observations, which are not immediately satisficing and, thus, must be revised. Among these observations, aspirations are changed most often (66%), followed by own actions and expectations (both around 17%).[11] Participants seem to encounter particular difficulties in complying with satisficing in the worst scenario, where the number of satisficing choice is 1311, which compares to 1340 (1441) satisficing choices in state 2 (3).

Turning to the second phase, where satisficing was voluntary, we find that out of the 1368 observations which were informed to be not satisficing, 150 decide to revise some aspects of their decision. As suggested by Fig. 3, also in phase 2, aspirations are revised more often (62% of the times) than one's

[11] Considering only the last 8 periods does not qualitatively alter the ranking: aspirations are changed 61% of the time, expectations 21%, and own actions 17%.

own and expected sales, which are modified at a similar frequency (expected sales: 21%; own sales: 17%).

The latter observation indicates that some individuals are willing to adjust their own aspiration levels so as to render their choices satisficing. This leads us to our second major research question: Do participants deliberately maintain satisficing in the second phase? Fig. 4 displays the frequency of choices that are satisficing for all three states simultaneously and for only one state across all 12 periods of phase 2.

[Fig. 4 about here]

In each single period, the frequency of satisficing is above 60%, and satisficing choices are more frequent in the best state 3 than in the other two states (on average, 1394 in state 3 vs. 1175 and 1173 in states 1 and 2, respectively). Overall, 3240 observations (out of 4608) are satisficing. Thus, on average, 70% of the participants comply with satisficing requirement (2) without being forced to do so. Moreover, the proportion of satisficing action profiles stays rather constant over time (Spearman's correlation coefficients between satisficing action profiles and periods is 0.164, $p = 0.604$).

According to satisficing requirement (2), aspirations must be not greater than expected profits. It is therefore instructive to investigate how aspirations compare to expected profits, and check whether or not the former converge to the latter. Fig. 5 and 6 display the time path of aspirations and expected profits over all 12 periods of phase 1 and phase 2, respectively. The sample for phase 2 includes only satisficing choices, i.e., choices that comply with (2).

[Fig. 5 and 6 about here]

For each state of nature, whatever the phase, aspirations lie constantly below expected profits. Wilcoxon signed rank tests (two-sided) confirm that in each phase and for each state, participants' elicited aspirations are significantly lower than their expected profits ($p < 0.001$ for all six comparisons). Thus,

subjects aspire to profits which are significantly smaller than those they might aim for, given their beliefs about the opponent's behavior. In other words, participants satisfice rather than maximize, thereby contradicting models based on an intermediate level of rationality, such as "belief learning" (Fudenberg and Levine [3], Young [22]).

According to Fig. 5, in phase 1, aspirations move towards expected profits for each state of nature. Indicating by $E(\pi_i)$ the average expected profit in state $i = 1, 2, 3$ (with average over players per matching group), and recalling that $\overline{A}_i$ denotes the average aspirations in state i, a correlation analysis confirms that the gap between $E(\pi_i)$ and $\overline{A}_i$ shrinks significantly over time for all states i (Spearman's $\rho = -0.306$, -0.474 and -0.489 for states 1, 2 and 3, respectively; $p < 0.001$). Turning to phase 2, we find that the gap between expected profits and aspirations stays rather constant over time (Spearman's $\rho = 0.027$, -0.059 and -0.017 for states 1, 2 and 3, respectively; $p > 0.40$ in all cases).[12]

4.2.2. A closer look at the individual data

In phase 1, we classify individuals depending on how long they need to satisfice at first attempt and stick to their prompt satisficing afterwards. In particular, we distinguish subjects as follows.

1. *Never satisficers*: subjects who are requested to change some aspect of the choice problem in each single period.
2. *Later satisficers*: subjects who do not achieve and maintain immediate satisficing until period t, with $t \in \{9, 10, 11, 12\}$.
3. *Intermediate satisficers*: like the former category, but with $t \in \{5, 6, 7, 8\}$.
4. *Early satisficers*: subjects who are immediately satisficing either over all 12 periods or at least over the last 9 periods.

[12] The results for both phases do not qualitatively change if we take into account only periods 5–12; the magnitude of the coefficient ρ just becomes a little smaller in absolute value in phase 1 for each of the three states.

In phase 2, where compliance with requirement (2) was willful, we refer categories to whether subjects satisfice or not.

1. *Non-satisficers*: subjects who never comply with requirement (2).
2. *Weak satisficers*: subjects who do not start abiding by and maintaining (2) until period t, with $t \in \{9, 10, 11, 12\}$.
3. *Moderate satisficers*: like the former category, but with $t \in \{5, 6, 7, 8\}$.
4. *Strong satisficers*: subjects who satisfice either over all 12 periods or at least over the last 9 periods.

[Table 2 about here]

Table 2 reports the proportion of subjects who fall in each of the identified categories for each phase. Individual data confirm previous aggregate analysis. In phase 1, most of our participants are early satisficers (more than 40%), and the proportion of those who satisfice *ab initio* and consecutively for at least the last 4 periods is also rather high (about 20%). Only a few subjects (less than 5%) never comply with satisficing immediately. Some participants do not fall in any of the identified categories: they immediately satisfice in some of the 12 periods of phase 1 in a random manner.

