Tacit Coordination in a Decentralized Market Entry Game with Fixed Capacity

Rami Zwick

Hong Kong University of Science and Technology

Amnon Rapoport

Hong Kong University of Science and Technology

March 16, 1999

Please address all correspondence to:
Rami Zwick
Department of Marketing
Hong Kong University of Science and Technology
Clear Water Bay,
Kowloon, Hong Kong
Phone: 852-2358-7695
Fax: 852-2358-2429
Email address: mkzwick@ust.hk

Acknowledgement
The research reported here has been supported in part by NSF Grant No. SBR-9512724 on market entry games awarded to Amnon Rapoport and Kenneth Koput, and in part by a grant from the Hong Kong Research Grants Council (Project No. CA98/99.BM01). The second author wishes to thank the Marketing Department at the Hong Kong University of Science and Technology for its support and hospitality.

Abstract

Tacit coordination is studied experimentally in a class of iterated market entry games with a relatively small number of potential entrants (n = 6), symmetric players, and fixed entry fees. These games are intended to simulate a situation where a newly emergent market opportunity may be fruitfully exploited by no more than a fixed and commonly known number of firms. Our results indicate a high degree of sensitivity to the game parameters that are manipulated in the study, namely, the market capacity, entry fee, and method of subject assignment to groups (fixed vs. random), as well as sophisticated adaptation to actual and hypothetical changes in wealth level. We find no support for convergence to equilibrium play on either the aggregate or individual level or for any trend across rounds of play to maximize total group payoff by lowering the frequency of entry. The coordination failure is attributed to certain features of the payoff function that induce strong competition in the attempt to penetrate the market.

1. Introduction

In his classical treatise on coordination in noncooperative n-person games with multiple pure-strategy equilibria, Schelling argued more than forty years ago that “some essential part of the study of mixed motive (non-zero-sum) games is necessarily empirical” (1960, p. 162). After twenty five more years of research in game theory and extensive attempts to develop “refinement” criteria (e.g., van Damme, 1987) to eliminate equilibria that, to a rational player, would appear to rest upon non-credible threats, Lucas concluded that equilibrium theory does not resolve the question of how groups of agents behave in a particular interdependent decision situation. Like Schelling before him, he argued that “It is hard to see what can advance the discussion short of assembling a collection of people, putting them in the situation of interest, and observing what they do” (1986, p. 237).

Faced with this challenge, experimenters have devised a large variety of games with multiple pure-strategy equilibria (e.g., the Battle-of-the-Sexes game; the “minimum” and “median” coordination games investigated, respectively, by van Huyck, Battalio, & Beil, 1990, 1991) to study coordination with no preplay communication in the controlled environment of the laboratory. Included in these games are market entry games (see Ochs, 1995, for a general review) whose purpose is to understand if and how competitive markets coordinate decentralized allocation decisions (e.g., Meyer, van Huyck, Battalio, & Saving, 1992; Ochs, 1990; Rapoport, Seale, Erev, & Sundali, 1998; Sundali, Rapoport, & Seale, 1995). The choice of market entry games for studying coordination is quite natural. When there are too many potential entrants wishing to exploit a new market opportunity, a problem arises regarding how entry may be coordinated. Without coordination, too many firms may decide to enter the market and consequently sustain losses. Conversely, fully aware of the consequences of excessive entry, firms may be reluctant to enter and exploit the market in the first place (Nti, 1996).

Previous Research

The coordination problem caused by simultaneous entry in markets with too many potential entrants has been the subject of several experimental studies, which differ from one another in many important details.

Ochs (1990). In the study reported by Ochs (1990), a market consisted of a set of h locations ("markets") at which units of stock were known to be available and a set of n agents ($n > h$) each of whom instructed to select a single location ("enter one of the h markets"). At the beginning of each period, a possibly different distribution of stocks $\underline{\mathbf{s}} = (s_1, s_2, \ldots, s_h)$ was publicly announced, where s_i ($s_i > 0$, $i = 1, 2, \ldots, h$) is the number of stock units in location i and $\sum s_i = n$. The payoff function depended on the number m_i of agents entering market i ($m_i \geq 0$, $\sum m_i = n$). If $m_i \leq s_i$, each agent entering market i gained x cents, whereas if $m_i > s_i$, then s_i agents were selected at random from the m_i agents and paid x cents each. In all other cases, unsuccessful agents earned y cents each ($y < x$). Clearly, any allocation of the n agents over the h markets which satisfies $m_i = s_i$ is an equilibrium. In addition to the multiplicity of asymmetric pure-strategy equilibria, this market entry game also has a unique symmetric equilibrium in mixed strategies.

Meyer et al. (1992). Meyer et al. (1992) studied another coordination problem in a binary allocation game where each of n symmetric agents, in a finitely repeated game, was required to choose between two pots ("markets") labeled A and B. Choices were made simultaneously. The payoff for each agent was determined from a payoff table associated with each of the markets and the number of agents entering each market. The payoff tables presented the earnings an agent could expect to gain if a total of 0 through n agents entered the given market; these earnings were in turn computed from either linear or isoelastic inverse demand functions. Because each market had the same payoff function associated with it, a pure strategy equilibrium for this game is characterized by equality of payoff and number of entrants across both markets. Similarly to the market coordination game examined by Ochs, this two-market entry game has multiple asymmetric equilibria in pure strategies as well as a unique symmetric mixed-strategy equilibrium in which the expected payoff is the same across both markets.

Sundali et al. (1995). Sundali et al. (1995), and subsequently Rapoport, Seale, Erev, and Sundali (1998), investigated coordination behavior in yet another class of market entry games which include only a single market with a commonly known capacity that is changed randomly from period to period. This game is played by a group N of n symmetric agents. On each period (stage game), a different integer c ($1 \leq c \leq n$), interpreted as the "capacity of the market", is publicly announced. Then each player i ($i \in N$) must decide privately whether to enter the market ($d_i = 1$) or stay out of it ($d_i = 0$). The payoff for each stage game is determined from

$$H_i(\underline{\mathbf{d}}) = \begin{cases} v & \text{if } d_i = 0 \\ k + r(c - m) & \text{if } d_i = 1 \end{cases}$$

where $H_i(\underline{\mathbf{d}})$ is agent i's payoff for the period, $\underline{\mathbf{d}} = (d_1, d_2, \ldots, d_n)$ is the vector of individual decisions, m is the number of entrants ($0 \leq m \leq n$), and k, r, and v, are real-valued parameters which have been varied across experiments. This game has complete information, binary actions, zero entry costs, and an incentive to enter the market which decreases linearly in the number of entrants. Unlike the previous two experiments by Ochs and by Meyer et al., it allows each agent the option of staying out of the market and receiving a payoff, positive or negative, which does not depend on the decisions of the of the other n - 1 agents. Similarly to these two studies, the game has multiple equilibria in pure strategies, in which a subset of the n players whose size depends on the values of the parameters c, k, r, and v, enter the market as well as a unique symmetric mixed strategy equilibrium.

Conclusions. These studies differ from one another not only in the number of markets, payoff function, and major purposes of the study, but also in other aspects of the experimental design including group size, number of periods, stationary vs. non-stationary sets of subjects, and amount of previous experience with the game. A comparison of the results of these studies indicates, perhaps not surprisingly, that these details matter. Consequently, understanding how entry is coordinated when there are more potential entrants than the market can bear can only emerge gradually from a systematic experimental study of a variety of market entry games that differ from one another in their institutional details.

A second general conclusion is that the equilibrium solution organizes the aggregate data in these studies quite well. In reviewing the experiment of Ochs (1990), Ochs reports that “The responsiveness of the distribution of choices to variants in the distribution of stock both within and across markets is remarkably consistent with the symmetric Nash equilibrium hypothesis” (1995, p. 235). Using subjects with previous experience, Meyer et al. report that “such experienced subjects used historical precedents to coordinate on pure-strategy equilibrium outcomes” (1992, p. 315). However, as pointed out by Ochs (1995), this interpretation of the data is neither general nor by any means compelling. The aggregate data of Ochs can be reasonably interpreted as consistent with the probability of an agent selecting a particular market i being proportional to $s_i/\sum s_i$. Meyer et al. observed that under their linear payoff condition their data were inconsistent with the mixed strategy equilibrium and that inexperienced subjects failed to converge to a pure-strategy equilibrium. Finally, Rapoport et al. (1998) report that the mixed strategy equilibrium in their study can account for the mean but not for the variability in the number of entrants. Their analysis of the data of individual subjects clearly rejects the mixed strategy equilibrium hypothesis.

