

# Satisficing in sales competition: experimental evidence

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## Abstract

In a stochastic duopoly market, sellers must form state-specific aspirations expressing how much they want to earn given their expectations about the other's behavior. We define individually and mutually satisficing sales behavior for given individual beliefs and aspiration profiles. In a first experimental phase, whenever satisficing is not possible, beliefs or aspirations have to be adapted, or other strategy profiles must be found. In a second phase, 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.

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# 1 Introduction

Fifty years ago, Herbert A. Simon (1955) published a paper that became a basis for five decades of development in the theory of choice. The paper investigated the informational and computational limits of human rationality and developed the central idea of bounded rationality theory, namely the “satisficing approach”. The cornerstone of this approach is a process that begins with a desired outcome, searches for actions sufficient to produce it, and adapts aspirations in the light of experience. According to Simon, decision-making in the form of satisficing 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,<sup>1</sup> only recently experimental economists have started investigating the avails of aspirations in laboratory. Some such experiments directly relate to Simon’s seminal work of aspirations and satisficing behavior, and render the satisficing approach applicable by considering portfolio selection tasks with state-specific aspirations (see, e.g., Fellner et al., 2005; Fellner et al., 2006; Güth et al., 2006; Güth, forthcoming).

The experiment reported in this paper still relies directly on Simon’s work, but differs from former experimental literature in two aspects. First, we consider a stochastic 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 are ready to change their aspirations whenever they cannot be satisfied or they would rather revise other components of their decisions.

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<sup>1</sup>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., Radner 1975a, 1975b; Leibenstein, 1976; and, more recently, Noreen and Burgstahler, 1997). An empirical test of how an optimizing search compares to a satisficing search has been conducted by, e.g., Markovitch and Rosdeutscher (1992).

The notion of “adjustment”, as it has been commonly used in theoretical models of boundedly rational behavior, allows agents to revise one of the elements 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, 1975b). In recent game theoretical models with satisficing players, aspirations are dynamically updated (Kim, 1999) or actions can be revised over time (Napel, 2003). However, the fundamental question of what *actually* individuals want to revise when their aspiration level, in a given period, cannot be met has hardly ever been addressed.<sup>2</sup> 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. We ask seller participants in our duopoly market experiment not only 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 are potentially realizable. 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 take ‘satisfactory’ decisions by themselves. Thus, in a second experimental 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

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<sup>2</sup>Tietz et al. (1978) and Tietz (1997) have imposed structured aspiration ladder of negotiators and confirmed aspiration balancing (both parties concede equally often in aspiration steps) in bargaining experiments, without eliciting beliefs or asking for action profiles.

beliefs, but allow them to freely choose their sales quantity. By this means, we can assess whether people voluntarily maintain satisficing after having experienced what it requires and how it generates behavior. The latter question is related to a former experiment by Güth et al. (2006), who have explored the absorbability (Güth & Kliemt, 2004) of the satisficing approach for decision problems with no strategic interaction.

A few existing work has studied whether aspiration-based satisficing behavior can explain findings typically observed in laboratory games. Kim (2002), for instance, used calibration methods to compare satisficing and fairness in ultimatum bargaining game experiments, and found that satisficing can explain the actual subjects' behavior surprisingly well. Napel (2003) considered repeated play of the ultimatum minigame to investigate the implications for efficiency and distribution of a satisficing heuristic in which players stick to their past action if it performed well relative to an endogenous aspiration level, and abandon it with positive probability otherwise (cf., Karandikar et al., 1998). Napel's simulations revealed that such satisficing behavior suffices to reach approximate efficiency, and provides a good explanation for the typically observed fair offers by proposers. These previous studies use simulations or calibrations to assess the performance of satisficing behavior in strategic settings. Like in earlier negotiation experiments (Tietz et al., 1978; Tietz, 1997), we investigate how well the satisficing approach, based on subjects' own aspiration levels, performs in a setting with strategic uncertainty where the structure of the game, the underlying payoff function, and the number of players are commonly known.<sup>3</sup>

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.

