Does Opponents' Experience Matter? Experimental Evidence from a Quantity Precommitment Game *

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Abstract

This paper investigates why subjects in laboratory experiments on quantity precommitment games consistently choose capacities above the Cournot level - the subgame-perfect equilibrium. We argue that this puzzling regularity may be attributed to players' perceptions of their opponents' skill or level of rationality. We first show theoretically that it is the case by modelling a two-stage game of capacity investment and pricing with bounded rational players. We then design an experiment in which we use the level of experience as a proxy for the level of rationality and match subjects with different levels of experience. We find significant differences in behavior depending on opponents' experience; moreover, players facing inexperienced players tend to choose higher capacities than they would otherwise.

JEL classification: C92; L11; L13.

Keywords: Experience, Experiment, Oligopoly, Quantity precommitment, Rationality.

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1 Introduction

One of the most prominent solutions to the Bertrand paradox, that price competition results in the competitive outcome even when only two firms compete, is to account for capacity constraints when studying price competition. Kreps and Scheinkman (1983), henceforth KS, study a game where firms simultaneously commit to a capacity level before they compete in prices, à la Bertrand. Their seminal result is that the unique subgame-perfect equilibrium implies capacities equal to the Nash equilibrium output in the equivalent Cournot game. A puzzling empirical regularity has been identified in several experiments focusing on the KS model. A large majority of subjects consistently choose capacities that exceed the Cournot equilibrium level (Davis, 1999). This is the case even when subjects are experienced in the game (Muren, 2000) or subjects are given time to understand the implication of capacity choice, in the first stage, for price choice in the second stage(Anderhub et al., 2003). Hence, it seems that incomplete understanding of the game cannot be the only explanation for choosing capacity higher than the predicted Cournot level.

It is well recognized that departure from equilibrium may be expected if at least one player is not perfectly rational (see Crawford et al., 2010, for a recent review). In particular, convergence on subgame-perfect equilibrium might be challenging/difficult in a sequential game with players with different levels of bounded rationality. [1]

This paper explores the perception of other players' bounded rationality as an explanation for choosing capacities above the Cournot outcome in the KS framework. Applying the Quantal Response Equilibrium (QRE) approach (McKelvey and Palfrey, 1995) to the KS model reveals that bounded rationality among players can explain this outcome. In particular we find that the rationality of opponents matters, with the effect that, all else equal, a player offers higher capacity the lower the rationality of her opponent is. The experiment reported here is designed to test if players' perceptions of their opponents' rationality have a systematic effect on behavior. While unable to directly control for players' beliefs about opponent's

[1] See for example experimental evidence testing backward induction in the centipede game in Palacios-Huerta and Volij (2009)

rationality, we manipulate subjects' expectation about opponent's cognitive level. We use the number of periods played as a proxy for rationality and we match subjects with different levels of experience. The experience of players is common knowledge. The implicit assumption is that experienced players (who have played the game before) can be expected to play more rationally (make fewer mistakes) than inexperienced ones (who are just starting to play). This is in line with the QRE literature where the precision with which decisions are made is increasing with experience (McKelvey and Palfrey, 1995).

We find that players' perception of their opponent's skill, or level of rationality, has a systematic effect on behavior. First, in line with our theoretical predictions, behavior varies with the opponent's experience: subjects choose significantly higher capacities when playing against inexperienced subjects than when playing against experienced ones. One possible explanation for this is that inexperienced subjects are less price responsive than experienced players. If a subject is facing an inexperienced competitor, expanding its capacity in the first stage might be profitable since inexperienced players are likely not to reduce their price enough in the second stage to sell their full capacity. Second, we estimate player's response precision within the QRE framework. We find that the level of precision is not only positively correlated with own experience but also increasing with opponent's level of experience. This may be due to a learning effects or that subjects put more effort into playing the game with more experienced opponents similar to the Yerkes-Dodson Law (Yerkes and Dodson, 1908).

It is quite common to mix experienced and inexperienced subjects in experiments, but only a few recent papers focus on the issue of heterogeneity in experience levels specifically. So far these studies (e.g., Johnson et al., 2002, with a bargaining game and Dufwenberg et al., 2005, on the formation of bubbles) have primarily looked at how the proportion of experienced players relative to inexperienced players matters for the outcome. This paper focuses on the effect of opponent's experience on individual behavior, like Slonim (2005) and Palacios-Huerta and Volij (2009) who investigate a similar hypothesis in a beauty contest game and a centipede game respectively. In contrast, this paper considers a quantity precommitment game and offers a formal analysis of the effect of opponent's experience on individual behavior. To our knowledge this work is the first to apply a AQRE approach to the Kreps and Scheinkman's model, showing that bounded rationality among players may lead to capacity above the predicted Cournot level. It also offers detailed results on the evolution of the level of precision when opponent's experience varies.

This paper also contributes to the growing literature on bounded rationality in industrial organization (see Ellison, 2006 and Armstrong and Huck, 2010), if observed capacity above the predicted Cournot level is viewed as a form of excess capacity. Excess capacity is observed in many markets, especially those where substantial initial investments are required (e.g., Gilbert and Lieberman, 1987; Kadiyali, 1996; or Goolsbee and Syverson, 2008). The theoretical literature often explains excess capacity as a result of strategic attempts to deter entry or to limit new entrants' market share (e.g., Dixit, 1979; Spence, 1977; and Milgrom and Roberts, 1982). The empirical evidence on these explanations is mixed however (Martin, 2001, p. 64). This paper might offer bounded rationality as an additional explanation for excess capacity. Our results suggest that the performance in oligopolies depends not only on the market participants but also on their competitor's experience. Interestingly, (Lieberman, 1987) found in the chemical industry that incumbents increase their rate of investment when facing new entrants, but reduce it when facing incumbents. Our main result could explain this pattern if entrants, who usually are less familiar with the market, are viewed as inexperienced players by the (experienced) incumbents.

Finally, our experimental design is similar to other experiments on capacity precommitment games (Davis, 1999; Muren, 2000; and Anderhub et al., 2003) but we match subjects with different levels of experience. Those earlier studies find capacity above Cournot level even with similarly experienced subjects. One potential explanation might be related to the subjects' overconfidence observed in many studies (see Benoit and Dubra, 2011, for an extensive review of the literature on this topic). If subjects underestimate the ability of their opponents to play this game even though they have played the game an identical number of times, they may still choose capacity above Cournot level.

The remainder of this paper is structured as follows. The next section presents the equilibrium predictions of the bounded rationality model applied to the capacity-constrained game. Section 3 provides a general description of the experimental design and procedures. Section 4 presents the results of the experiment. Section 5 concludes.

2 Theoretical predictions

In this section we apply the quantal response equilibrium (QRE) concept to a capacity commitment price game developed by Kreps and Scheinkman (henceforth KS, 1983). In particular, the robustness of the predicted Cournot equilibrium outcome when players are boundedly rational is discussed.