A third and related general conclusion concerns a shift in emphasis in the research on coordination in iterated market entry games. Clearly, there is no compelling reason to believe, *a priori*, that agents sharing no common history on which to condition their choices will achieve perfect coordination in these games (Ochs, 1995). Nor is there any particular reason to believe that agents can randomize their choices across iterations of the same stage game, producing sequences of responses that pass statistical tests for independent and identically distributed events. The time series analysis conducted by Meyer et al. and the analysis of switches in decision across iterations of the same stage game suggest that it is more reasonable to take an evolutive defense (Binmore, 1987) of the equilibrium concept, which maintains that subjects are boundedly rational and sometimes poorly motivated, finding their way to equilibrium play by some process of trial-and-error adjustment. This approach has been pursued by Erev and Rapoport (1998) and Rapoport et al. (1998).

Building on the market entry game that was studied theoretically by Nti (1996), the present study investigates coordination behavior in a different noncooperative n-person game intended to simulate a situation where a newly emergent market opportunity may be fruitfully exploited by no more than h firms[1]. (See also the "market niche" game in Gardner, 1995, that has a similar qualitative structure.) The game shares a few features with the market entry games described above. Like the game introduced by Sundali et al. (1995) and Rapoport et al. (1998), it has only a single market with fixed capacity, and it allows firms to stay out of it and receive a

[1] The assumption here is that if more than h firms enter the market, the intense competition drive all of them to unprofitable outcome, losing the funds invested in the entry effort.

fixed payoff. And like the game studied by Ochs (1990), firms are successful as long as the number of entrants does not exceed the market capacity h.

However, the present game differs from previous market entry games is four major respects. First, it introduces an entry cost which is non-recoverable. Second, in the case of over-entry the individual payoff no longer decreases linearly in the number of entrants as in studies of Sundali et al. (1995) and Rapoport et al. (1998). And in the case the number of entrants does not exceed the market capacity, the individual payoff is no longer independent of the number of entrants, as in Ochs (1990). Rather, we use a payoff function in which the punishment for excess entry is considerably more severe than in previous studies, with entrants losing their cost of entry if the number of entrants exceeds the market capacity by even a single entrant. Third, the cost of deviation from pure-strategy play in the present study is several times higher than in previous studies. For example, the pure-strategy equilibrium payoff in the study of Sundali et al. was the same for entrants and non-entrants and the cost of unilateral deviation was relatively small. In contrast, as explained below, non-entrants in our study receive nothing whereas entrants receive a relatively high payoff that, under pure-strategy equilibrium play, exceeds their entry cost by a factor ranging from 2.3 to 99. A fourth and final difference concerns the number of players. Previous studies of coordination in market entry games focused on relatively large groups (n = 20 in the studies of Sundali et al, and Rapoport et al.). In the present study, group size is much smaller (n = 6). Consequently, with the parameter values used in the present study, the effect of any player on the group outcome is considerably enhanced. All of these features were incorporated into our experiments in order to extend the study of tacit coordination to conditions that invoke fiercer competition among potential entrants.

Section 2 describes the new coordination game and characterizes its equilibria. Sections 3 and 4 describe the method and the results of two experiments using either stationary or non-stationary sets of subjects. Section 5 concludes with a brief discussion of the results.

2. The Market Entry Game

The market entry game is played by a group N of n players, n $\geq$ 2. On each period (stage game), each player must decide privately and anonymously whether or not to enter a given market that may be profitably exploited by no more than h players. Each player is charged an irrecoverable entry fee of size k. The payoff function—the same for all n players—is given by

$$H_i(d_i, m) = \begin{cases} u_i(v) & \text{if } d_i = 0 \\ u_i(e/m - k) & \text{if } d_i = 1 \text{ and } 1 \leq m \leq h \\ u_i(-k) & \text{if } d_i = 1 \text{ and } m > h \end{cases}$$

where m is the number of entrants (0 $\leq$ m $\leq$ n), k (0 < k) is the common cost of entry, and e is the market potential available to be jointly exploited by no more than h firms (exclusive of the entry cost). We assume that e > k > v. Asymmetry between players could be introduced, for example, by charging differential entry fees, k_i, by varying the payoff for staying out, v_i, or both. However, in the present study we set k_i = k for all i, and normalize the payoff for staying out at v = 0.

With the payoff structure described above, the market entry game is an n-person generalization of the game of Chicken. It reduces to the standard two-person game of Chicken if n = 2 and h = 1, where a risk-neutral entrant receives a positive payoff of e - k if he is the sole entrant, and -k if both players enter. It also reduces to the standard game of Chicken if n = h = 2, provided that k > e/2. In our two experiments, we vary the values of both h and k, but always require that e/m > k for any 1 $\leq$ m $\leq$ h.

Equilibrium Analysis

The market entry game (Eq. 1) has $\binom{n}{h}$ asymmetric equilibria in pure strategies where exactly m = h players enter, and n – m stay out. As mentioned earlier, the payoffs for the two subgroups of entrants and non-entrants are quite different. Under pure-strategy equilibrium play, entrants receive a positive payoff and non-entrants receive nothing. To derive the symmetric mixed strategy equilibrium, denote the equilibrium probability of entry by y. In equilibrium, each player should be indifferent between entering and staying out. Hence,

$$u\left[\frac{e}{1}-k\right]\binom{n-1}{0}y^0(1-y)^{n-1}+u\left[\frac{e}{2}-k\right]\binom{n-1}{1}y^1(1-y)^{n-2}+\ldots+u\left[\frac{e}{h}-k\right]\binom{n-1}{h-1}y^{h-1}(1-y)^{n-h}-$$

$$u(k)[\ 1-\binom{n-1}{0}y^0(1-y)^{n-1}-\binom{n-1}{1}y^1(1-y)^{n-2}-\ldots-\binom{n-1}{h-1}y^{h-1}(1-y)^{n-h}\ \ ]=u(v). \qquad (1)$$

Collecting terms, this expression can be written more compactly as

$$\sum_{m=0}^{h-1}\left(u[\frac{e}{m+1}-k]\binom{n-1}{m}y^m(1-y)^{n-1-m}\right)=u(k)\left(1-\sum_{m=0}^{h-1}\binom{n-1}{m}y^m(1-y)^{n-1-m}\right)-u(v). \qquad (2)$$

The equilibrium probability of entry, denoted by y*, is the solution of this polynomial equation. If h = 1, Eq. (2) reduces to

$$u(e-k)(1-y)^{n-1}=u(k)\left[1-(1-y)^{n-1}\right]-u(v). \qquad (3)$$

The equilibrium probability of entry in this case can be computed directly from the expression:

$$y=1-[\ \frac{u(k)-u(v)}{u(e-k)+u(k)}\ ]^{\frac{1}{n-1}}. \qquad (4)$$

In particular, assuming risk-neutrality on the part of all the n players, and setting v = 0 as in our two experiments, Eq. (4) reduces to (see also Nti, 1996):

$$y = 1 - \left(\frac{k}{e}\right)^{\frac{1}{n-1}}. \qquad (5)$$

In the experiments described in Section 3 below, we keep the values of v at zero, the group size at 6, and the endowment at HK$500.00, but manipulate the parameters h and k in a 2 × 2 factorial design, with h assuming the values 1 and 3 and k assuming the values 5 and 50. This results in four different games (denoted by (h, k)). Assuming risk-neutrality, the equilibrium probability of entry, y*, for these four games, computed from Eq. (2) for h = 3 and from Eq. (5) for h = 1 (n = 6 in each case), are presented in column 3 of Table 1.

--Insert Table 1 about here—

These equilibrium probabilities of entry do not maximize group profit and, consequently, individual profit. In all four games, the n players can increase their expected payoffs if all decrease their probability of entry. Assuming risk-neutrality, the probabilities that maximize group (and, consequently, individual) expected payoff, denoted by y**, are the ones that maximize the expression (for selected values of h, k, and n):

$$\sum_{m=1}^{h}\left(\frac{e}{m} - k\right)\binom{n}{m} y^m (1-y)^{n-m} - k \sum_{m=h+1}^{n} m \binom{n}{m} y^m (1-y)^{n-m}. \qquad (6)$$

If h = 1, this expression simplifies to

$$ey(1-y)^{n-1} - ky. \qquad (7)$$

Differentiating this expression with respect to y and setting the derivative equal to zero yields the following expression from which y** can be computed numerically:

$$(1-y)^{n-2}(1-ny) = \frac{k}{e}. \qquad (8)$$

Table 1 (column 5) presents the values of y** for each of the four games played in our experiments. The associated expected payoffs are displayed in the right-hand column of the table. These are to be compared with the expected payoff under equilibrium play, EV(y*) = 0, which is considerably lower. Figure 1 depicts the expected value functions for the four games for values of y ranging between 0 and 1.