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<sup>3</sup>In this sense, our setting differs from experimental studies on "reinforcement learning", where subjects are ignorant of demand and cost functions, and adapt their actions over time in line with their profit experience (see Bendor et al., 2001 for a good overview of this literature).

## 2 The stochastic market and theoretical analysis

We study a homogeneous duopoly Cournot 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<sup>4</sup>

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

Here,  $p_i$  is the price 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  $0 < D_1 < D_2 < \dots < D_n$ . For the sake of simplicity, we assume that all  $n$  ( $\geq 2$ ) realizations of the stochastic variable  $D_i$  are equally probable. When selling  $x_i^j$  in state  $i$ , seller  $j$  ( $j = a, b$ ) earns

$$(1) \quad \pi_i^j = p_i x_i^j.$$

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  $i = 1, \dots, n$ , yielding the same state-dependent equilibrium profit of  $(D_i/3)^2$  for both sellers. The symmetric equilibrium strategy profiles are  $\mathbf{x}^a = \mathbf{x}^b = (D_1, \dots, D_n)/3$ . The latter assumes common knowledge of own profit maximization and true beliefs. Denoting by  $\hat{\mathbf{x}}^j = (\hat{x}_1^j, \dots, \hat{x}_n^j)$  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  $\hat{\mathbf{x}}^b = \mathbf{x}^a$ . Of course, boundedly rational sellers may not be able to predict their competitor's strategy profile perfectly.

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  $j$ 's aspiration profile is  $\mathbf{A}^j = (A_1^j, \dots, A_n^j)$  with  $A_i^j \leq A_{i+1}^j$  for all  $i < n$ , then the action profile  $\mathbf{x}^j = (x_1^j, \dots, x_n^j)$  with  $x_i^j \leq x_{i+1}^j$  for all  $i < n$ , satisfies the

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<sup>4</sup>Every 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.

aspiration profile  $\mathbf{A}^j$  of  $j$  if

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

We refer to (2) as seller  $j$ 's *individually satisficing requirement*.<sup>5</sup> 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 meaning that  $\mathbf{x} = (\mathbf{x}^a, \mathbf{x}^b) = \hat{\mathbf{x}} = (\hat{\mathbf{x}}^b, \hat{\mathbf{x}}^a)$ . Notice that  $\mathbf{x} = \hat{\mathbf{x}}$  implies rational expectations and, thus, one of the two axioms (rational expectations and optimality) of strategic equilibria (see Aumann & Brandenburger, 1995). This shows that mutual satisficing based on true beliefs is equivalent to equilibrium behavior.<sup>6</sup>

### 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 programmed using the z-Tree software (Fischbacher, 1999). 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.<sup>7</sup> 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

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<sup>5</sup>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, 1979, and Lilly, 1994).

<sup>6</sup>See, e.g., van Witteloostuijn (1988) and Lilly (1994) for earlier studies demonstrating that maximizing and satisficing can lead to comparable results.

<sup>7</sup>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).

randomly formed in each of the 24 repetitions (strangers design).<sup>8</sup> 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 a random variable and on the total quantity chosen by the two firms in the market.

The stochastic variable  $D_i$  of the linear aggregate demand function 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:  $\pi_1^* = 16$ ,  $\pi_2^* = 64$ ,  $\pi_3^* = 256$ .

In order to investigate our first major research question (i.e., whether satisficing is achieved by revising beliefs, adapting aspirations, or searching for new own sales strategy), 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

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<sup>8</sup>This should avoid the possibility of tacit collusion. See Holt (1985) and Huck et al. (2001) for experimental studies showing that collusion occurs only in partners design, where subjects are matched in fixed groups for the entire experiment.

the three states, (*ii*) the quantity they expected the other to produce and sell in each state, and (*iii*) the period-profit they wished to guarantee themselves in each state.