The individual data for phase 2 are also quite comforting for the satisficing approach: 48% subjects spontaneously satisfice for at least the last two-thirds of the phase (in particular, 37% behave satisfactorily over all 12 periods). Only 11% of the subjects (mainly, those "never satisficing" or "unclassifiable" in the first phase) never obey requirement (2). Moreover, 29 out of 53 early satisficers in phase 1 are strong satisficers in phase 2, and 18 out of the 24 intermediate satisficers in phase 1 are either strong or moderate satisficers in phase 2. These results suggest that a non negligible number of individuals has absorbed satisficing.

5. Conclusions

To experimentally test the satisficing approach in a strategic setting, we relied on a multi-period homogeneous duopoly market. In every period, seller participants had to choose their own sales profile, predict the competitor's sales profile, and form profit aspirations for each state of demand. An individual is said to satisfice if she achieves her aspired period-profit, given her expectations about the other's behavior. In the first experimental phase, we forced seller participants to satisfice. In the second phase, we still imposed the satisficing routine, but allowed participants to freely choose their sales strategy.

Our major results are that, throughout the experiment, the overwhelming majority of seller participants adapts aspirations until they can be met, and voluntarily maintains satisficing in the second phase. Aspirations are systematically below expected profits, suggesting that individuals do not form aspirations by maximizing expected profits. Since the worst state of nature triggers, overall, less satisficing choices than the other two states, participants seem less often satisficing when there is little to gain.

More than 40% of the subjects can be classified as 'early satisficers' (they immediately satisfice at least over the last 9 periods of phase 1), and 48% are 'strong satisficers' (they spontaneously satisfice at least over the last 9 periods of phase 2). Thus, the experimental evidence garnered here suggests that people follow boundedly rational requirements in duopoly markets.

There are several ways of extending our experimental design. Eliciting point-expectations about the other's sales amount has the advantage to allow for comparisons between satisficing and optimizing (choosing the best reply to one's point-expectation). Its drawback is that one considers oneself as satisficing, disregarding similar attitudes for the competitor. To avoid such weakness, one could replace expected sales by expected aspiration profiles: this would allow each seller participant to check whether there exist sales constellations implying one's own and the other's expected satisficing. More obvious varia-

tions may concern either the market situation, e.g., by assuming heterogeneous products or not allowing sellers to condition on the state of demand, or the experimental procedures, e.g., by changing how participants are monetarily rewarded.

Appendix A. Translated instructions (originally in German)

Instructions for the first phase (period 1–12)

Welcome and thanks for participating in this experiment. Please read the following instructions carefully. From now on any communication with other participants is forbidden. If you have any questions, raise your hand. We will answer your questions individually. All participants receive identical instructions.

Throughout the experiment, you can earn money. How much you earn depends on your decisions, on the decisions of other participants matched with you, and on chance. The unit of experimental money will be the ECU (Experimental Currency Unit), where 1 ECU = €0.01. This means that 100 ECU = €1.

Detailed information on the experiment

In this experiment, you will have to make decisions repeatedly. In every period, you will be randomly matched into pairs. The participants forming a pair will randomly change after each period, so that the other member of your pair will be different from one period to the next. The identity of the other participants you will get in touch with will not be revealed to you at any time.

In the experiment, you have the role of a firm that, like one other firm (the participant you are matched with), produces and sells one and the same product on a market. In each period, you and the other firm in your pair have to decide, simultaneously and independently, what quantity you wish to produce. You as well as the other firm in your pair can choose to produce any integer amount between 0 and 20; i.e., your choice of quantity must be $0, 1, 2, \ldots, 19$, or 20. In the following, we shall refer to the quantity chosen by you as x_{you}, and to the quantity chosen by the other firm as x_{other}.

In each period, your profit depends on a random variable D, and on the quantities chosen by you and the other firm as follows:

$$\textit{Your period-profit} = [D - x_{\text{you}} - x_{\text{other}}] \times x_{\text{you}}.$$

In words, we subtract the quantities chosen by you and the other firm from the random variable D, and multiply the resulting amount by the quantity chosen by you. If the sum of the quantity chosen by you and the quantity chosen by the other firm is greater than D (i.e., if $x_{\text{you}} + x_{\text{other}} > D$), your period-profit will be zero so that you can never make losses.

The random variable D can take on one of three different values, depending on which of three scenarios occurs.

- If scenario 1 occurs, D will be equal to **12**.
- If scenario 2 occurs, D will be equal to **24**.
- If scenario 3 occurs, D will be equal to **48**.

The three scenarios are equally likely, meaning that $D = 12$ with $1/3$ probability, $D = 24$ with $1/3$ probability, and $D = 48$ with $1/3$ probability.

The decision aid

To help you decide how much to produce in each period, we provide you with a decision aid aiming at "satisfactory" decisions, i.e., decisions achieving your desired period-profit in each scenario. In particular, in each period, the decision aid will guide you through the following steps.

a. First, it will ask you to choose the quantity you wish to produce in each of the three scenarios. Specifically, you have to answer these three questions:

- How much do you want to produce in scenario 1?
- How much do you want to produce in scenario 2?
- How much do you want to produce in scenario 3?