--Insert Figure 1 about here--

Figure 1 shows that if all the players deviate from equilibrium play by lowering their probability of entry y, all can increase their expected payoff considerably. Note, too, that the expected value functions are not at all flat, and that even small deviations from y* result in substantial gains or losses. As mentioned earlier, this result differentiates the present study from previous market entry game studies. Moreover, gains or losses associated with deviations of *all* the players from the equilibrium entry probability y* are considerably higher than those in all previous market entry studies. Therefore, the incentive of collective deviation from y* in the present study is stronger. If the subjects could reach tacit agreement after multiple iterations of the stage game, one would expect that the relative frequency of entry deviates from y* in the direction of y**.

Reported below are two experiments that were designed to test the implications of the equilibrium solutions. There are two general "directional" hypotheses that predict a decrease in the rate of entry as the entry cost k is increased from 5 to 50, and an increase in the rate of entry as the market capacity h is changed from 1 to 3. The pure-strategy equilibrium, which requires symmetric players to behave asymmetrically, is only testable on the group level. In contrast, the symmetric mixed-strategy equilibrium is testable on the individual level. Clearly, it is unrealistic to expect perfect coordination by boundedly rational and inexperienced players from the outset;

hence, the large number of iterations of each of the four games, which allows for learning. Because the dynamics of play often depends on the group composition, we conduct two experiments in a between-subjects design, one with stationary and the other with non-stationary groups of subjects.

3. Method

Subjects

One hundred and forty four undergraduate business students from the Hong Kong University of Science and Technology participated in two experiments. Each subject participated in a single session that lasted about 60 minutes. Subjects were recruited through advertisements placed on bulletin boards on campus and class announcements. The announcements promised monetary reward contingent on performance in a marketing study.

Procedure[2]

The subjects were seated in a computer laboratory containing fifty terminals that prohibited any communication between subjects. All the decisions were made and transmitted through terminals. The instructions were read off the PC screens.

The subjects were run in groups ranging in size from 12 to 24. They were instructed that they would play many rounds of the same six-person game. On each round, each player would have to make a binary decision (press either a Blue or Red button) privately and anonymously. Individual payoffs on each round would depend on the decision made by the subject as well as the decisions made by the other five group members. In Experiment RA that used the <u>random assignment</u> method, the subjects were told that the group composition would be determined randomly at the beginning of each round. In Experiment FA that used the <u>fixed assignment</u>

method, they were instructed that group composition would remain fixed for the entire duration of the experiment.

On each round, before the subjects decided which button to press, a table showing the payoffs for each possible outcome of the round was presented on the screen (Table 2). After all the subjects made their decision by pressing either the Blue or Red button, the computer displayed the outcome of the round by highlighting (in yellow) the appropriate column.

--Insert Table 2 about here--

In each experiment, the subjects participated in 96 rounds of play with payoff tables changing from round to round (see below). They were informed that at the end of the session their payoff would be determined by the outcomes of eight randomly selected rounds. At the beginning of the session, each subject was given a fixed endowment worth HK$60. At the end of the session, the mean payoff from the eight randomly chosen trials was added (if positive) or subtracted (if negative) from this endowment. Across all 96 rounds, the subjects lost on the average $7.75, leaving them with mean take home payoff of $52.25[3]. In comparison, with v = 0, the net payoff that would have accrued under equilibrium play is $60.

Experimental Design

Ninety-six subjects participated in Experiment RA, and 48 in Experiment FA. A 2 (market capacity) × 2 (entry cost) × 2 (entry color) × 12 (replications) within-subjects factorial design was used in each of the two experiments. The endowment was fixed at e =$500 for each round of play. Market capacity was either h = 1 or h = 3, and entry cost was set at either k = $5 or k = $50. Table 3 presents the individual payoff for entrants as a function of number of entrants

[2] The computer program we have used (java) as well as full instructions for the study are available for download in http://home.ust.hk/~mkzwick/megame/megame.html

(m), market capacity (h), and entry cost (k). Entry color was randomly changed from round to round to prevent response biases. The subjects played each combination of the first three factors 12 times (replications) for a total of 96 rounds. The 96 rounds were divided into 12 blocks of 8 rounds each. Within each block, the 8 rounds were presented in a different random order.

--Insert Table 3 about here--

4. Results

Group Level Analysis

We conducted eight different χ^2 tests (four games by two experiments) to test for the null hypothesis of no association between number of entrants and entry color (either Blue or Red). None of these tests was significant ($p > 0.2$). With no evidence for response bias due to color, the results of all subsequent analyses are collapsed across the color variable.

To investigate the effect of experience, the 24 trials (12 replications by 2 colors) in each game were divided into 6 blocks of 4 trials each. Table 4 presents the frequency distributions of number of entries by experiment, and nested within each experiment by game (h, k), and block. For each of the eight boxes, the rows indicate the number of entrants (0, 1, . . . , 6) and the columns the block of play. The seventh column presents the frequency distribution summed across the six blocks, and the right-handed column shows the corresponding relative frequency distribution. The number of subjects who entered the market in each block are shown at the bottom of each column (the frequency of entry in each column is $4 \times 16 = 96$ for Experiment RA and $4 \times 8 = 32$ for Experiment FA). The shaded areas indicate those rounds for which the number of entrants (when it is not zero) is equal to or smaller than the market capacity. Players who entered the market in these rounds earned a positive return. The percentage of these rounds is

[3] The hourly wage for on-campus job was HK $50 per hour.

displayed in a shaded cell to the right of each box. Players who entered the market in all other rounds lost their entry fee. The row in each game that corresponds to the pure strategy equilibrium (m = h) is enclosed by a single line boarder.

--Insert Table 4 about here--

Table 5 presents the mean (and standard deviation) of the number of players who entered the market in each game, the mean entry proportion (i.e., the mean divided by 6), and the corresponding mixed strategy equilibrium probability of entry y* (see Table 1). The following results can be observed by jointly examining Tables 4 and 5; they are all confirmed by the statistical analyses reported below.

--Insert Table 5 about here--

<u>Block effect</u>. Cochran-Armitage tests for trend in proportions (Margolin 1988)[4] were conducted on the marginal frequencies at the bottom of each box in Table 4. Evidence for a trend across blocks appeared in only two cases out of eight (two experiments by four games): an increasing trend in game (1, 50) of Experiment RA[5], and a decreasing trend in game (3, 5) of Experiment FA[6]. Overall, iteration of the game does not seem to have affected the aggregate proportion of entry in a systematic way.

<u>Capacity effect.</u> In correspondence with the equilibrium solutions, the higher the market capacity (h), the higher the rate of entry. The overall entry proportions across the two entry fees for h = 1 and 3 are 0.507 and 0.780 in Experiment RA, and 0.432 and 0.712 in Experiment FA. (All the tests for pair-wise comparisons of distributions across blocks [h = 1 vs. h =3] within entry cost

[4] Margolin, B.H. (1988), "Test for trend in proportions," in Encyclopedia of Statistical Sciences, Volume 9, Eds. Samuel Kotz and Norman L. Johnson, New York: Wiley, pp. 334-336.
[5] A similar analysis at the session level reveals that the trend is significant for only one of the five sessions in Experiment RA.

level and experiment are significant [χ^2 = 313.46 and 282.55, for k = 5 and 50, respectively, in Experiment RA ($p < 0.001$); and χ^2 = 210.30 and 179.54, for k = 5 and 50, respectively, in Experiment FA ($p < 0.001$)]).

Entry cost effect. In general, the higher the entry cost (k), the lower the rate of entry. Although this effect is consistent with the equilibrium solutions, it is not as pronounced as the market capacity effect. The overall entry proportions across the two capacity levels for k = 5 and 50 are 0.674 and 0.612 in Experiment RA and 0.592 and 0.552 in Experiment FA. (All the tests, except the one for the pair-wise comparisons of distributions across blocks [k = 5 vs. 50] within capacity level and experiment, are significant [χ^2 = 13.13 and 33.18, for h = 1 and 3, respectively, in Experiment RA ($p < 0.001$); and χ^2 = 1.02 ($p > 0.3$) and 9.51 ($p < 0.001$), for h = 1 and 3, respectively, in Experiment FA].)