After having completed the tasks above, 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.<sup>9</sup> 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 choice may be different.

To assess our second major research question (i.e., whether individuals voluntarily rely on 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 avoid that the satisficing requirement is not met due to utterly unrealistic beliefs or insincere aspirations, 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

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<sup>9</sup>This let participants experiment with the various aspects of the problem.

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

$$(3) \quad \pi_i^j = [D_i - x_i^j - x_i^k]x_i^j \geq A_i^j$$

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  $\pi_l^j \geq A_l^j$ . One may object to paying aspirations rather than actual profits as this may affect market incentives. One justification is that this only implements the usual interpretation of aspiration levels, namely that one primarily cares for achieving aspired period-profits. The other justification is that we did not want to elicit ‘cheap-talk’ aspirations (like, for instance, Fellner et al. 2005), but rather try to render the aspiration choices payoff relevant.

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, and their own period-earnings as determined by the random move selecting whether they got paid according to aspirations or beliefs.

## 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 own 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,  $p = 0.980$ ).<sup>10</sup> 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 theoretical solution of 16 ( $p = 0.029$  in both phases).

Turning to beliefs, in general, they 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 are found to 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 only ( $p > 0.28$  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; one-sided Wilcoxon test). Such finding already suggests that our participants are not always able to make optimizing choices.

Figure 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 stays rather constant after the fourth period (Spearman’s  $\rho$  between aspirations and “*periods 5–12*” are 0.047 and 0.001 for states 1, and 2;  $p > 0.10$  always).

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<sup>10</sup>Unless otherwise stated, all statistical tests are based on the 16 independent observations.

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 ( $\rho = 0.016$ ,  $p = 0.409$ ).<sup>11</sup> 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 appear to become “more demanding”, in the sense of improving their desired period-profit, in the second 12 periods.

[Figure 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  $\bar{A}_i$  the average aspirations in state  $i$ , with averages over players for each matching group, Spearman’s  $\rho$  between  $\bar{A}_3 - \bar{A}_1$  and “*periods 1–12*”, in phase 1, is 0.402,  $p < 0.001$ ). The same holds if we look at 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 ( $\rho_{\bar{A}_3 - \bar{A}_2} = 0.384$ ,  $\rho_{\bar{A}_2 - \bar{A}_1} = 0.306$ ;  $p < 0.001$  in both cases). If we consider only the last 8 periods, the gap between aspirations in the best state 3 and either other state still widens over time, though to a smaller degree ( $\rho$  between  $\bar{A}_3 - \bar{A}_1$  and “*periods 5–12*” is 0.192;  $\rho$  between  $\bar{A}_3 - \bar{A}_2$  and “*periods 5–12*” is 0.254;  $p < 0.03$  in both cases); however, the increasing time trend in the spread between  $\bar{A}_2$  and  $\bar{A}_1$  vanishes ( $\rho = 0.014$ ,  $p = 0.870$ ). All considered aspiration gaps remain stable in the second phase ( $\rho_{\bar{A}_3 - \bar{A}_1} = 0.003$ ;  $\rho_{\bar{A}_3 - \bar{A}_2} = -0.034$ ;  $\rho_{\bar{A}_2 - \bar{A}_1} = 0.02$ ;  $p > 0.05$ ).

## 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 details about individual behavior.

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<sup>11</sup>The picture does not change if we consider only periods 5 to 12.

### 4.2.1 Aggregate data

We start examining what participants revise more often among beliefs, aspirations, and own choices when satisficing requirement (2) does not hold. To address this issue, we separate the data according to phase because compliance with satisficing is mandatory in phase 1 and voluntary in phase 2. Figure 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. Figure 3 provides the same number for phase 2.

[Figures 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 is confirmed if we consider 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%).<sup>12</sup> Furthermore, most inconsistencies with satisficing are detected in state 1 where the number of satisficing choices is 1311, which compares to 1340 (1441) satisficing choices in state 2 (3). Participants seem, therefore, to encounter particular difficulties in complying with satisficing in the worst scenario.