For each scenario, you can choose any integer amount between 0 and 20. Furthermore, the amount you choose in scenario 3 must be not smaller than the amount you choose in scenario 2, which must be not smaller than the amount you choose in scenario 1. If you, for instance, decide to produce 10 in scenario 3, your production in scenario 2 can be at most 10 (i.e., 10 or less); if you opt for a production of 7 in scenario 2, then your production in scenario 1 can be at most 7 (i.e., 7 or less).

b. Then, the decision aid will ask you to predict the production decisions of the other firm. Specifically, you have to answer three further questions:

- How much do you expect the other firm to produce in scenario 1?
- How much do you expect the other firm to produce in scenario 2?
- How much do you expect the other firm to produce in scenario 3?

For each scenario, your expectation about the other firm's production must be an integer number between 0 and 20. Furthermore, your expectation for scenario 3 must be not smaller than your expectation for scenario 2, and the latter must be not smaller than your expectation for scenario 1. If you, for instance, expect the other firm to produce 13 in scenario 3, your expectation in scenario 2 can be at most 13; supposing you expect from the other a production of 11 in scenario 2, then you expectation in scenario 1 cannot be higher than 11.

c. Finally, the decision aid will ask you to specify the period-profit you wish to guarantee yourself in each of the three scenarios. In particular, you will have to answer three more questions:

- Which period-profit would satisfy you in scenario 1?
- Which period-profit would satisfy you in scenario 2?
- Which period-profit would satisfy you in scenario 3?

In the following, we will refer to the period-profits you find satisficing as your *profit aspirations*. Your profit aspirations in scenario 3 must be not smaller than your profit aspirations in scenario 2, which must be not smaller than your profit aspirations in scenario 1.

d. After you have answered the 9 questions above, the decision aid will inform you whether your stated profit aspiration in each scenario can be achieved or not. That is, you will learn whether, given your own production choices and your expectations about the other firm's production, you can achieve your profit aspiration in each scenario.

e. If your stated profit aspiration *cannot* be achieved in some scenario, the decision aid will ask you to revise your own production choice, your expectation about the other firm's production, or your profit aspiration for that specific scenario. You can modify all three aspects above, two of them, or only one.

f. Only when you can achieve your stated profit aspiration in each scenario, you can move on to the next period.

The decision aid will assist you in every period, i.e., in each period you *must* go through all the steps mentioned above, and cannot move to the next period *until* the profit aspiration in each scenario can be achieved by your production choices and your expectations about the other's production.

Your experimental earnings in each period

Though your period-profit influences your experimental earnings, you are not paid according to your period-profit directly. Rather, your experimental earnings in each period will be determined as follows.

At the end of each period, the computer will randomly select one scenario and, thus, the value of D in that period. You can be paid either according to the difference between your expectation and the quantity actually chosen by the other firm in the selected scenario, or according to your profit aspirations. These two possibilities are equally

likely: with 50% probability your period-payment will be based on your expectation, and with 50% probability your period-payment will be based on your profit aspirations. If, by random choice, your payment is based on the difference between your expectation and the quantity actually chosen by the other, then the smaller this difference, the higher your payment. That is, the more accurate your expectation, the more you earn. If, by random choice, your payment is based on your aspirations, the computer checks whether, for the randomly selected scenario, your profit aspiration exceeds your period-profit in that scenario.

- If your profit aspiration in the randomly selected scenario does not exceed your period-profit, you earn an amount of ECU equal to your profit aspiration in the selected scenario.
- Otherwise, the computer will check whether your stated profit aspiration in another scenario does not exceed your period-profit in the selected scenario. You will, in this case, earn the highest profit aspiration not exceeding your period-profit in the selected scenario.
- If all your three profit aspirations exceed your period-profit in the selected scenario, your earnings in that period will be 0 (zero) ECU.

The information you receive at the end of each round

At the end of each period, you will be informed about (1) the actual production amounts chosen by the other firm in each of the three scenario; (2) the randomly selected scenario; (3) your period-profit in the selected scenario; (4) your period-experimental earnings as explained above.

Your final earnings

At the end of the experiment, your experimental earnings in each period will be added up. The resulting sum will be converted to euros and paid out.

Before the experiment starts, you will have to answer some control questions to ensure your understanding of the experiment, and the functioning of the decision aid.

Please remain quiet until the experiment starts and switch off your mobile phone. If you have any questions, please raise your hand now.

Instructions for the second phase (period 13–24)

The only change with respect to the first part is that now you are free to decide whether you want to make satisficing choices or not. That is, now, after having gone through the step-procedures of the decision aid, you can

- either confirm the three production choices (one per scenario), although they do not satisfy your profit aspirations
- or change any of them.

In the latter case, you will be informed of whether your final production choices allow you to achieve your profit aspirations or not.

Your experimental earnings in each period will be determined as in the first part.

The information you receive at the end of each period will also be the same as in the first part.

References

[1] R. Aumann, A. Brandenburger, Epistemic conditions for Nash equilibrium, Econometrica 63 (1995) 1161–1180.

[2] U. Fischbacher, Zurich toolbox for readymade economic experiments, Working Paper No. 21, University of Zurich, Switzerland, 1999.

[3] D. Fudenberg, D. Levine, The Theory of Learning in Games, MIT Press, Cambridge, MA, 1998.