2.1 The benchmark model

We first consider a standard version of the KS model, with symmetric duopoly and linear demand. The game consists of two stages. In the first stage, subjects simultaneously choose their capacity levels k_i from a set of actions A_k. The cost of each unit of installed capacity is c. In the second stage, having learned the capacity chosen by their opponent, subjects simultaneously choose a price p_i from a set of actions A_p. Production is costless but cannot exceed capacity. For a given set of prices aggregate capacity can exceed demand, in which case the efficient rationing rule applies. Assume, for now, that the action sets are continuous and non-negative, $A_k = A_p = R_+$. Player i's payoff is given by:

$$\pi_i(k_i, k_j, p_i, p_j) = \begin{cases} p_i \min(k_i, d(p_i)) - ck_i & \text{if } p_i < p_j, \\ p_i \min(k_i, \max(d(p_i) - k_j, d(p_i)/2)) - ck_i & \text{if } p_i = p_j, \\ p_i \min(k_i, \max(d(p_i) - k_j, 0)) - ck_i & \text{if } p_i > p_j. \end{cases} \tag{1}$$

where $i, j \in \{1, 2\}$ and $i \neq j$, and where $d(p_i) = \alpha - \beta p_i$.

Following from Proposition 2 in KS and using the same parameters as the ones used in the experiment, $\alpha = 120$, $\beta = 1$ and $c = 30$, it can be shown that the subgame-perfect equilibrium is unique and is equal to the Cournot outcome in terms of capacities, prices and profits:

$$k_i^* = 30,\ p_i^* = 60 \text{ and } \pi_i^* = 900 \quad \text{for } i \in \{1, 2\}. \tag{2}$$

In comparison, a competitive market would yield an aggregate output equal to 90, prices equal to the marginal cost, 30, and zero profits. In the following subsection the quantal response equilibrium concept is applied to this game, where players are assumed to be boundedly rational.

2.2 A Quantal Response Equilibrium analysis of the KS game

The quantal response equilibrium framework relates to the notion of bounded rationality and games with imperfect implementation of optimal strategies. In particular, players are not expected to choose best responses with probability one, but rather to use probabilistic decision rules. The probability of a particular strategy being chosen is increasing in the expected payoff to that strategy. Since standard QRE applies only to normal-form games, we used a *logit*-agent quantal response equilibrium (*logit*-AQRE), where players are assumed to act as independent agents at each information set (see McKelvey and Palfrey, 1995, 1998, for more details).

A *logit*-AQRE of the KS game can be defined as follows. Assume that payoffs are observed with error. Let b^* denote a complete strategy profile. $\overline{\pi}(k_i, b^*)$ describes the expected payoff when player i chooses the capacity level k_i with probability one while the opponent's strategy and own price strategy follow b^*. Similarly, $\overline{\pi}(p_i, b^*)$ is the expected payoff when the strategy profile b^* is played, except that own price is p_i with probability one. The expected payoff functions are calculated from (1) assuming that the beliefs are consistent with the realizational probabilities associated with b^*.[2]

Subject i is assumed to employ a logistic choice function with precision param-

[2] The realizational probabilities derive from the selected strategy b. First let $\rho(k|b)$ be the probability of the particular capacity vector $k = (k_1, k_2)$, given strategy profile b. Then let $\rho(p|k, b)$ be the conditional probability of the vector p when k has occurred and the strategy profile b is selected. Finally $\rho(k, p|b) = \rho(p|k, b)\,\rho(k|b)$ is the probability of an outcome which involves k and p given strategy b. For a given strategy profile b the expected payoff to player i, and all her agents at the first stage, is

$$\overline{\pi}_i(b) = \sum_{q_i \in A_q} \sum_{p_i \in A_p} \rho(k_i, p_i|b)\,\pi_i(k, p),$$

where $\pi_i(k, p)$ is defined in (1). The expected payoff at the second stage, when k is common eter $\lambda_i \geq 0$, i.e. to choose k_i with probability

$$b^*_{i,k_i} = \frac{e^{\lambda_i \overline{\pi}(k_i,b^*)}}{\sum\limits_{k_i \in A_k} e^{\lambda_i \overline{\pi}(k_i,b^*)}}, \quad i \in \{1,2\} \tag{3}$$

and to choose p_i with probability $b^*_{i,p_i|\mathbf{k}}$, conditional on the aggregate capacity k where

$$b^*_{i,p_i|\mathbf{k}} = \frac{e^{\lambda_i \overline{\pi}(p_i,b^*)}}{\sum\limits_{p'_i \in A_p} e^{\lambda_i \overline{\pi}\left(p'_i,b^*\right)}}, \quad i \in \{1,2\}\,. \tag{4}$$

The parameter λ_i captures the decision maker's response precision. When $\lambda_i = 0$ the errors completely dominate any information about the payoff function, and player i chooses all available strategies with equal probability. On the opposite extreme, when $\lambda_i \to \infty$ the errors become negligible, in which case player i chooses her best response to b^* with probability one. In general, players act more rationally the higher their λ_i parameter is.

The *logit*-AQRE is found by solving a system of equations (3) and (4) for all information sets for particular levels of λ_i. It turns out to be extremely difficult, if not impossible, to find a closed form solution to this problem, the main reason being discontinuities in the payoff function (1). Nevertheless, the problem can be solved numerically.

2.3 Simulation results

To solve the above model numerically we consider a discrete action space limited to multiples of five: $A_k = A_p = \{10, 15, 20, ..., 80\}$. We parameterize the set of possible response functions b with the parameter λ.[3] Note that if $\lambda_i \to \infty \; \forall i \in \{1,2\}$,

knowledge, is

$$\overline{\pi}_i\,(b|k) = \sum_{p_i \in A_p} \rho\,(p_i|k,b)\,\pi_i\,(k,p)\,.$$

[3]While continuous space techniques exist for normal form games (Anderson et al., 1998) we are unaware of similar tools for extensive form games. The results do not seem to be too sensitive to the discrete approximation of the action space and we obtain a manageable number of nonlinear equations. The program was solved using the GAMS/PATH mixed complimentarity problem solver. The code can be obtained from the authors upon request.