Turning to the second phase, where compliance with satisficing was voluntary, we find that out of the 1368 observations which were informed to be not

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<sup>12</sup>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%.

satisficing, 150 decide to revise some of the possible profiles. As suggested by Figure 3, also in phase 2, aspirations are revised more often (62% of the times) than one's own and expected choices, which are modified at a similar frequency (expectations: 21%; own choices: 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? Figure 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.

[Figure 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, meaning that, pooling the 12 periods of phase 2, 1080 times participants behave satisfactorily by specifying action and beliefs profiles which satisfy their aspiration profile. 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. Figures 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).

[Figures 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 in our experiment aspire to profits which are significantly smaller than those they might aim for, given their beliefs about the opponent's behavior. In other words, our participants appear to satisfice rather than maximize expected profits, thereby contradicting models based on an intermediate level of rationality, such as "belief learning" (Fudenberg & Levine, 1998; Young, 1998).

According to Figure 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  $\bar{A}_i$  denotes the average aspirations in state  $i$ , a correlation analysis confirms that the gap between  $E(\pi_i)$  and  $\bar{A}_i$  shrinks significantly over time for all  $i$  (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).<sup>13</sup>

#### 4.2.2 A closer look at the individual data

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

1. *Never satisficers*: subjects who are requested to change some component of the choice problem in each single period.
2. *Later satisficers*: subjects who do not succeed in choosing and persisting with immediately satisficing sales profiles until period  $t$ , with  $t \in$

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<sup>13</sup>The results for both phases do not qualitatively change if we take into account only periods 5–12; the magnitude of the coefficient  $\rho$  just becomes a little smaller in absolute value in phase 1 for each of the three states.

{9, 10, 11, 12}.

3. *Intermediate satisficers*: subjects who do not choose and persist with immediately satisficing sales profiles until period  $t$ , with  $t \in \{5, 6, 7, 8\}$ .
4. *Early satisficers*: subjects who choose immediately satisficing sales profiles either over all 12 periods or at least over the last 9 periods.

In phase 2, where compliance with satisficing requirement (2) was willful, we rely on a similar classification, but refer categories to whether subjects choose satisficing sales actions or not.

1. *Non-satisficers*: subjects who never comply with requirement (2).
2. *Weak satisficers*: subjects who do not start abiding by and persisting with (2) until period  $t$ , with  $t \in \{9, 10, 11, 12\}$ .
3. *Moderate satisficers*: subjects who do not choose and persist with satisficing sales profiles until period  $t$ , with  $t \in \{5, 6, 7, 8\}$ .
4. *Strong satisficers*: subjects who choose satisficing sales actions 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 choose satisfactory sales profiles *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 manage to comply with satisficing immediately. There are some participants who do not fall in any of the identified categories. These subjects make immediate satisficing choice in some of the 12 periods of phase 1 in a purely random manner.

The individual data for phase 2 are also quite comforting for the satisficing approach: 48% subjects spontaneously choose satisficing sales profiles for at least the last two-thirds of the phase (in particular, 37% behave satisfactorily over all 12 periods). Only 11% of the subjects never obey requirement (2); these

“non satisficers” are those who, in the previous phase, either never satisfy or are unclassifiable.

The final step in our analysis is to investigate whether there is any overlapping between the various categories of the two phases. We find that 29 out of 53 early satisficers in phase 1 are strong satisficers in phase 2. Moreover, 18 out of the 24 intermediate satisficers in phase 1 are either strong or moderate satisficers in phase 2. These results indicate that, when making sales decisions in stochastic duopoly markets, a non negligible number of individuals follows boundedly rational satisficing.