[4] W. Güth, Satisficing in portfolio selection - Theoretical aspects and experimental tests, Journal of Socio-Economics (forthcoming).

[5] W. Güth, H., Kliemt, Bounded rationality and theory absorption, Homo Oeconomicus 21 (2004) 521–540.

[6] W. Güth, M.V. Levati, M. Ploner, Is satisficing absorbable? An experimental study, Papers on Strategic Interaction No. 10-2006, Max Planck Institute of Economics, Jena, Germany, 2006.

[7] C. Holt, An experimental test of the consistent-conjectures hypothesis, American Economic Review 75 (1985) 315–325.

[8] S. Huck, W. Müller, H.-T. Normann, Stackelberg beats Cournot - On collusion and efficiency in experimental markets, Economic Journal 111 (2001) 749–765.

[9] D. Kahneman, A. Tversky, Prospect theory: an analysis of decision under risk, Econometrica 47 (1979) 263–291.

[10] Y. Kim, Satisficing and optimality in 2×2 common interest games, Economic Theory 13 (1999) 365–375.

[11] H. Leibenstein, Beyond Economic Man, Harvard University Press, Cambridge, MA, 1976.

[12] G. Lilly, Bounded rationality: A Simon-like explication, Journal of Economic Dynamics & Control 18 (1994) 205–230.

[13] S. Markovitch, I. Rosdeutscher, Systematic experimentation with deductive learning: satisficing vs. optimizing search, Proceedings of the Knowledge

Compilation and Speedup Learning Workshop, Aberdeen, Scotland, 1992.

[14] S. Napel, Aspiration adaptation in the ultimatum minigame, Games and Economic Behavior 43 (2003) 86–106.

[15] E. W. Noreen, D. Burgstahler, Full-cost pricing and the illusion of satisficing, Journal of Management Accounting Research 9 (1997) 239–263.

[16] R. Radner, A Behavioral model of cost reduction, Bell Journal of Economics 6 (1975) 196–215.

[17] R. Radner, Satisficing, Journal of Mathematical Economics 2 (1975) 253–262.

[18] H. A. Simon, A behavioral model of rational choice, Quarterly Journal of Economics 69 (1955) 99–118.

[19] H. A. Simon, Rational decision-making in business organizations. American Economic Review 69 (1979) 493–513.

[20] R. Tietz, Adaptation of aspiration levels–theory and experiment, in: W. Albers, W. Güth, P. Hammerstein, B. Moldovanu, E. van Damme (Eds.), Understanding Strategic Interaction - Essays in Honor of Reinhard Selten, Springer: Berlin, 1997, pp. 345-364.

[21] R. Tietz, H.-J. Weber, U. Vidmajer, C. Wentzel, On aspiration forming behavior in repetitive negotiations, in: H. Sauermann (Ed.), Bargaining Behavior, Beiträge zur experimentellen Wirtschaftsforschung, Mohr Siebeck: Tübingen, 1978, pp. 88–102 (vol. 7).

[22] P. Young, Individual Strategy and Social Structure, Princeton University Press, Princeton, NJ, 1998.

[23] A. van Witteloostuijn, Maximising and satisficing opposite or equivalent concepts?, Journal of Economic Psychology 9 (1988) 289–313.

[24] R. Zwick, A. Rapoport, A. Lo, A. Muthukrishnan, Consumer search: Not enough or too much?, Marketing Science 22 (2003) 503–519.

Table 1
Descriptive statistics on profits, choices, expectations and aspiration levels separately for phase 1 (period 1–12) and phase 2 (period 13–24)

Phase	Variable	Mean	Median	Std. Dev.
1 (period 1–12)	*Profit*	9.87	9.63	0.95
	x_1	4.06	3.87	0.42
	x_2	8.29	8.14	0.68
	x_3	15.11	15.49	1.08
	$\hat{x}_1$	3.67	3.68	0.28
	$\hat{x}_2$	7.57	7.55	0.61
	$\hat{x}_3$	14.08	14.21	1.14
	A_1	13.94	13.63	1.54
	A_2	55.37	55.77	5.39
	A_3	221.79	220.16	16.09
2 (period 13–24)	*Profit*	9.80	9.61	1.14
	x_1	4.25	4.10	0.68
	x_2	8.47	8.25	0.91
	x_3	15.74	15.86	1.15
	$\hat{x}_1$	3.86	3.86	0.38
	$\hat{x}_2$	7.84	7.93	0.83
	$\hat{x}_3$	14.53	14.84	1.34
	A_1	21.38	20.51	5.77
	A_2	70.60	67.72	12.13
	A_3	239.87	239.80	28.82

Table 2
Percentage of participants in accordance with each type

Phase 1		Phase 2	
Never satisficers	5	Non satisficers	14
Later satisficers	26	Weak satisficers	14
Intermediate satisficers	24	Moderate satisficers	13
Early satisficers	53	Strong satisficers	61
Unclassifiable	20	Unclassifiable	26