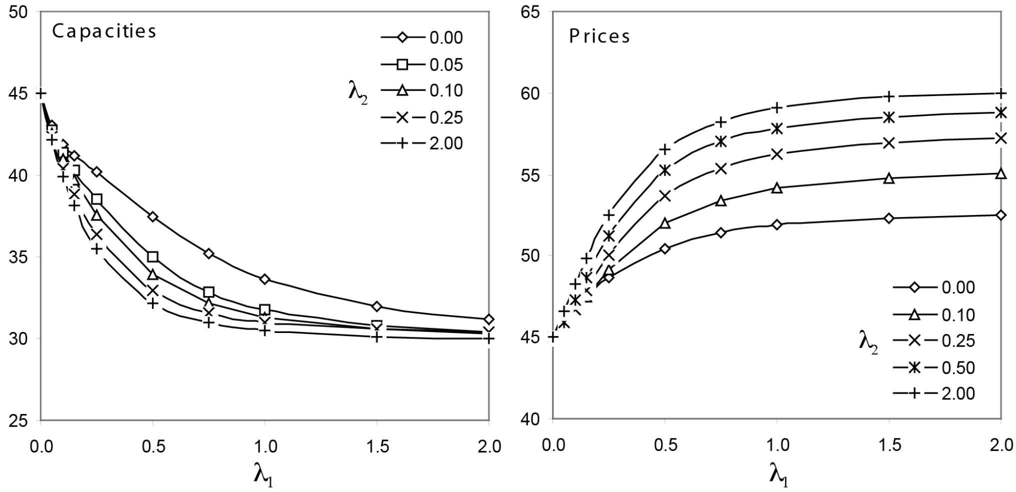

Figure 1: Mean capacity and price in logit-AQRE equilibrium

both players select the Cournot equilibrium (which is $k_i^* = 30$, $p_i^* = 60$). For all values of λ, except those close to ∞, the equilibrium strategies are non-degenerate distributions over the action space. This is not to say that each player is expected to use mixed strategies, but rather that her expected behavior is best described by a probability distribution, where the likelihood that she chooses particular strategies is linked to the expected payoff from those strategies. Furthermore, each player views her opponent's behavior in probabilistic terms, and expectations about these distributions are consistent with the equilibrium strategies.

The means of capacities and prices generated by *logit*-AQRE under different λ_i are shown in Figure 1. The graphs are drawn from player 1's perspective, with her precision level λ_1 on the x-axis. Each curve shows the relationship between player 1's average capacity and her precision level, for a given player 2's precision level. A change in the opponent's precision level, λ_2, is represented by a shift of curve.[4]

From the left hand graph in Figure 1, player 1's average capacity decreases in her own precision, and seems to converge toward the Cournot output level (i.e., 30). This is especially true when the opponent's experience level is high. In other words, when both players observe their payoffs with high precision the *logit*-

[4]The numerical values of the λ's are specific to the model and can only be compared in relative terms. The model is not solvable for λ's much larger than 2.

AQRE converges to the unique subgame-perfect equilibrium. An increase in λ_2 corresponds to a downward shift in the graph to the left, implying that player 1's average capacity is decreasing in λ_2. In other words, the expected capacity chosen by a player is both decreasing with respect to her own experience level (λ_1), and to the experience level of her opponent (λ_2).

From the right hand graph in Figure 1, the expected prices increase with a player's own experience (λ_1), and with her opponent's experience (λ_2). The simulated price choices are more complicated to interpret however, as the price strategies are conditional on the selected quantities. An inexperienced player will choose quantities with mean close to the mean of the action space. As a result the market clearing price will be lower on average than the Cournot outcome, at least when the action space's mean is larger than the Cournot outcome.[5]

The upwards bias in capacities (and downwards bias in prices) due to the inexperience of opponents is caused by what we like to call *imperfect price response.* Prices and capacities are not chosen independently. When capacities are close to the Cournot level and players are rational, they will respond to increased aggregate capacity by reducing prices according the the slope of the demand curve, which in this case is -1. In the case of a less rational player her reponse will be less predictable. In the extreme case of a perfectly clueless player, for instance, the price response will be zero as she fails to take the increased capacity into account when the chooses her price. Interestingly, this creates an incentive for her opponent to increase her capacity.

Consider the following example where players can only choose among three capacity levels $k_i \in \{20, 30, 40\}$ and three price levels $p_i \in \{55, 60, 65\}$. Notice that the feasible choices are symmetric around the Cournot outcome. Player 1 is perfectly rational. She chooses a strategy that maximizes her expected payoff given a consistent belief about player 2's strategy. Player 2 is perfectly irrational and

[5]Note that the set of rationalizable strategies, available to subjects in the experiment and used in our simulation, is highly asymmetric around the sub-game perfect equilibrium values. Our findings are however robust with respect to the choice of action space, especially in the case of capacities. The presence of a bias towards larger capacities and lower prices does not seem to be caused by the choice of action space, although it is an important determinant of the shape of the bias with respect to the level of players' rationality and their perceptions about the rationality of others. The case when the action space is symmetric around Cournot output is depicted in Figure 7 in Appendix B.

she choses all her actions with equal probability. If player 1 chooses the Cournot output, 30, her optimal price strategy is[6]

$$p_1^*\left(k_1 = 30, k_2 = \begin{bmatrix} 20 \\ 30 \\ 40 \end{bmatrix}\right) = \begin{bmatrix} 65 \\ 60 \\ 55 \end{bmatrix}. \tag{5}$$

and because player 2 chooses each available price level with probability $\frac{1}{3}$, player 1's expected profit is

$$E(\pi_1 \mid q_1 = 30) = \frac{1}{3} \times 30\,(65 + 60 + 55) - 30 \times 30 = 900.$$

Notice that she manages to sell all of her capacity whatever player 2 does. If, however, player 1 chooses $q_1 = 40$, her optimal price strategy, depending on q_2 is

$$p_1^*\left(k_1 = 40, k_2 = \begin{bmatrix} 20 \\ 30 \\ 40 \end{bmatrix}\right) = \begin{bmatrix} 60 \\ 55 \\ 55 \end{bmatrix} \tag{6}$$

and her expected profit is

$$E(\pi_1 \mid k_1 = 40) = \frac{1}{3} \times 60 \times 40 + \frac{2}{3} \times 55 \times \left(\frac{2}{3} \times 40 + \frac{1}{3} \times \frac{65}{2}\right) - 30 \times 40 = 975.$$

Going from left to right, the right hand side is obtained as follows. Player 2 chooses $k_2 = 20$ with probability $\frac{1}{3}$, in which case player 1 chooses $p_1 = 60$ and manages to sell to capacity. her revenue is 60×40. But if player 2 chooses $k_2 = 30$ or 40, player 1 should choose a low price $p_1 = 55$. Then she is able to sell to capacity as long as player 2 chooses a higher price (with probability $\frac{2}{3}$) and receive 55×40 in revenue. However, with probability $\frac{1}{3}$ player 2 will match firm 1's low price and demand is