## 5 Conclusions

We have experimentally tested the satisficing approach in a strategic setting. In particular, we relied on a multi-period homogeneous stochastic duopoly market, where, in every period, seller participants must choose their own sales profile, predict the competitor’s sales profile, and form state-specific profit aspirations. In this endeavor, an individual’s actions profile is said to be individually satisficing if it allows the potential achievement of the desired period-profit, given the expectations about the other’s behavior.

In the first experimental phase, we forced duopolists to specify mutually satisficing state-specific aspirations, by revising any component of their decision problem. In the second phase, we still imposed the satisficing routine, but allowed participants to freely choose their sales strategy.

On the aggregate level, the two main results are that the overwhelming majority of seller participants is willing to adapt aspirations until they become potentially realizable, and keeps on voluntarily choosing satisficing sales profiles. We also observe that aspirations in any state of nature are systematically below expected profits, suggesting that individuals do not even attempt to maximize expected profits when forming their aspiration levels. A further interesting

result of our experiment is that the worst state of nature triggers, overall, less satisficing choices than the other two states. It seems, therefore, that the prospective of a very low gain somehow leads participants to be not satisficing.

The analysis of the individual data shows that more than 40% of the subjects can be classified as ‘early satisficers’ (they immediately choose satisficing sales profiles at least over the last 9 periods of phase 1), and 48% are ‘strong satisficers’ (they spontaneously set satisfactory strategies at least over the last 9 periods of phase 2). Thus, while recent experimental contributions have provided mixed and unclear evidence for the satisficing approach in portfolio selection tasks (see Güth, forthcoming, for a survey), the experimental evidence garnered here suggests that people follow boundedly rational requirements in stochastic duopoly markets.

One can think of several ways of extending the experimental design used in this study to address other interesting questions associated with satisficing. For instance, although 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), it has the drawback that one considers only herself as satisficing, but not her competitor. In a follow-up study, we intend to replace expected sales profiles with expected aspiration profiles, so as to check whether there exist sales profiles allowing one’s own and the other’s expected profit aspirations to be fulfilled.

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# 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, . . . , 19, or 20. In the following, we shall refer to the quantity chosen by you as  $x_{\text{you}}$ , and to the quantity chosen by the other firm as  $x_{\text{other}}$ .

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

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

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 your 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 satisfying 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 satisfying 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.

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

<i>Phase</i>	Variable	Mean	Median	Std. Dev.
1 (period 1–12)	<i>Profit</i>	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)	<i>Profit</i>	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

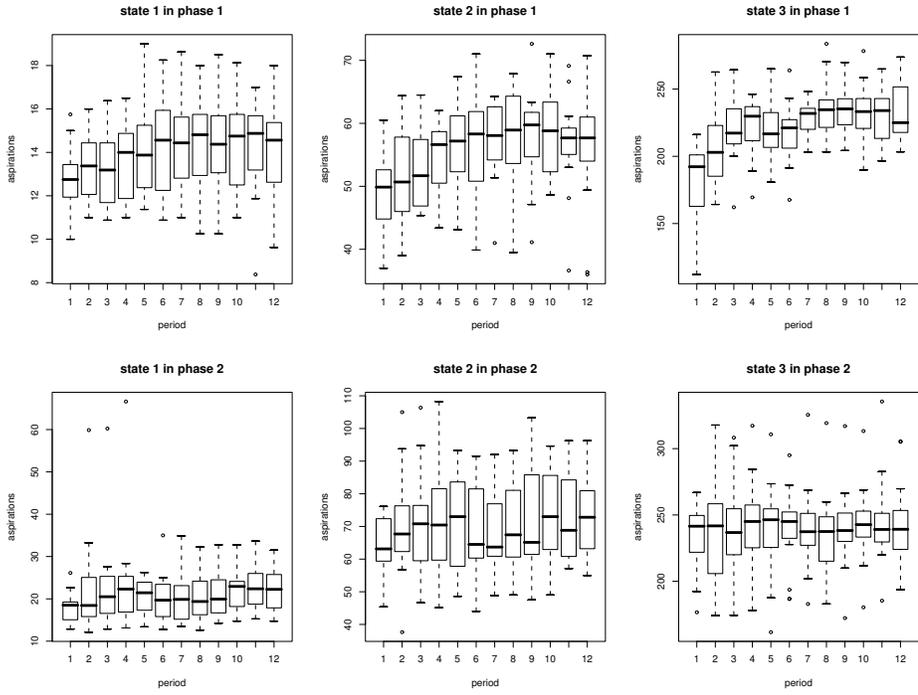


Figure 1: Aspirations across periods for each state of nature in both phases.