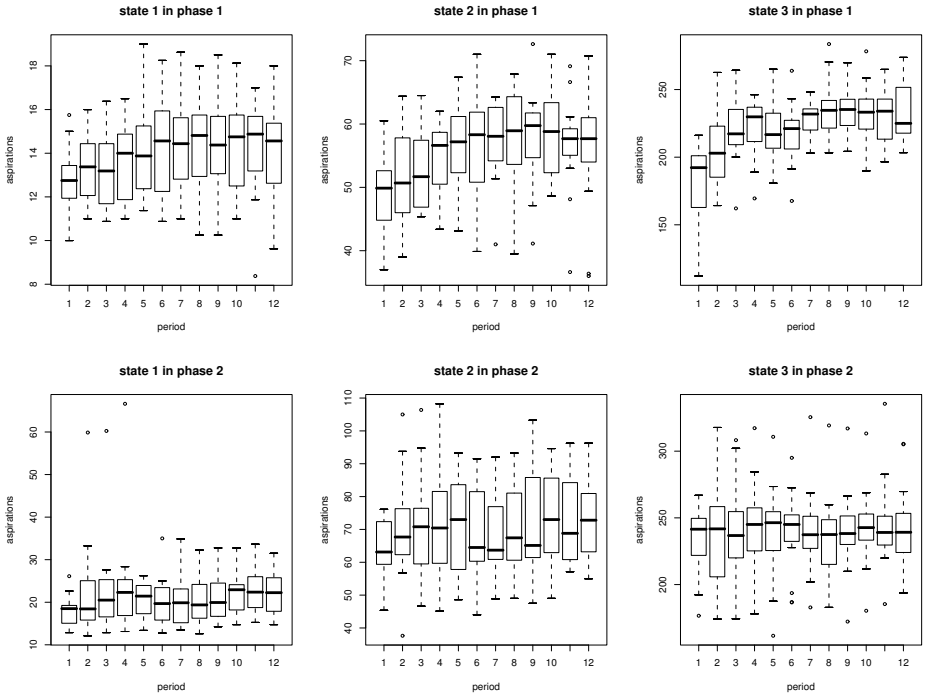

Fig.1. Aspirations across periods for each state of nature in both phases.

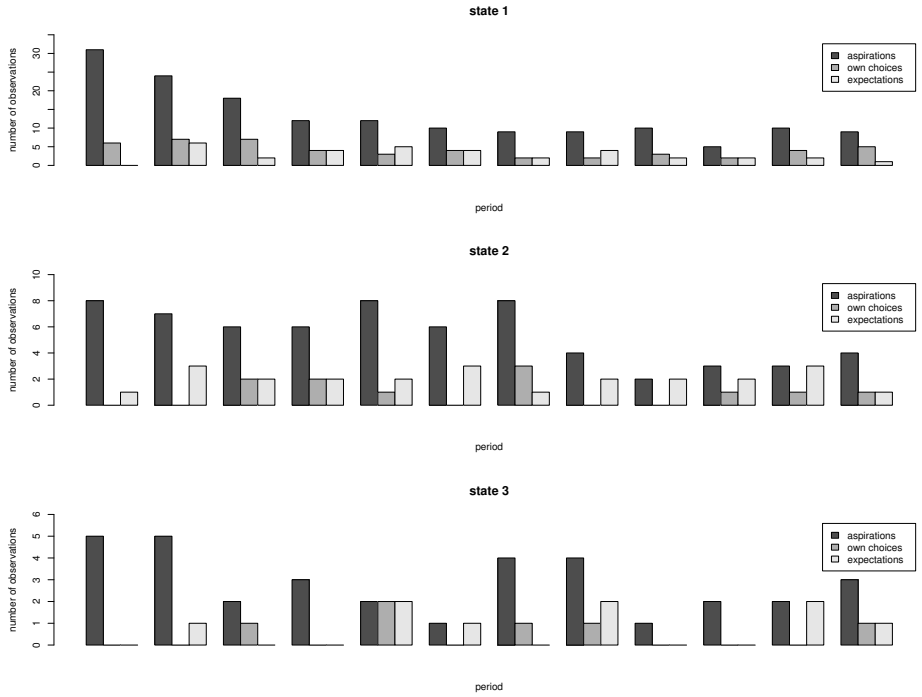

Fig. 2. Number of changes in own choices, expectations and aspirations over all 12 periods of phase 1, separately for each state of nature.