[6] The optimal price strategy (5) comes straight from (1). Take for instance the case when $(q_1, q_2) = (30, 30)$. If player 1 selects $p_1 = 65$ she will not be able to sell to full capacity. With probability $\frac{2}{3}$, when $p_2 = 55$ or 50, player 1 can only sell the residual demand $120 - 30 - 65 = 25$ and with probability $\frac{1}{3}$, $p_2 = 65$ the aggregate demand is split leaving $\frac{55}{2}$ for player 1. Her expected revenue is then $65 \times \left(\frac{2}{3} \times 25 + \frac{1}{3} \times \frac{55}{2}\right) = 1679.2$. If she chooses $p_1 = 60$, she will be able to sell all her capacity, no matter what p_2 is, giving her the expected revenue $60 \times 30 = 1800$. Clearly $p_1 = 55$ is inferior as sales are already at the capacity level at $p_1 = 60$.

split equally between the two players resulting in the revenue $55 \times \frac{65}{2}$ for player 1. Cost is independent of actual sales and is always 30×40. The expected profit is 975 compared with 900 when the capacity is equal to the Cournot output. Hence, choosing a capacity level greater than the Cournot output is optimal under these circumstances. Clearly this example is rather specific but suggests a more general rule, that an opponent's imperfect price response gives an incentive to increase capacity. This pattern is clearly visible in the QRE simulation, as players with a fixed level of rationality choose higher capacities against opponents with lower levels of rationality. The magnitude of the effect is also affected by the player's own level of rationality. Naturally, a player cannot take advantage of her opponents irrationality if she is completely irrational himself. To test whether the imperfect price response was the key explanation for the bias, we repeated the simulations with prices restricted to market clearing levels. In this replication of the original Cournot model, limited rationality by opponents does not create an upwards bias in capacity.

The following hypotheses summarize our findings.

Hypothesis 1 *As a player's experience increases, her capacity (price) decreases (increases).*

Hypothesis 2 *Given the level of experience, a player's capacity (price) decreases (increases) as her opponent's experience increases.*

Hypothesis 3 *The price choices of inexperienced subjects are less responsive to capacity than the price choices of experienced subjects.*

The first hypothesis implies that there convergence towards Cournot Nash equilibrium can be expected as players gain experience. But only when both players are fully rational ($\lambda_i \to \infty \; \forall i \in \{1, 2\}$) should the Cournot outcomes be expected.[7] The second hypothesis predicts the effect of opponent's experience on the player's decision. As far as we know, such an effect has not been emphasized in the previous literature on market experiments. The third hypothesis predicts that lack

[7]This is in line with experimental literature on learning in quantity competition game (Cox and Walker, 1998; Huck et al., 1999; Rassenti et al., 2000). It is shown that subjects converge to the Cournot outcome when they gain experience.

of experience produces an imperfect price response, which is a key driving force behind the the second hypothesis.

3 Experimental Design and procedures

The key design feature of our experiment is that we match subjects with varying levels of experience, and describe the procedure to them. We use experience as a proxy for the level of rationality. In this way, we can vary players beliefs' about their opponent's level of rationality, thereby emphasizing the effects of opponent's limited rationality. In each period, the subjects play a capacity commitment game (described in Section 2.2) where they choose sequentially a capacity and a price.[8]

Two groups of subjects (A, B), played the roles of firms in a duopoly market in four sessions. 96 subjects played the game for 20 periods (or two phases of 10 periods).[9] All subjects could practice playing the game for two periods before starting each phase, so that in total the players had four trial periods. The experimental sessions were run in the following way. Group A started out. In their first phase, subjects in group A played against each other. Inexperienced subjects played against other inexperienced subjects. Then group B was introduced to the session. For ten periods subjects in group A played against subjects in group B. That is, experienced subjects played against inexperienced subjects. In their second phase, subjects in group B played against each other. In other words, experienced subjects played against other similarly experienced subjects. In the following exposition we refer to different phases using the subscripts $_1$ and $_2$. The label A_1 for instance refers to group A in their first phase, when they are *inexperienced*, while A_2 is group A in their second phase when they are *experienced*. Note that this method of labeling also has a transparent reference to opponent's experience, as subjects in group A always play against inexperienced players while

[8]The payoff function was not described to the subjects in algebraic form, but using words. See the complete instructions in Appendix A.

[9]One subject had to leave the experiment, but was replaced by an assistant. All observations from that subject are omitted in the following analysis, before and after the substitution. This should have no impact on other players' actions, however, since this subject played against other subjects in a different room. Her opponents were not informed about the switch, and had no means of learning about it.

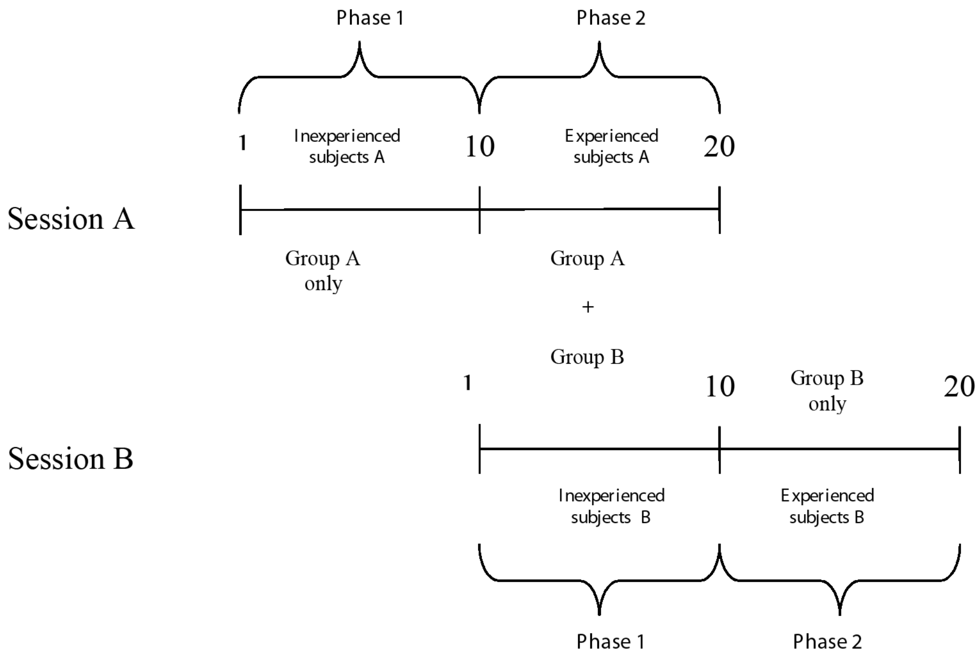

Figure 2: Experimental procedure for sessions A and B

subjects in group B always face experienced subjects. Subjects were matched so that they never played against the same opponent more than once (random matching). All players were carefully and truthfully informed about the matching procedure, with particular emphasis on the level of their opponent's experience. To summarize, we have three treatments: A_1A_1 (A_1 plays against A_1), A_2B_1 (A_2 plays against B_1), B_2B_2 (B_2 plays against B_2). Recall that the composition of the group was common knowledge among subjects.