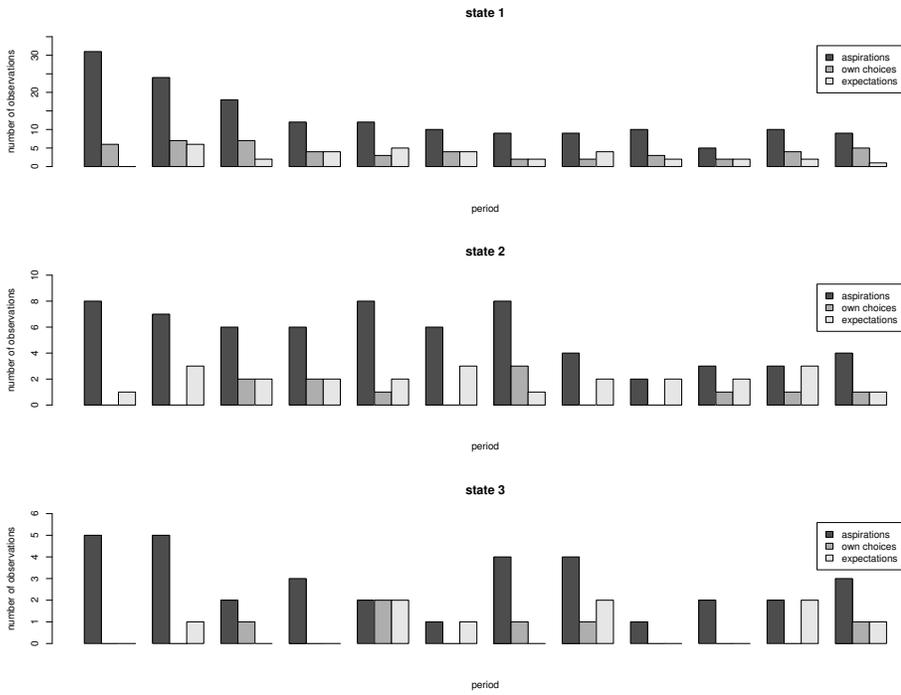


Figure 2: Number of changes in own choices, expectations and aspirations over all 12 periods of phase 1, separately for each state of nature.