Assignment Method Effect. When group norms are allowed to form in Experiment FA, entry rate decreases significantly. In each of the four games, the subjects in Experiment FA entered the market less frequently than the ones in Experiment RA [Z = 5.03, 3.23, 6.18, and 3.61 for games (1, 5), (1, 50), (3, 5) and (3, 50), respectively, $p < 0.05$].

Tests of Pure-Strategy Equilibrium Play

The significant effects due to market capacity and entry cost, and the non-significant effect due to block are all in qualitative agreement with equilibrium play. We turn next to tests of the pure- and mixed-strategy equilibrium solutions. The two major findings concerning the pure-strategy equilibrium solution are as follows:

---

[6] A similar analysis at the group level reveals that the trend is significant for three of the eight groups in Experiment FA.

First, the percentage of games supporting pure strategy equilibrium play is relatively low compared to other market entry studies, ranging from 5.99 [game ($h = 3$, $k = 5$) in Experiment RA] to 22.4 [game ($h = 3$, $k = 50$) in Experiment FA].

Second, the percentage of plays supporting pure-strategy equilibrium play does not vary systematically with market capacity (h), cost of entry (k), or experiment. The only significant difference is due to the market capacity $k = 50$ in Experiment FA (22.40 vs. 6.77; $z = 4.34$, $p < 0.001$). All other comparisons are not significant. In all cases, the percentage of pure-strategy equilibrium plays is higher for $k = 50$ than $k = 5$; however, this effect is significant in both experiments only for $h = 3$ (12.50 vs. 5.99, and 22.40 vs. 10.42, $z = 3.114$, 3.169, $p < 0.001$), but not for $h = 1$ (8.85 vs. 6.51, and 6.77 vs. 6.25, $z = 1.219$, 0.207, $p > 0.05$). Finally, the percentage of pure-strategy equilibrium plays is higher in Experiment RA than Experiment FA for $h = 3$ (for both $k =5$ and 50), but the opposite is true for $h = 1$. Only one of these comparisons ($h = 3$ and $k = 50$) is significant (22.40 vs. 12.50, $z = 3.083$, $p < 0.001$).

Tests of Mixed-Strategy Equilibrium Play

We obtain very different results when the focus is shifted from the pure-strategy to the mixed-strategy equilibrium solution. Table 5 presents evidence in *qualitative* agreement with the mixed-strategy equilibrium on the *aggregate* level. In each experiment, the observed entry proportions are ordered in the same way as the mixed strategy equilibrium proportions. Nevertheless, in all cases, the exact proportions differ significantly from the equilibrium proportions ($z = -6.73$, 11.05, -4.11, and 10.95 for games (h, k), (1,5), (1, 50), (3, 5), (3, 50) in Experiment RA, and $z = -11.05$, 3.72, -9.84, and 3.40, for the corresponding games in Experiment FA). Rejection of the null hypothesis of equality of proportions is not at all surprising given our large sample sizes. For the tests to be insignificant, the difference between the observed and predicted percentages should not exceed 2 percent (3 percent) in Experiment RA (FA). In both experiments, the observed proportions of entry exceed the expected proportions when k = 50, but the opposite is true for k = 5. This suggests that the assumption of risk neutrality may not be valid.

Utility Analysis. Particularly when both gains and losses are involved, alternative assumptions about the players' attitude to risk warrant investigation. In the analyses reported below, we assume the general payoff function in Eq. (1) with a common power utility function of the form $u(x) = -(-x)^s$, if $x < 0$, and $u(x) = x^r$, if $x \geq 0$. The two parameters r and s allow the distinction between the domains of gains and losses. In particular, when they are not constrained, they allow for risk aversion in the domain of gains and risk seeking in the domain of losses (e.g., Tversky & Kahneman, 1992).

We consider first the case of a single parameter utility function, with $r = s \equiv w$. Figure 2 displays the mixed-strategy equilibria as a function of w ($0 \leq w \leq 2$). It is evident from the figure that there is no single value of w such that for all four games, the expected and observed proportions are within 2 or 3 percent of each other[7]. Further, there is no single value of w that generates predictions which are closer to the observed proportions of entry than assuming that $w = 1$.

--Insert Fig. 2 about here—

We next investigate the more general case where we no longer require that r = s. Figure 3 exhibits the mixed strategy equilibrium solutions as a function of s and r ($0 \leq s \leq 2$, $0 \leq r \leq 2$). Any point in the shaded areas can be supported as a mixed-strategy equilibrium for a

[7] For such a w to exists, the horizontal lines corresponding to the observed proportions should intersect the same vertical line corresponding to a w value.

particular combination of the two parameters *s* and *r* in the corresponding game. The horizontal lines crossing the shaded area depict the observed overall entry proportion in each game of Experiment RA. We have explored systematically a two-dimensional *r* by *s* grid to find all the best fitting (*r*, *s*) combinations for which the expected entry proportions in all four games are within 2 percent (3 percent) of the observed proportions in Experiment RA (FA). Table 6 presents these (*s*, *r*) combinations. For Experiment FA we had to enlarge the deviation interval from 3 to 4 percent in order to find an appropriate combination. Table 6 shows quite clearly that the two-parameter utility function that we postulated yields mixed-strategy equilibrium predictions that account quite well for the aggregate results of all four games in each experiment. The major effect of the difference in the method of assigning subjects to groups is to lower the value of the parameter r from Experiment RA to FA, namely, to increase the magnitude of risk aversion in the domain of gains when group composition remains unaltered over iterations of the game.

--Insert Table 6 about here--

Figure 4 displays an example of our utility function with parameter values $r = 0.65$ and $s = 0.3$ (see Table 6). In correspondence with Prospect Theory, the function is concave in the domain of gains and convex in the domain of losses. However, in contrast to the Prospect Theory value function, it is steeper for gains than losses. This function indicates that the attractiveness of gains is valued more highly than that of losses of the same amount. It fits quite well with the subjects' post experimental reports that they had ignored the possible losses in favor of the very attractive gains. This behavior might have been encouraged by the fact that losses in the present study might have been perceived as reduced gains, considering that all losses were deducted from the endowment.

--Insert Fig. 4 about here—

Individual Level Analysis

Inspection of individual data shows considerable differences in individual decision policies. Six subjects in Experiment RA and four in Experiment FA almost always[8] entered the market in each of the four games. In addition, seven subjects in Experiment RA and three in Experiment FA almost always entered the market in three of the four games. Two subjects in Experiment FA almost never[9] entered the market in each of the four games, and one subject in Experiment RA almost never entered the market in three of the four games. These behavioral patterns are inconsistent with mixed-strategy equilibrium play. The remaining subjects exhibited different patterns of behavior. Rather than attempt to classify these policies, we tested three hypotheses about the order of entry that are implied by the mixed-strategy equilibrium solution.

Denote the probability of entry, given h and k, by $p_{h,\,k}$. The first hypothesis states that $p_{3,5} > p_{3,\,50} > p_{1,5} > p_{1,50}$. Altogether, the relative frequencies of entry of only 24 subjects (25%) in Experiment RA and 7 subjects (14.6%) in Experiment FA supported this hypothesis.

Two weaker hypotheses concern the effects of market capacity and entry cost separately. The first states that $p_{3,k} > p_{1,k}$, for k=5, 50. Our results show that this hypothesis is supported by the behavior of most of the subjects. In particular, 79 (82.3%) and 37 (77.1%) subjects in Experiments RA and FA, respectively, supported this hypothesis.

The second hypothesis states that $p_{h,5} > p_{h,50}$, for h=1, 3. The number of subjects for whom the this hypothesis holds was 40 (41.7%) and 17 (35.4%) in Experiments RA and FA, respectively. Fourteen (14.6%) and 6 (12.5%) subjects in Experiments RA and FA, respectively, violated this hypothesis for h=1 and h = 3 simultaneously.

Dynamics of Play

Adaptive learning models, whether belief-based (e.g., Camerer & Ho, in press) or reinforcement-based (e.g., Roth & Erev, 1995), typically attempt to account for the dynamics of play on the aggregate level. In fact, reinforcement-based models of learning have accounted quite well for changes in behavior over iterations of the game in related market entry games (Erev & Rapoport, 1998; Rapoport et al., 1998). With no evidence for significant block effects in our previous analysis, the same approach does not seem promising in the present study. Rather, we limit our analysis to the testing of several qualitative implications of reinforcement-based learning models.