The experiment was conducted at the Stockholm School of Economics and Reykjavik University. Subjects were all business majors. A full session lasted about an hour and a half, including the time spent reading the instructions. Subjects were paid according to their total profits earned during a sessions plus show-up fee in SEK and ISK. We used an artificial laboratory currency, "experimental dollars" (e$) where 1 US$ equals ca. e\$ 750. The participants earned, on average roughly US$ 45, with a minimum of US$ 16 and a maximum of US$ 55.

The experiment was programmed and conducted using z-tree (Fischbacher, 2007). In each period, subjects went through three steps. In the *capacity choice* *step* each subject entered a capacity of her choice in the interval 0 to 90 with a maximum of two decimals. In the *price choice step* her previously chosen capacity level and current opponent's capacity level were displayed. She then entered a price level between 0 and 120 with up to two decimals. In the *result step* all choices made by the subject and her opponent and the resulting profits were displayed. The capacity choice and price choice screens both featured a profit calculator, where subjects could insert different hypothetical values for their own and their opponent's capacity and prices and compare the resulting profits.

4 Experimental results

4.1 Descriptive Statistics

Figure 3 displays the average of capacity and price for each group of subjects. There is a steady decline in capacities and an increase in prices, on average, as subjects gain experience. Recall that players are considered as *inexperienced* when they play during the first ten periods out of twenty (phase 1) and are labelled A_1 and B_1 respectively. Players are considered as *experienced* when they play during the last ten periods (phase 2) and are labelled A_2 and B_2 respectively. Given our experimental design, group A (A_1 or A_2) always faces relatively *less* experienced opponents than group B (B_1 or B_2) does.

Phase 1. Capacity and price choices of the inexperienced players A_1 and B_1 are shown in Panels a and c in Figure 3. In the first five periods, average capacity is close to half of the aggregate competitive output level (or 45) for B_1 and even higher levels (or 52) for A_1. The per-period capacity averages rapidly decline in periods 6 to 10. Prices tend to increase, on average, in both groups, except in the first few periods. Subjects A_1 tend to choose lower prices than subjects B_1 do.

Phase 2. Capacity and price choices of experienced players A_2 and B_2 are shown in Panels b and d in Figure 3. In group A_2, where players have inexperienced opponents, the capacity choices continue to decrease but at a slower rate than in phase 1. In group B_2, where the opponents are experienced, the average capacity levels off at around 36.5. The average capacity is higher in group A_2 than in group B_2 in all periods. The difference in capacity choice between groups appears

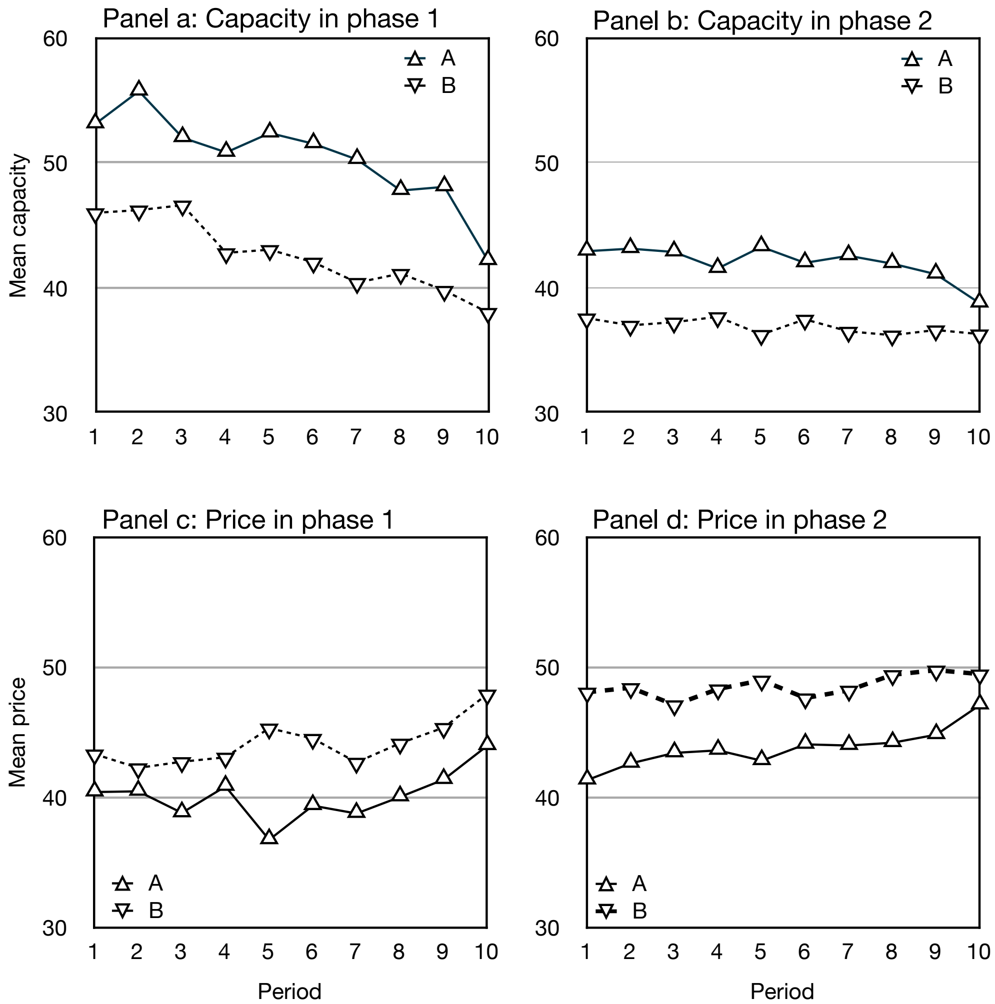

Figure 3: Capacity and price by group, period and phase

even more clearly when we look at the distribution of capacity choices shown in Figures 8 and 9 in Appendix C. In particular, capacity choices slowly converge to a bimodal distribution, with modes at 30 (i.e. the Cournot output) and 40. The frequency of capacity levels around 40 is about twice as high for subjects A_2 (facing inexperienced opponents) as it is for subjects B_2 (facing experienced opponents). Hence, players facing inexperienced opponents (like subjects A_2) tend to choose higher capacities than similarly experienced players facing experienced opponents (like subject B_2) do. Prices tend to increase, on average, in both groups except in the last few periods of phase 2, when they seem to stabilize. Subjects A_2 choose lower prices than subjects B_2 on average.

These descriptive statistics confirm the first hypothesis that average capacity (prices) is decreasing (increasing) with own experience and we observe a stronger convergence in the direction of the Cournot Nash equilibrium when both players are experienced (when subjects B_2 play against B_2). To assess whether these qualitative results are statistically significant and to learn more about the effect of the opponent's experience, we carry out a more formal analysis in the rest of this section.