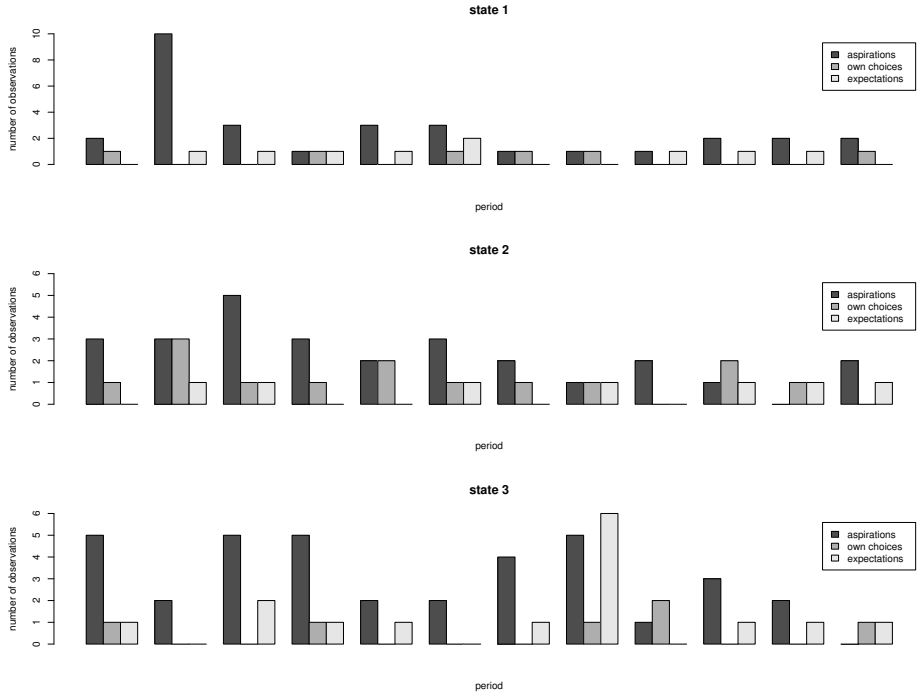

Fig. 3. Number of changes in own choices, expectations and aspirations over all 12 periods of phase 2, separately for each state of nature.

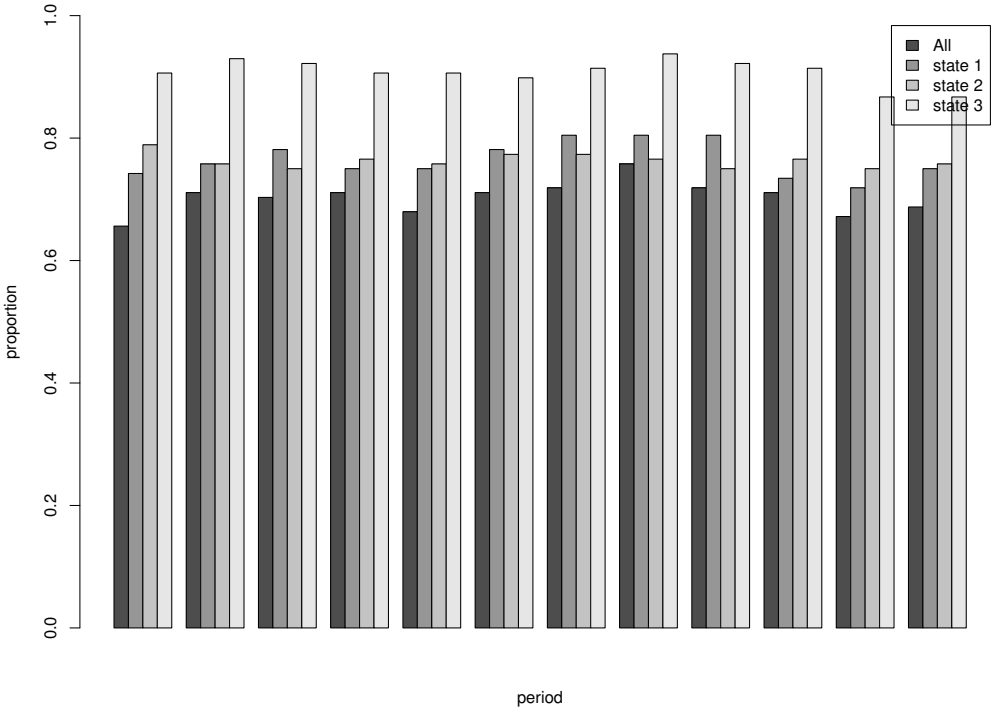

Fig. 4. Frequency of observations complying with satisficing for all three states and for each state separately over all 12 periods of phase 2.

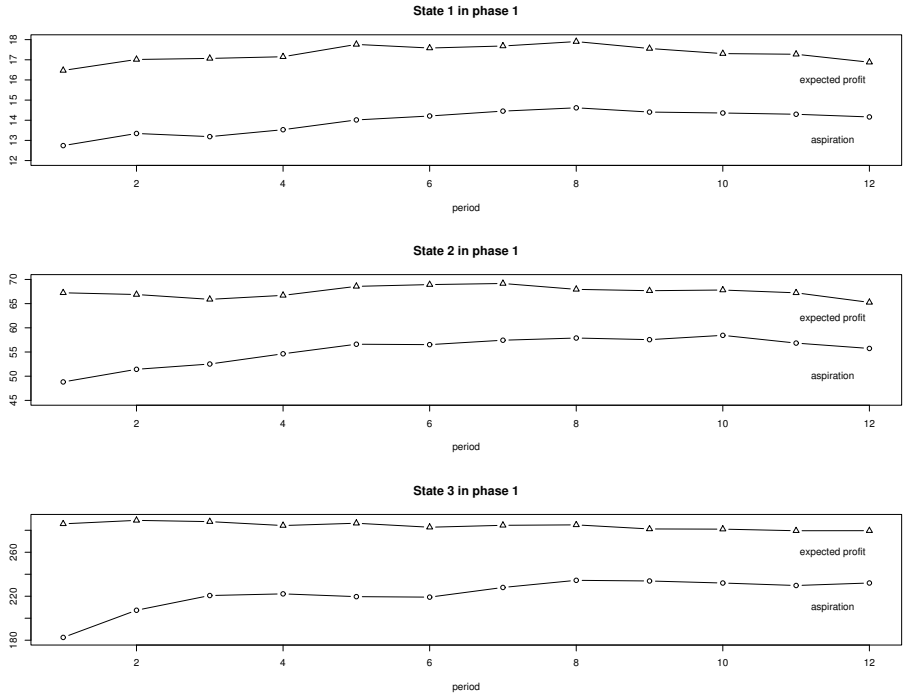

Fig. 5. Aspirations and expected profits over all 12 periods of phase 1.