Two general implications are of sufficient generality to be shared by most reinforcement-based learning models:

(1) A subject is more likely to enter the market after previous successful entry in the same game, and less likely to enter it after unsuccessful entry.

(2) A subject is more likely to stay out of the market after previous successful non-entry in the same game, and is less likely to stay out after unsuccessful non-entry.

A successful entry is unambiguously defined as a one that results in positive reward. Thus, in our study a subject successfully enters the market in round t if $m \leq h$ for that round; otherwise, the entry is not successful. We consider two alternative definitions for successful non-entry, based on alternative assumptions about the subject's perception of success. First, a subject successfully stays out of the market in round t if $m \geq h$ for that round (this expresses the fact that the subject realizes that he could not have benefited from switching his decision). Second, a non-entry is

---

[8] 22 or more entries in 24 trials

[9] 2 or less entries out of 24 trials

successful if m > h. Under this definition, a previous non-entry decision is perceived by the subject as unsuccessful if those who entered actually made money. Note that only rounds where m = h players enter the market are classified differently under the two alternative definitions, and that relatively few rounds ended in such a way (Table 4). Consequently, the analyses based on the two definitions yielded practically the same results. In the sequel, we report the results based on the first definition.

Clearly, for a reasonable analysis of sequential dependencies of this type, subjects need to be exposed to the consequences of various decisions. Consequently, we excluded from the analysis all the rounds of those subjects who either entered or stayed out almost always. Further, subjects whose decisions could be accounted for by the randomization implied by the mixed-strategy equilibrium (based on the outcomes of a run test) were also excluded from the following analysis[10].

Table 7 presents the proportions of entry decision (IN/OUT) as a function of the success or failure of the decision on the previous round of the same game[11]. The tendency to repeat a successful action is manifested in both the IN and OUT decisions. The χ^2 test for association is not significant only for the IN decisions in Experiment RA, although the tendency is in the same direction. Clearly, subjects were affected by their history of successful or failed decisions. Repeating the same analysis, but assuming a round-to-round rather than game-to-game adaptation yielded non-significant results for both IN and OUT decisions in both experiments. This result shows that subjects were sensitive to the specific game parameters (capacity and cost) and adjusted their decisions accordingly.

---

[10] Thirty four (14) subjects from RA (FA) experiment met the randomization requirement and were excluded from the analysis. Six (4) subjects from the RA (FA) experiment were excluded since they entered the market almost always.

--Insert table 7 about here--

Our next and more conventional analysis used logistics regression to test the effects of the following variables on the subjects' choices on round t: (1) game parameters of the current round (h, k); (2) the outcome of round t – 1 (denoted in Table 8 as $(1 - t)_R$); and (3) the outcome of the most recent round of the same game $(t - 1)_C$. Table 8 presents the estimated parameter values and their significance levels. The regression models the probability of entry, given the three independent variables specified above.

--Insert Table 8 about here--

The (-2 Log Likelihood) statistic for assessing goodness of fit is highly significant ($\chi^2_{(10)} = 719.082$, p = 0.0001 for Experiment RA, and $\chi^2_{(10)} = 554.084$, p = 0.0001 for Experiment FA). If we examine all decision pairs across all subjects such that one decision is to enter and the other to stay out, then in 72.8 percent (79.2 percent) of the pairs the entry decision is associated with a predicted higher probability of entry based on the logistics model in Experiment RA (FA). Clearly, the subject's decision is more strongly affected by the market capacity on the particular round than by the entry cost (note the significant market capacity effect for both experiments, and the entry cost effect for Experiment RA). The insignificant effect of the entry cost variable in Experiment RA is apparent from the comparison of the overall proportion of entry for the entry fees k = 5 (0.592) and k = 50 (0.552).

The analysis further shows that in addition to the effects of the parameters of the current round, the subjects' decisions are affected by their personal experience on previous rounds. In general, the subjects are influenced more by the outcome of their decision in the most recent round of the *same* game than by the outcome of the previous round. In particular, similar to the

[11] On average, a round of the same game (ignoring color) repeated itself every 4 rounds.

results in Table 7, subjects from both experiments are more likely to stay out of the market after a successful rather than unsuccessful non-entry[12].

In summary, the behavior of subjects whose decisions cannot be accounted for by simple decision rules (always enter, always stay out, enter randomly with a fixed probability) is most sensitive to the outcome of their decision in the most recent round of the same game and not the actual change in their wealth.

We further investigated the effect of the *degree* to which the market was over- (under) subscribed in the most recent round of the same game. For example, an unsuccessful entry when the market capacity was h = 3 could be due to m = 4, 5, or 6 entrants (resulting in an over-entry of 1, 2, and 3, respectively). We hypothesized that the probability of entering the market in the next round of the same game decreases in the excess entry, m – h. Similarly, we hypothesized that the probability of entering the market after a successful non-entry decreases in the excess entry m – h. Table 9 presents results that confirm both hypotheses. In all cases, where a statistical test is possible, the results of a Cochran-Armitage test for trend in proportions are significant, indicating a decreasing trend.

--Insert Table 9 about here--

5. Discussion and Conclusions

Like all previous market entry game studies that have tested the equilibrium solution, we find no support for the symmetric mixed strategy equilibrium solution on the *individual* level. Although the behavior of 31 (32.3%) subjects from Experiment RA and 12 (25%) from Experiment FA can be explained in all experimental conditions as adopting a random entry

[12] Note the negative parameter sign for Succ OUT.

strategy based on the observed overall proportion of entry[13], these proportions are significantly different from the predicted proportions for risk neutral players. Unlike the market entry game studies that preceded the present study, we also find no support for equilibrium play—pure or mixed—on the *aggregate* level. In both of our experiments, the subjects are clearly sensitive to the values of the two game parameters, namely, the market capacity h and the entry cost k. They are also sensitive to the method of allocating subjects to groups, with non-stationary groups significantly entering the market more frequently than stationary groups. The assumption of a two-parameter utility function, which is concave in the domain of gains and convex in the domain of losses, organizes the aggregate results in each of the two experiments remarkably well. However, the hypothesis of a common utility function is clearly falsified by the pattern of individual differences.

We report strong evidence that the subjects recall the last outcome of each of the four games and adjust their behavior accordingly, entering more frequently after a successful entry on the same game and staying out more often after a previous successful non-entry. Moreover, our results suggest that this sensitivity extends to the degree to which the market was over- or under-subscribed in the most recent play of the same game. This pattern of behavior demonstrates a sophisticated adaptation process that takes into account not only the actual changes in wealth level (in according with basic reinforcement principles) but also what “could have been” and what “has been observed about others”. These sequential dependencies are localized in nature, accounting for trial to trial oscillation in behavior, but cannot be considered stable long-term learning effects. In particular, we observe no systematic decrease in frequency of entry across

[13] For these subjects we could not reject the hypothesis that the total number of runs, in each condition, is as expected based on a sample from binomially distributed populations with p_i = overall observed rate of entry in condition i, using 4 independent run tests.

trials that would have significantly enhanced group and, consequently, individual payoff. In fact, our subjects did not achieve a satisfactory solution for the coordination problem. Not only did they fail to maximize total group payoff by lowering their frequency of entry, but in both experiments they would have been better off staying out on all 96 rounds of play rather than being lured into the market by the high payoffs for successful entry.

The present study is part of a programmatic research intended to discover the variables that determine coordination success or failure in interactive situations that prohibit binding agreements. We are not yet in a position to answer the general question why some experiments on tacit coordination result in coordination success (e.g., Ochs, 1990; Sundali et al.; Rapoport et al.) and others in coordination failure (e.g., van Huyck et al. 1990, 1991). These studies differ from one another on too many dimensions to allow a direct comparison. Within the narrower class of market entry games, our results suggest that coordination success or failure may depend on certain features of the payoff function and the stability of the associated equilibrium solutions. The comparison of the present study to the ones conducted by Sundali et al. and Rapoport et al. is particularly pertinent here because in all of these studies the option of staying out of the market was present. The equilibrium solutions for the market entry game studied by Sundali et al. and Rapoport et al. have two major features. First, the payoffs to entrants and non-entrants under pure strategy play are either the same or very close to each other. Second, the expected number of entrants under symmetric mixed strategy equilibrium play and the number of entrants under pure strategy equilibrium play are almost the same.[14] Coupled with the relatively large number of players in these two studies (n = 20), these features render the equilibrium solutions very stable.