4.2 Statistical analysis

4.2.1 Capacity choice

First we shall consider the choice of capacity alone. Analysis of pricing follows. To test our hypotheses about differences in group behavior while allowing for individual effects, we estimate a time-weighted regression model on the whole dataset, following Noussair et al. (1995) and Davis (1999):

$$k_{it} = \beta_i \frac{1}{t} D_i + \beta_A \frac{t-1}{t} D_A + \beta_B \frac{t-1}{t} D_B + \varepsilon_{it} \tag{7}$$

where k_{it} is observed capacity of subject i, D_i is a subject dummy variable and D_A and D_B are group dummies. The index t refers to the period of play. The weights to the subject dummy variables, $\frac{1}{t}$, are larger for observations in early periods than in later periods. The weights on the group dummies $(\frac{t-1}{t})$ are lower in early periods and higher in later periods. The key feature of the regression model is that it puts

Table 1: Regression results on capacity choice

	Model I		Model II		Model III	
Parameter	Phase 1	Phase 2	Phase 1	Phase 2	Phase 1	Phase 2
β_A	47.03	41.47	46.61	41.29	46.77	40.50
	(1.12)	(0.99)	(1.09)	(0.99)	(1.06)	(0.83)
β_B	40.32	36.50	40.34	36.49	39.53	35.45
	(0.72)	(0.42)	(0.72)	(0.42)	(0.68)	(0.41)
β_{k^e}			0.27	0.14		
			(0.06)	(0.08)		
β_{k^i}					0.34	0.61
					(0.05)	(0.08)
R^2	0.37	0.38	0.39	0.38	0.42	0.49
n	1070	1070	1070	1070	1070	1070
$Cournot A^*$	15.25	11.58	15.17	11.33	15.87	12.72
$Cournot B^*$	14.39	15.65	15.60	14.39	14.04	13.37
$A\, vs.\, B^\dagger$	5.05	4.97	4.75	4.45	5.69	5.23

Standard errors, in parentheses, are corrected for heteroscedasticity (White's method).
* t-statistic (df=959) of the two-sided test of $\beta_{A/B} = 30$.
† t-statistic (df=960) of the two-sided test of $\beta_A = \beta_B$.
The cutoff point for the 1% significance level is 2.58 in both cases.

relatively more weight on individual behavior in early periods but more weight on group behavior in later periods. This allows us to control for individual-specific effects while using the full dataset to estimate the group effects.[10] The parameters β_A and β_B are estimates of the converging capacity levels in groups A and B respectively. Table 1 lists the main parameter estimates and test statistics.

The descriptive analysis supports hypothesis 1, that capacity decreases with experience. Still, we reach a similar conclusion as earlier studies.

Result 1 *Capacities fail to converge to the Cournot value (30) irrespective of own experience and the experience of opponents.*

As shown in Table 1 t-tests for the converging levels of capacity, β_A and β_B, to be equal to 30 are strongly rejected, even at the 1% level of significance. This

[10] Noussair et al. (1995)were the first to use this econometric model to capture the convergence process observed in experimental markets. See their discussion about the underlying assumptions of such an econometric approach.

is consistent with earlier experimental results that aggregate market output converges to a capacity significantly above the Cournot level, both in triopoly markets (Davis, 1999; Muren, 2000) and duopolies (Anderhub et al., 2003).[11]

To test whether subjects' behavior depends on opponents' experience we compare capacity choices of subjects with similar experience facing opponents with varying degrees of experience.

Result 2 *Subjects choose significantly higher capacities when playing against inexperienced subjects than they do when playing against experienced subjects.*

Recall that for a given period subject A's opponent is less experienced than subject B's opponent. To check whether opponents' experience affects the capacity choice we test the following hypotheses using model (7):

$$H_0 : \beta_A = \beta_B.\ H_1 : \beta_A \neq \beta_B.$$

The resulting t-statistics are reported in Table 1 (see $A\, vs.\, B$).[12] Irrespective of subject's own experience (Phase 1 or Phase 2), H_0 is rejected at the 1% level of significance.

To assess the importance of the opponent's experience, we consider simple forms of adaptive learning as potential explanations for the observed results. We consider two learning models that have been tested in experimental studies focusing on Cournot games (e.g., Huck et al., 1999; Rassenti et al., 2000). Under fictitious play (Model II in Table 1) each subject chooses a capacity which is a best response to a weighted average of previously observed capacity choices made by previous opponents. More precisely, the expected opponent capacity is $k_t^e = 0.5k_{t-1}+0.5k_{t-1}^e$ for $t \in \{1, 10\}$.[13] The variable used in the regression is the per-group deviation

[11]This experiments differs from earlier ones in that subjects are randomly matched in each period. To be able to compare our results to earlier results we ran one session with fixed pairs throughout the session (20 periods). Capacity converges to a slightly lower level (compared with random matching sessions) but still is significantly different from the Cournot level at 1% level of significance.

[12]Almost identical results were produced using a two-factor fixed-effects panel regression. Such a model has more general individual and time effects but the tests are less intuitive. Nonparametric tests for equal medians in each period are less conclusive, due to the small number of observations in each period, but suggest similar results.

[13]In period 1 we use values from the second round of the practice period.

from mean quantities or $k_t^e - \bar{k}_i$ where $i \in \{A, B\}$. This is done, simply for the purpose of maintaining the levels of the other parameters but does not affect any of the tests. Similar time weights are applied as in the case of the group dummy variables in equation (7). The Expected opponents capacity parameter in model II turns out to be quite significant and positive in Phase 1 but only marginally significant in Phase 2 (p-value of 0.07). More impartantly, the sign of the parameter estimate is inconsistent with fictitious play, as the best response to increasing expected capacity by an opponent is to reduce capacity.

In model III we introduce imitation of best performance as a potential determinant of capacity choice. Recall that players observe their opponent's capacity choice and payoff at the end of each period. The variable k_t^i is defined as the observed capacity (including their own previous capacity choices) in any previous period from 1 to $t-1$ that has yielded the highest payoff. As in model II this variable enters the regression equation as deviations from group averages and with time weights. The imitation capacity parameter in model III turns out to be highly significant and positive in both phases.[14]

The converging values of group A is still significant higher than for group B (in both phases) in models II and III suggesting that opponents experience is a strong explanatory factor even when we control for basic adaptive learning behavior. Still we find evidence that suggests that imitations also plays a significant part in the subjects' decision making.

4.2.2 Price choice

If we repeat the above analysis using prices as the dependent variable we get similar results as predicted by the analysis of Section 2.2. Prices are significantly higher at the same level of own experience when opponents are inexperienced.

When we look at the relationship between prices and capacities we find strong support for Hypothesis 3.