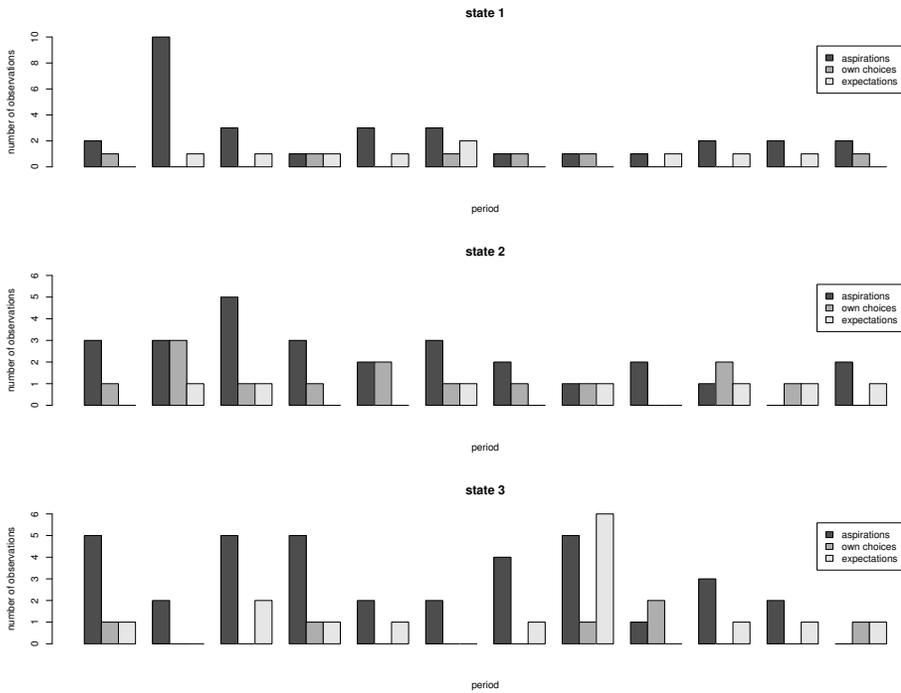


Figure 3: Number of changes in own choices, expectations and aspirations over all 12 periods of phase 2, separately for each state of nature.

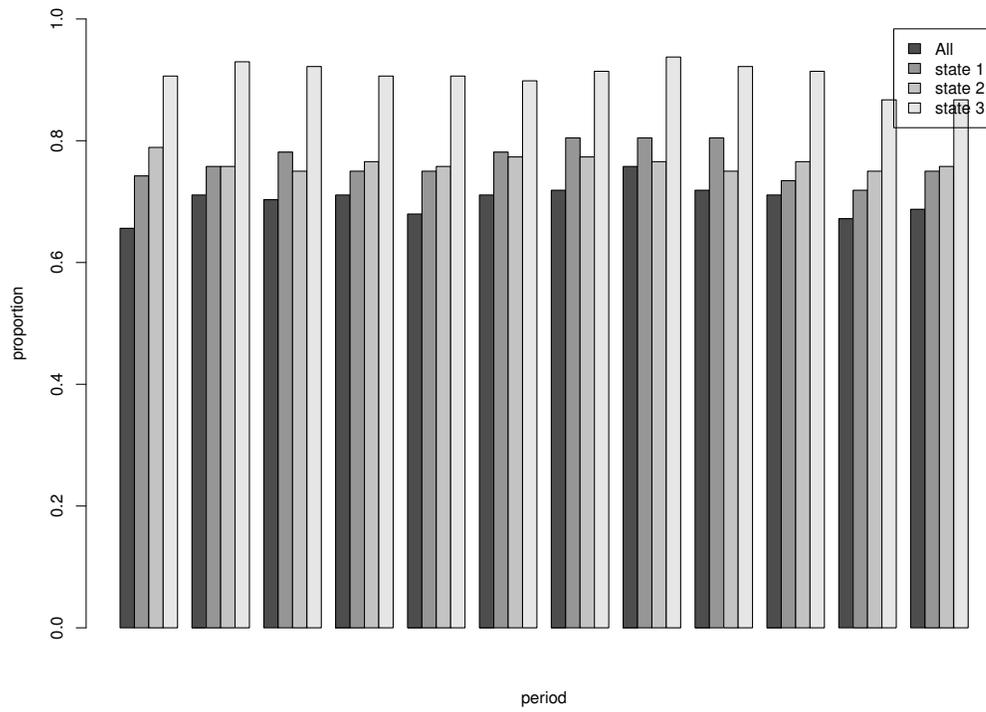


Figure 4: Frequency of observations complying with satisficing for all three states and for each state separately over all 12 periods of phase 2.