[14] In the market entry game studied by Sundali et al. the number of entrants under pure strategy equilibrium play equals to either c or c – 1, where c is the market capacity. The expected number of entrants under mixed strategy equilibrium play, np, satisfies the inequality $c - 1 \leq np \leq c$. Similar results hold for the study by Rapoport et al.

In these studies, subjects are in effect facing a tacit coordination task under no-conflict condition. The pure strategy equilibrium in these cases calls for the formation of two subgroups of specific sizes (as a function of market capacity). However, in equilibrium an individual subject is indifferent as to which subgroup to join. This creates a very stable membership structure in the sense that if, on a certain trial, the group is subdivided into two subgroups of the correct size (even by chance), no subject has an incentive to change membership from that trial onward. In contrast, our design creates a tacit coordination task under conditions of strong conflict in which both of these features are absent. In (pure) equilibrium, subjects' payoffs vary considerably as a function of subgroup membership. For example, for markets with capacity 1 and $5 entry cost, the sole entrant's payoff is $495 and each of the other five players receives nothing. Even if the correct (pure strategy) division occurs on a specific trial, it can not be expected that the identity of the sole entrant will remain the same on the next trial. In addition, there are substantial differences in our study between the expected number of entrants under pure or mixed equilibrium play.[15] Additional studies that systematically manipulate the payoff function and, consequently, the equilibrium solutions are needed in order to pin down the variables that lead to coordination failure or success in market entry games.

[15] The expected number of entrants under the symmetric mixed strategy equilibrium solution for games (1, 5) and (1, 50) are 3.612 and 2.214 compared to a single entrant under pure strategy equilibrium play.

References

Binmore, K. (1987). Modeling rational players, I, II. Economics and Philosophy, 3, 9 – 55; 4, 179 – 214.

Camerer, C. F., & Ho, T.-H (in press). Experience-weighted attraction learning in games. Econometrica.

Erev, I., & Rapoport, A. (1998). Coordination, “magic”, and reinforcement learning in a market entry game. Games and Economic Behavior, 23, 145 – 176.

Gardner, R. (1995). Games for Business and Economics. New York: Wiley.

Lucas, R. E. Jr. (1986). Adaptive behavior and economic theory. In R. M. Hogarth and M. W. Reder (Eds.), Rational Choice: The Contrast between Economics and Psychology. Chicago: The University of Chicago Press.

Meyer, D. J., van Huck, J., Battalio, R., and Saving, T. (1992). History’s role in coordinating decentralized allocation decisions: Laboratory evidence on repeated binary allocation games. Journal of Political Economy, 100, 292 – 316.

Nti, K. O. (1996). Potential competition and coordination in a market entry game. Smeal College of Business Administration, Penn State University, Unpublished Manuscript.

Ochs, J. (1990). The coordination problem in decentralized markets: An experiment. Quarterly Journal of Economics, 105, 545 – 559.

Ochs, J. (1995). Coordination problems. In J. H. Kagel and A. E. Roth (Eds.), Handbook of Experimental Economics. Princeton: Princeton University Press, pp. 195 – 251.

Rapoport, A., Seale, D. A., Erev, I., & Sundali, J. A. (1998a). Equilibrium play in large group market entry games. Management Science, 44, 129 – 141.

Roth, A. E., & Erev, I. (1995). Learning in extensive-form games: Experimental data and simple dynamic models in the intermediate term. Games and Economic Behavior, 8, 164 – 212.

Schelling, T. (1960). The Strategy of Conflict. Cambridge, MA: Harvard University press.

Sundali, J. A., Rapoport, A, & Seale, D. A. (1995). Coordination in market entry games with symmetric players. Organizational Behavior and Human Decision Processes, 64, 203 - 218.

Tversky, A., & Kahneman, D. (1992). Advances in prospect theory: Cumulative representation of uncertainty. Journal of Risk and Uncertainty, 5, 297 - 323.

Van Damme, E. (1987). Stability and Perfection of Nash Equilibria. Berlin: Springer-Verlag.

Van Huyck, J. B., Battalio, R. C., & Beil, R. O. (1990). Tacit coordination games, strategic uncertainty, and coordination failure. American Economic Review, 80, 234 – 249.

Van Huyck, J. B., Battalio, R. C., & Beil, R. O. (1991). Strategic uncertainty, equilibrium selection, and coordination failure in average opinion games. Quarterly Journal of Economics, 106, 885 – 910.

Table 1

Probabilities of Entry y* and y** for Four Different Market Entry Games

n	h	k	y*	y**	EV(y**)
6	1	5	0.602	0.163	32.66
6	1	50	0.369	0.137	25.94
6	3	5	0.846	0.312	66.23
6	3	50	0.635	0.271	53.13

y*: Equilibrium probability of entry
y**: Probability of entry maximizing group expected payoff
EV(y**): Individual expected payoff associated with y**.

Table 2

An Example of a Decision Screen

Round = 31							
Number of players who press RED/ BLUE	0/6	1/5	2/4	3/3	4/2	5/1	6/0
Payoff to each RED player	--	450	-50	-50	-50	-50	-50
Payoff to each BLUE player	0	0	0	0	0	0	--
Blue Red Please press a button							

- In this example, h = 1, c = 50 and Red is interpreted as an entry decision.
- RED was shown in red fonts and BLUE in blue fonts.

Table 3

Payoff to each entrant as a function of the number of entrants

		Number of entrants: m					
k	h	1	2	3	4	5	6
5	1	495.00	-5.00	-5.00	-5.00	-5.00	-5.00
	3	495.00	245.00	161.67	-5.00	-5.00	-5.00
50	1	450.00	-50.00	-50.00	-50.00	-50.00	-50.00
	3	450.00	200.00	116.67	-50.00	-50.00	-50.00

Table 5
Observed and predicted means (and standard deviations) of number of entries

Experiment RA

Game	Observed Mean (SD)	Observed Proportions	Equilibrium Proportions y*
(h = 1, k = 5)	3.201	0.533	0.602
	(1.187)		
(h = 3, k = 5)	4.891	0.815	0.846
	(0.922)		
(h = 1, k = 50)	2.88	0.480	0.369
	(1.132)		
(h = 3, k = 50)	4.469	0.745	0.635
	(1.054)		

Experiment FA

(h = 1, k = 5)	2.656	0.443	0.602
	(0.925)		
(h = 3, k = 5)	4.448	0.741	0.846
	(0.83)		
(h = 1, k = 50)	2.531	0.422	0.369
	(0.903)		
(h = 3, k = 50)	4.099	0.683	0.635
	(0.841)		

Table 6

Parameter values[1] ensuring that the observed entry proportion is within 2% (4%)[2] in Experiment RA (FA)

	(h, k) →	(1,5)	(1,50)	(3,5)	(3,50)
Experiment RA					
Observed proportions →		0.53	0.48	0.81	0.74
r	*s*	Mixed strategy equilibrium			
0.6	0.2	0.51-0.52	0.46	0.81-0.82	0.76
0.7	0.2	0.52-0.53	0.46-0.47	0.82	0.76
0.7	0.3	0.52-0.55	0.46-0.47	0.82-0.83	0.76
0.7	0.4	0.54-0.55	0.46	0.83	0.75-0.76
Experiment FA					
Observed proportions →		0.44	0.42	0.74	0.68
r	*s*	Mixed strategy equilibrium			
0.5	0.2-0.29	0.45-0.47	0.39-0.40	0.78	0.71-0.72

1 The parameter values are rounded to the nearest 0.1. For example, (0.6, 0.2) in the first row of the table indicates that any combination from (0.55, 0.65) X (0.15, 0.25) yields 4 mixed strategy equilibria that are within the indicated tolerance level with respect to the observed proportions.