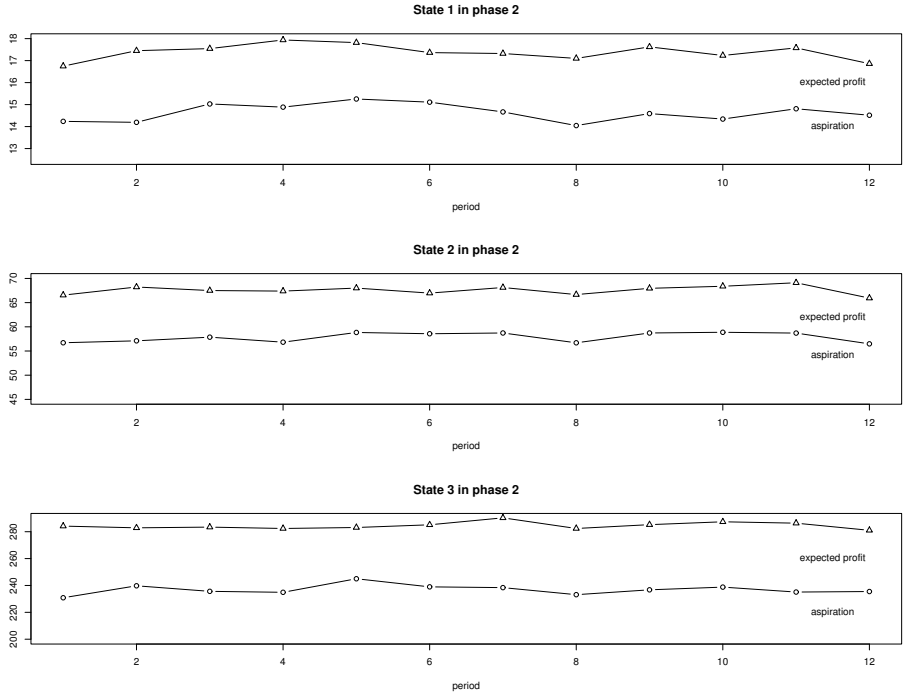

Fig. 6. Aspirations and expected profits over all 12 periods of phase 2.

Nr.	Author	Title
07-03	Siegfried K. Berninghaus Werner Gueth M. Vittoria Levati Jianying Qiu	Satisficing in sales competition: experimental evidence
07-02	Jannis Bischof Michael Ebert	Inconsistent measurement and disclosure of non-contingent financial derivatives under IFRS: A behavioral perspective
07-01	Jörg Oechssler Carsten Schmidt Wendelin Schnedler	Asset Bubbles without Dividends - An Experiment
06-16	Siegfried K. Berninghaus Hans Haller	Pairwise Interaction on Random Graphs
06-15	Markus Glaser Philipp Schmitz	Privatanleger am Optionsscheinmarkt
06-14	Daniel Houser Daniel Schunk Joachim Winter	Trust Games Measure Trust
06-13	Markus Glaser Sebastian Müller	Der Diversification Discount in Deutschland: Existiert ein Bewertungsabschlag für diversifizierte Unternehmen?
06-12	Philipp Schmitz Markus Glaser Martin Weber	Individual Investor Sentiment and Stock Returns - What Do We Learn from Warrant Traders?
06-11	Siegfried K. Berninghaus Sven Fischer Werner Gueth	Do Social Networks Inspire Employment? - An Experimental Analysis -
06-10	Christopher Koch Carsten Schmidt	Disclosing Conflict of Interest - Does Experience and Reputation Matter?
06-09	Clemens Kroneberg Volker Stocké Meir Yaish	Norms or Rationality? The Rescue of Jews, Electoral Participation, and Educational Decisions

Nr.	Author	Title
06-08	Guido Cozzi Paolo Giordani Luca Zamparelli	An Uncertainty-Based Explanation of Symmetric
06-07	Volker Stocké	Explaining Secondary Effects of Familiesí Social Class Position. An Empirical Test of the Breen-Goldthorpe Model of Educational Attainment
06-06	Volker Stocké Tobias Stark	Trust in Surveys and the Respondentsë Susceptibility to Item Nonresponse
06-05	Clemens Kroneberg	The Definition of the Situation and Variable Rationality: The Model of Frame Selection as a General Theory of Action
06-04	Rainer Greifeneder Cornelia Betsch	Maximieren und Bedauern: Skalen zur Erfassung dipositionaler Unterschiede im Entscheidungsverhalten
06-03	Volker Stocké Christian Hunkler	Measures of Desirability Beliefs and their Validity as Indicators for Socially Desirable Responding
06-02	Anders Anderson	Is Online Trading Gambling with Peanuts?
06-01	Volker Stocké Tobias Stark	Political Involvement and Memory Failure as Interdependent Determinants of Vote Overreporting
05-43	Volker Stocké Tobias Stark	Stichprobenverzerrung durch Item-Nonresponse in der international vergleichenden Politikwissenschaft
05-42	Volker Stocké	Response Privacy and Elapsed Time Since
05-41	Josef Hofbauer Jörg Oechssler Frank Riedel	Brown-von Neumann-Nash Dynamics: The Continuous Strategy Case
05-40	Markus Glaser Thomas Langer Jens Reynders Martin Weber	Framing Effects in Stock Market Forecasts: The Difference Between Asking for Prices and Asking for Returns