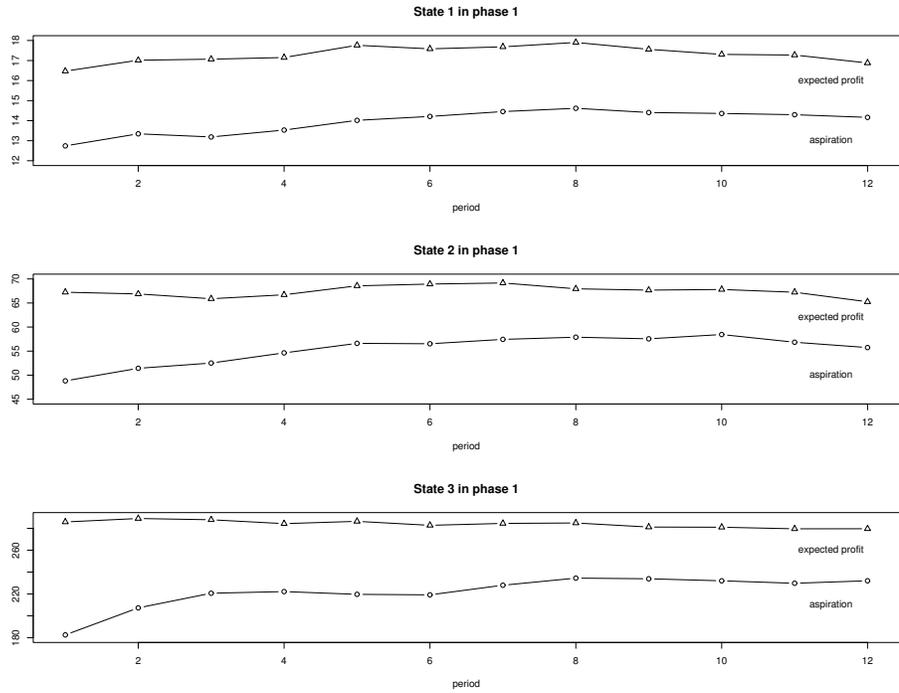


Figure 5: Aspirations and expected profits over all 12 periods of phase 1.

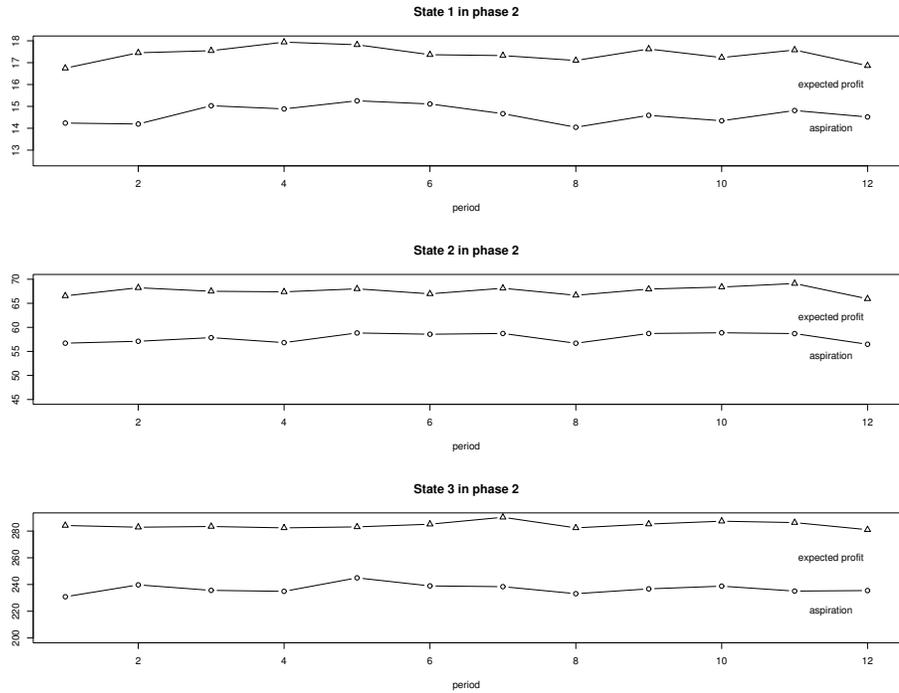


Figure 6: Aspirations and expected profits over all 12 periods of phase 2.