2 There are no *(s, r)* combinations such that the observed proportions are within 3% of the expected

Table 7

Proportions of entry decision (IN or OUT) in round t as a function of the success or failure of the decision in round t-1 in the same game

		Experiment					
		RA			FA		
		t			t		
t - 1		IN	OUT	ALL	IN	OUT	ALL
IN	Failure	0.74	0.26	0.95	0.73	0.27	0.93
	Success	0.79	0.21	0.05	0.91	0.09	0.07
	ALL	0.74	0.26	N = 2207	0.74	0.26	N = 824
Chi-Square		1.127 (p = 0.289)			8.537 (p < 0.003)		
OUT	Failure	0.63	0.37	0.04	0.63	0.37	0.02
	Success	0.37	0.63	0.96	0.23	0.77	0.98
	ALL	0.45	0.55	N = 1542	0.23	0.77	N = 878
Chi-Square		16.56 (p < 0.001)			17.20 (p < 0.001)		

Table 8
Parameter estimates and significant values from the LOGISTIC regression model

Sequence	Variable	Parameter Estimate	Standard Error	Wald Chi-Square	p
Experiment RA					
	INTERCPT	-0.213	0.410	0.269	0.604
t	**K**	-0.005	0.002	6.322	**0.012**
	H	0.313	0.039	64.850	**0.000**
$(t-1)_R$	IN	0.517	0.307	2.826	0.093
	Succ IN	-0.223	0.342	0.428	0.513
	Succ OUT	-0.393	0.308	1.629	0.202
	PAY	-0.001	0.001	0.561	0.454
$(t-1)_C$	IN	0.495	0.289	2.944	0.086
	Succ IN	0.510	0.464	1.212	0.271
	Succ OUT	-0.806	0.286	7.939	**0.005**
	PAY	-0.001	0.001	0.437	0.509
Experiment FA					
	INTERCPT	-0.5316	0.6375	0.6954	0.404
t	**K**	0.0025	0.0030	0.6757	0.411
	H	0.1348	0.0626	4.6314	**0.031**
$(t-1)_R$	IN	1.4035	0.6952	4.0756	**0.044**
	Succ IN	0.3538	0.4793	0.5448	0.460
	Succ OUT	0.5167	0.6935	0.5552	0.456
	PAY	-0.0037	0.0020	3.3423	0.068
$(t-1)_C$	IN	-0.0013	0.5916	0.0000	0.998
	Succ IN	2.1544	0.9128	5.5708	**0.018**
	Succ OUT	-1.9213	0.5863	10.7391	**0.001**
	PAY	-0.0025	0.0027	0.8671	0.352

Table 9
Entry percentages (in round t) as a function of the difference m – c between the number of players who entered the market and the market's capacity in the most recent round of the same game

			Experiment RA				Experiment FA			
	$(t-1)_C$		Failed E		Succ NE		Failed E		Succ NE	
h	t		% Entry	N[3]	% Entry	N	% Entry	N	% Entry	N
3	m - h	0			57.0	107			34.6	107
		1	82.6	282	41.9	246	76.9	130	22.1	204
		2	77.3	454	44.4	151	68.1	185	18.8	69
		3	73.3	337			61.8	55		
	Statistic[1]		-2.756		-1.783		-2.233		-2.552	
	Prob[2]		0.003		0.037		0.013		0.005	
1	m - h	0			48.0	127			46.7	60
		1	77.8	158	34.5	328	89.2	120	20.9	215
		2	71.6	345	27.3	348	71.7	145	13.7	146
		3	69.6	319	24.7	146	66.7	120	8.9	56
		4	64.9	174	20.0	30	78.6	14	0.0	2
		5	66.7	30						
	Statistic		-2.542		-4.689		-3.561		-5.184	
	Prob		0.006		0.001		0.001		0.001	
3			Succ E		Failed NE		Succ E		Failed NE	
	m - h	-3			83.3	6				
		-2	100.0	2	60.0	5				
		-1	66.7	6	70.0	30	80.0	5	72.7	11
		0	81.6	76			92.3	39		

1 - Cochran-Armitage Trend Test

2 – Prob. (Left-sided)

3 - N = total number of cases (Entry + Non Entry)

Figure 1

Expected Payoff as a Function of Probability of Entry

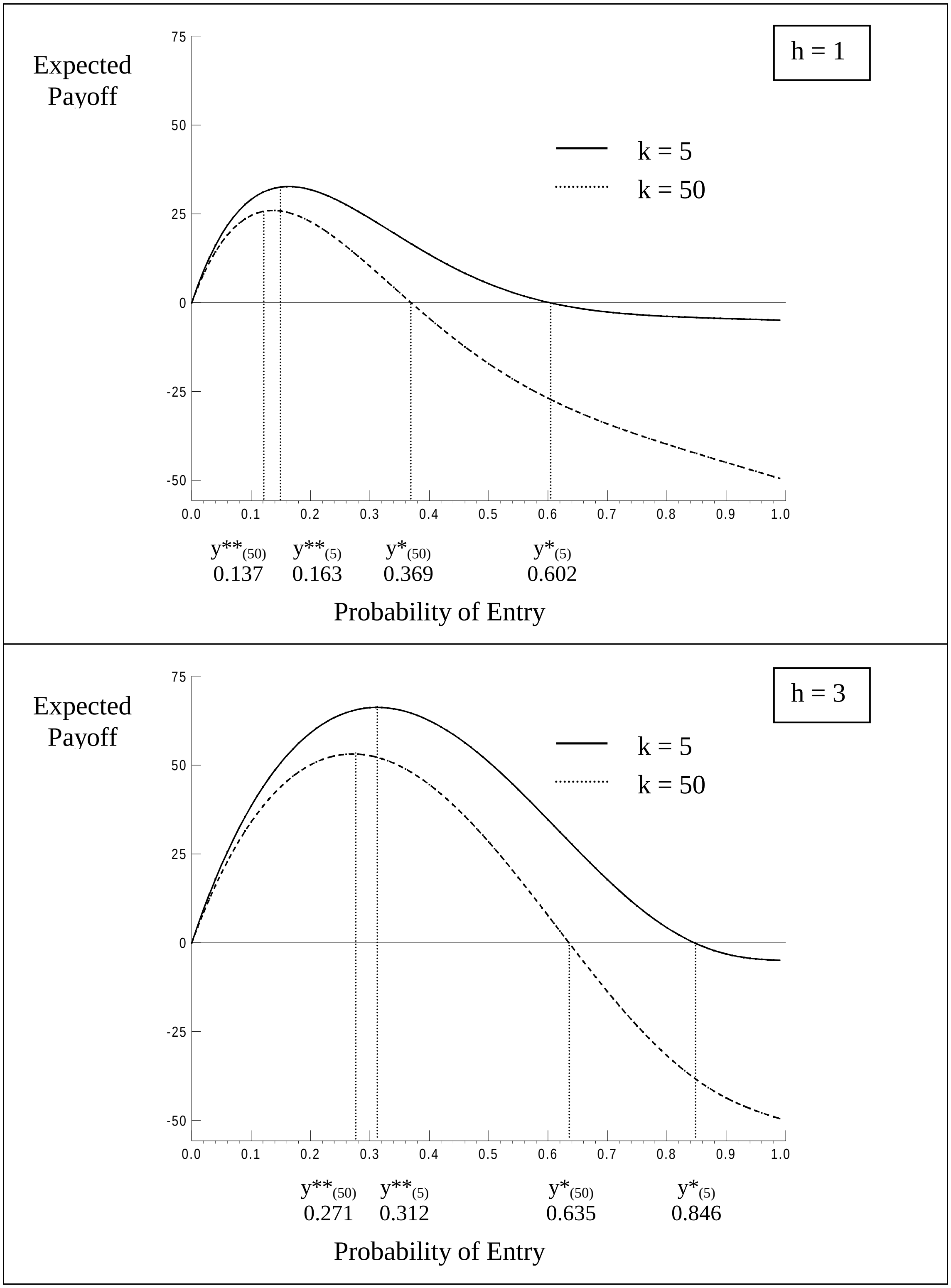


Figure 2

Mixed strategy equilibria as a function of w ($0 \le w \le 2$)