Nr.	Author	Title
05-39	Tri Vi Dang	Alternating Offer Bargaining with Endogenous Information: Timing and Surplus Division
05-38	Tri Vi Dang	On Bargaining with Endogenous Information
05-37	Patric Andersson	Overconfident but yet well-calibrated and underconfident: A research note on judgmental miscalibration and flawed self-assessment*
05-36	Peter Dürsch Albert Kolb Jörg Oechssler Burkhard Schipper	Rage Against the Machines - How Subjects Learn to Play Against Computers
05-35	Siegfried K. Berninghaus Hans Haller Alexander Outkin	Neural Networks and Contagion
05-34	Jacques Durieu Hans Haller Philippe Solal	Interaction on Hypergraphs
05-33	Markus Glaser Martin Weber	Which Past Returns Affect Trading Volume?
05-32	Zacharias Sautner Martin Weber	Corporate Governance and the Design of Stock Option Programs
05-31	Zacharias Sautner Martin Weber	Subjective Stock Option Values and Exercise Decisions: Determinants and Consistency
05-30	Patric Andersson Richard Tour	How to Sample Behavior and Emotions of Traders:
05-29	Carsten Schmidt Ro'i Zultan	The Uncontrolled Social Utility Hypothesis Revisited
05-28	Peter Albrecht Joachim Coche Raimond Maurer Ralph Rogalla	Optimal Investment Policies for Hybrid Pension Plans - Analyzing the Perspective of Sponsors and Members

Nr.	Author	Title
05-27	Oliver Kirchkamp Rosemarie Nagel	Learning and cooperation in network experiments
05-26	Zacharias Sautner Martin Weber	Stock Options and Employee Behavior
05-25	Markus Glaser Thomas Langer Martin Weber	Overconfidence of Professionals and Lay Men: Individual Differences Within and Between Tasks?
05-24	Volker Stocké	Determinanten und Konsequenzen von Nonresponse in egozentrierten Netzwerkstudien
05-23	Lothar Essig	Household Saving in Germany:
05-22	Lothar Essig	Precautionary saving and old-age provisions: Do subjective saving motives measures work?
05-21	Lothar Essig	Imputing total expenditures from a non-exhaustive
05-20	Lothar Essig	Measures for savings and saving rates in the German SAVE data set
05-19	Axel Börsch-Supan Lothar Essig	Personal assets and pension reform: How well prepared are the Germans?
05-18	Lothar Essig Joachim Winter	Item nonresponse to financial questions in household surveys: An experimental study of interviewer and mode effects
05-17	Lothar Essig	Methodological aspects of the SAVE data set
05-16	Hartmut Esser	Rationalität und Bindung. Das Modell der Frame-Selektion und die Erklärung des normativen Handelns
05-15	Hartmut Esser	Affektuelles Handeln: Emotionen und das Modell der Frame-Selektion
05-14	Gerald Seidel	Endogenous Inflation - The Role of Expectations and Strategic Interaction

Nr.	Author	Title
05-13	Jannis Bischof	Zur Fraud-on-the-market-Theorie im US-amerikanischen informationellen Kapitalmarktrecht: Theoretische Grundlagen, Rechtsprechungsentwicklung und Materialien
05-12	Daniel Schunk	Search behaviour with reference point preferences:
05-11	Clemens Kroneberg	Die Definition der Situation und die variable Rationalität der Akteure. Ein allgemeines Modell des Handelns auf der Basis von Hartmut Essers Frame-Selektionstheorie
05-10	Sina Borgsen Markus Glaser	Diversifikationseffekte durch Small und Mid Caps?
05-09	Gerald Seidel	Fair Behavior and Inflation Persistence
05-08	Alexander Zimper	Equivalence between best responses and undominated
05-07	Hendrik Hakenes Isabel Schnabel	Bank Size and Risk-Taking under Basel II
05-06	Thomas Gschwend	Ticket-Splitting and Strategic Voting
05-05	Axel Börsch-Supan	Risiken im Lebenszyklus: Theorie und Evidenz
05-04	Franz Rothlauf Daniel Schunk Jella Pfeiffer	Classification of Human Decision Behavior: Finding
05-03	Thomas Gschwend	Institutional Incentives for Strategic Voting:
05-02	Siegfried K. Berninghaus Karl-Martin Ehrhart Marion Ott	A Network Experiment in Continuous Time:
05-01	Geschäftsstelle	Jahresbericht 2004
04-70	Felix Freyland	Household Composition and Savings: An Empirical Analysis based on the German SOEP data
04-69	Felix Freyland	Household Composition and Savings: An Overview