Result 3 *The price choices of inexperienced subjects are less responsive to capacity than the price choices of experienced subjects.*

[14]We do not find a significant difference between groups if models II and III are re-estimated with separate fictitious play and imitations parameters for each group.

Table 2: Analysis of the relationship between price and capacity

Group	*A*		*B*	
Phase	*1*	*2*	*1*	*2*
β_0	75.00**	94.58**	86.07**	106.39**
	(2.55)	(2.27)	(2.14)	(2.13)
β_{k_i}	-0.41**	-0.52**	-0.51	-0.71**
	(0.03)	(0.03)	(0.04)	(0.04)
β_{k_j}	-0.30**	-0.69**	-0.49**	-0.86**
	(0.03)	(0.03)	(0.03)	(0.04)
R^2	0.47	0.73	0.62	0.73
n	470	470	480	480

Standard errors shown in parentheses.

* (**) Significantly different at the 5% (1%) level.

Consider the following regression for each group and phase in turn:

$$p_{it} = \beta_i \frac{1}{t} D_i + \beta_0 \frac{t-1}{t} + \beta_{k_i} \frac{t-1}{t} k_i + \beta_{k_j} \frac{t-1}{t} k_j + \varepsilon_{it} \tag{8}$$

where the dependent variable is price chosen by subject i in period t. As in equation (7), D_i are subject dummies with time dependent weights. β_0 is a common converging constant. In addition we have two separate explanatory variables related to capacity: own capacity, k_i, and opponents capacity k_j. These last three variables have time weights emphasizing the observations in later periods.

The results are shown in Table 2. The β_k parameters are clearly more negative, and closer to -1 in the in the second phase relative to the first one and more negative in group B than A. This suggests that not only do the subjects become more price responsive when the experience of their opponents increases but also as their own experience increases. Note that if we use separate parameters to estimate response to own capacity and opponents' capacity we find an interesting and significant pattern. In early periods when subjects are relatively inexperienced they respond more strongly to their own capacity choices than their opponents' capacity choices. In later periods when they have gained more experience the opposite is true as the response to opponents capacity choices is stronger.

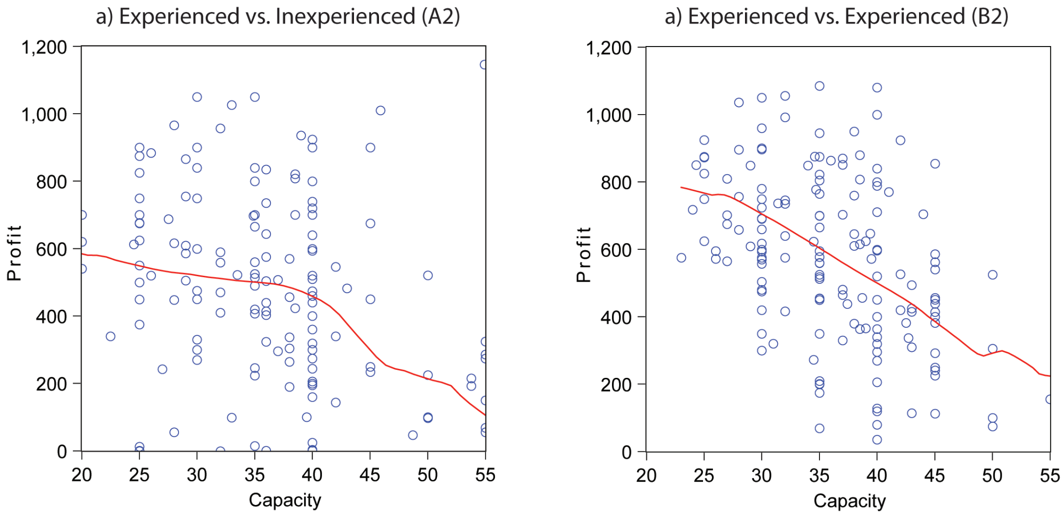

Figure 4: Profits and capacity choice by experienced subjects, scatter plot with kernel fit (Epanechikov, bw=9.0)

4.2.3 Payoffs

It is also interesting to consider whether increased incentives to choose capacities above the Cournot level when opponents are inexperienced are observed ex post.

Result 4 *Choosing capacity moderately higher then the Cournot level does not significantly reduce the payoff when playing against inexperienced subjects. When opponents are experienced increased capacity has a significant negative effect on payoff.*

Figure 4 plots actual profits made in the experiment against capacity for the last five periods of the experiment in group A and B separately. The left panel displays group A_2, experienced players facing inexperienced opponents while the right panel represents group B_2, experienced players facing inexperienced opponents. Profits tend to decrease as capacity increased, as can be expected in general. Interestingly, the negative relationship between profit and capacity is much weaker in for group A_2 at least in the neighborhood of the Cournot output level. A Kernel fit, also shown in Figure 4, illustrates this even better.

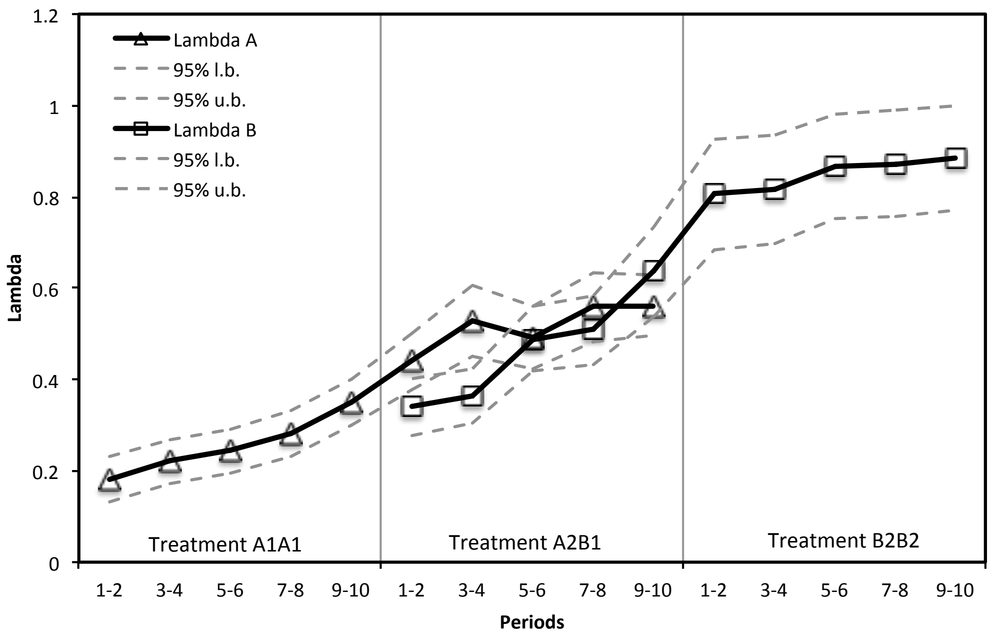

Figure 5: Estimated λ and 95% confidence intervals

4.3 Estimation of the AQRE model using experimental data

To test how well QRE predicts behavior we use the data from the experiment and estimate the logit-AQRE model described in Section on page 6. We estimate the precision parameters (λ_i), maximizing the following likelihood function,

$$ln\mathcal{L}_{\text{AQRE}} = \sum y_{it}\left(k_i, k_j, p_i\right) \times \ln\left(b_{k_i}\left(\lambda_1, \lambda_2\right) + b_{p_i|k}\left(\lambda_1, \lambda_2\right)\right). \tag{9}$$