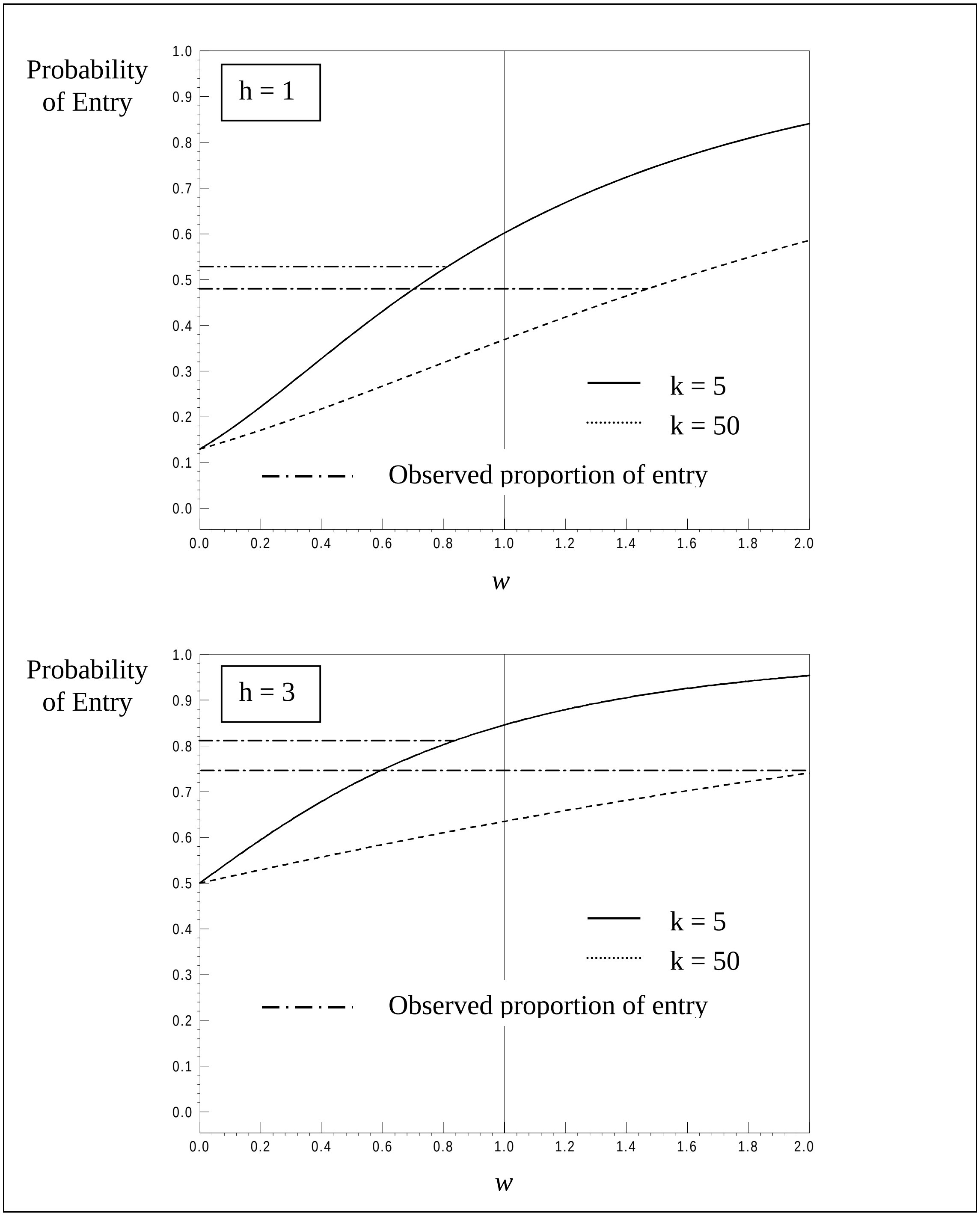


Figure 3

Predicated mixed strategy equilibria as a function of *r* (on the x-axis) and *s*

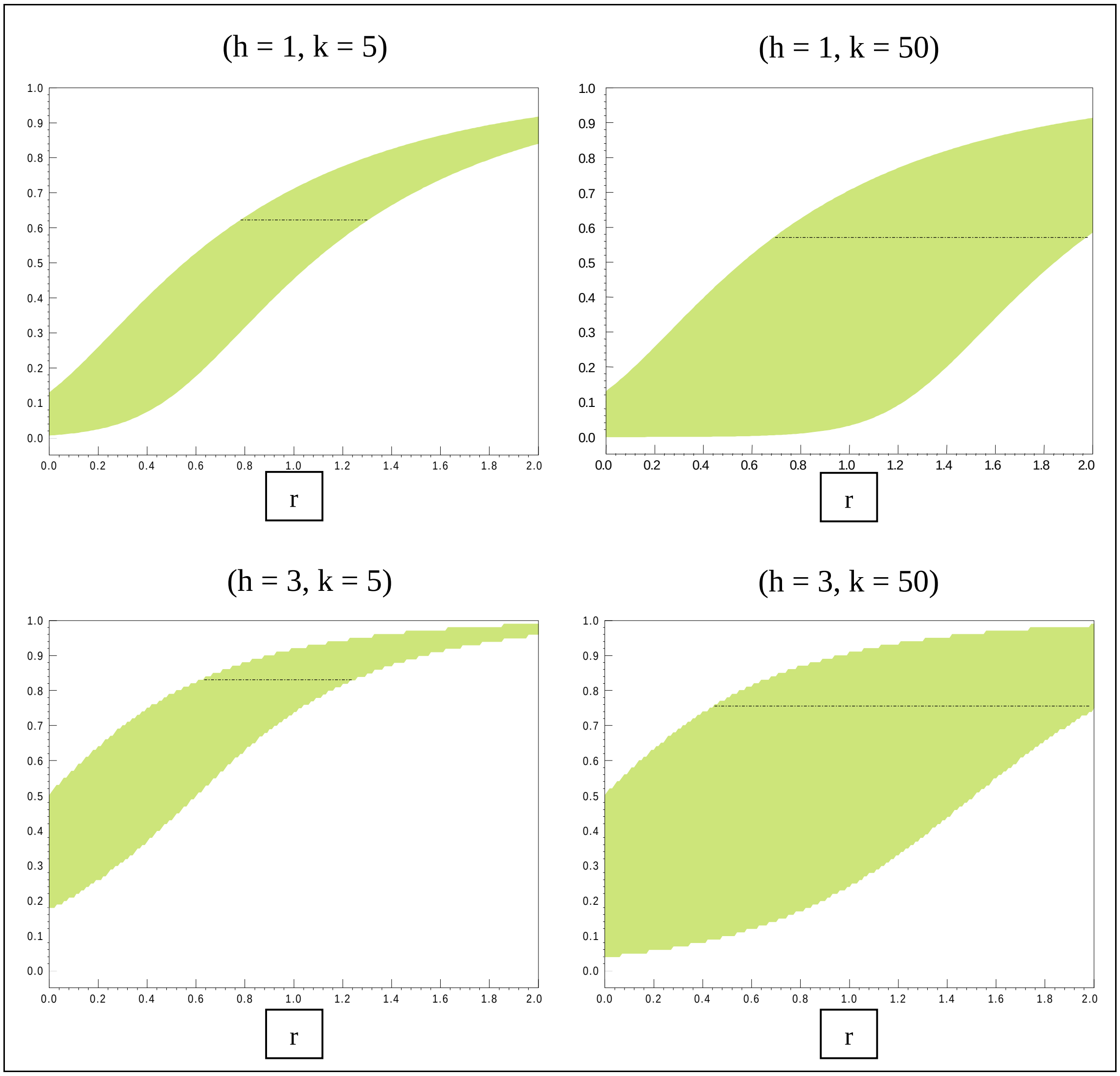
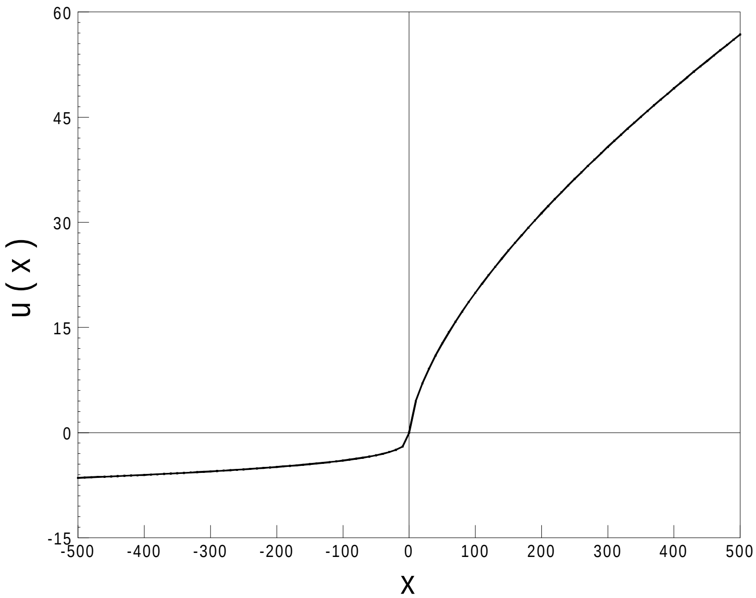


Figure 4

Utility function for s = 0.3 and r = 0.65



$$u_i(x) = \begin{cases} u_i(x) = -(-x)^{s_i} & if \;\; x < 0 \\ u_i(x) = x^{r_i} & if \;\; x \geq 0 \end{cases}$$ for a subject i.