The summation applies to subjects, periods and all possible combinations of k_i, $k_j \in A_k$ and $p_i \in A_p$. The index variable $y_{it}(k_i, k_j, p_i)$ takes the value of 1 if subject i selects capacity k_i and price p_i in period t while her current opponent chooses k_j, otherwise the value is zero.[15] The b functions are the equilibrium response functions as defined in (3) and (4). Each treatment is broken down into five experience levels, each including data from two consecutive periods.

Figure 5 depicts the precisions parameters λ_A and λ_B over time. First in treatment A_1A_1 where group A plays internally, then in treatment A_2B_1 where

[15]Selected quantities and prices are rounded up or down to the nearest point in the discrete action space.

group A in their second phase plays against and then group B in their first phase. Finally we have treatment B_2B_2 where group B plays internally. The estimates for λ_A and λ_B generally increase with the number of periods played, reflecting the tendency of subjects to choose optimal strategies with more precision as they become more experienced in playing the game.

Interestingly λ_B is always higher than λ_A for any given experience level. We can think of at least two reasons for this. First, subjects in group B might learn to play the game more quickly through imitation when, in their first phase, they are matched with the more experienced subjects of group A. We have already found suggestive evidence pointing to that hypothesis. This is however not the only effect since $\lambda_B > \lambda_A$ right from the first period.[16] A second cause for this phenomenon might be that inexperienced subjects in group B put more effort into finding their best strategy, compared with similarly experienced A players because they expect to face tougher competition. Agranov et al. (2011) find that in the context of a guessing game, that subjects' cognitive levels observed by the researchers are a "reflection of the full cognitive subject's abilities and their beliefs on others' abilities". If this also applies to our setup, then inexperienced players would exhibit higher cognitive level when playing against experienced subjects (treatment A2B1) than when playing against similarly inexperienced players (treatment A1A1).

The parameter estimates together with the log-likelihood values ($\ln \mathcal{L}_{\text{AQRE}}$) are reported in Table 4 (Appendix C). For comparison the log likelihood of the random model (i.e., when $\lambda_A = \lambda_B = 0$).

In Table 5 (first two columns), we compare the predictions based on the estimated *logit*-AQRE model for each experience level, and the actual choice (adjusted for the discrete action space). It is clear that, even though the model provides fairly good qualitative predictions, it systematically "under-predicts" capacities and "over-predicts" prices. The predicted standard deviations are close to the actual levels. This suggests that the *logit*-AQRE model is unable to completely capture the underlying causes of the observed behavior. That does not necessarily undermine our thesis of opponent's bounded rationality as a rationale for capacities above the Cournot level, but it does imply that a more complete

[16] This is also the case if we look at the first practice period, when subjects had no past history to imitate. Even in this case group B chose lower capacity than group A on average.

model of behavior is needed to capture actual behavior in more detail. We discuss this issue further in the concluding section.

5 Conclusion

This paper explores how bounded rationality can affect the market outcome in a capacity choice game. We consider a two-stage model of capacity investment and pricing, using the a *logit*-agent quantal response equilibrium framework. With fully rational players, a Cournot outcome is the unique equilibrium (as in Kreps and Scheinkman, 1983). However, when players are facing bounded rational opponents, choosing capacity above the Cournot level is predicted. This result is confirmed by our experiment, where we use the level of experience (the number of periods played) as a proxy for the level of rationality, and match subjects with different levels of experience. We find that capacities are relatively high when opponent's level of experience is relatively low, and that prices are relatively low when opponents lack experience. The observed deviations are much larger than predicted by the model however, thereby indicating that the current model specification is too restrictive.

At least two extensions seem worthy for further research. First, we find considerable heterogeneity of capacity choices within each group. Allowing for different levels of rationality within each group as in models of strategic thinking (Crawford et al., 2010). would capture this, and possibly increase the level of the predicted bias.

Second, extending the AQRE model to allow for inconsistent response functions is another interesting alternative. Weizsacker's (2003) extension of the normal form QRE allows for response functions that depend on the perceived opponent's choice distributions, which need not be consistent with the opponent's actual equilibrium strategy. Analysis of experimental data suggests that perceptions are quite frequently biased in the direction of underestimating the rationality of other players (e.g., Camerer and Lovallo, 1999). In the logit quantal response framework, this amounts to a downward bias in player's perception of their opponent's precision level. If the same bias were to appear in the KS model the predictions of such a model would probably be closer to the actual outcome, as the average capacities should increase, given that beliefs about the opponent's precision level decrease.

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A Instructions

{}: group A, []: for group B

Welcome to this experiment in the economics of decision making, which should take approximately 90 minutes. You will be paid a minimum of SEK 100 for your participation, but you can earn much more if you make good decisions. At the end of the session you will be paid, in private and in cash, an amount that will depend on your decisions. Please read the instructions carefully. If you have any questions please raise your hand, and you will be helped privately.

General Rules

This experimental session will consist of several periods. In each period you play the role of a firm which produces a good and sells it in a market.

{One other firm, represented by a randomly selected participant, sells his product in the same market in each period. For the first 10 periods you will play against other participants sitting in this room. You will never face the same participant more than once. After period 10 the experiment will restart, but now you will play against a different group of participants located elsewhere. *Unlike you, these participants have no prior experience of this experiment.* As before, you will only play against each of the new participants once.}

[One other firm, represented by a randomly selected participant, sells his product in the same market in each period. For the first 10 periods you will play against a different group of participants located elsewhere. *Unlike you, these participants have experience of this experiment, they have played the game before.* You will never face the same participant more than once. After period 10 the experiment will restart, but now you will play against other participants sitting in this room. As before, you will only play against each of the new participants once.]

By making good decisions you can earn profits in experimental dollars (e-dollars). At the end of the session you will be paid SEK 100 plus the e-dollars you have earned at the exchange rate of 1 SEK for every 50 e-dollars. Simply put, the more experimental dollars you earn the more cash you will receive at the end of the session.

In each period you make two separate decisions for your firm. First you decide how much you would like to produce (Q1) and then, after you have observed the production level of your competitor (Q2), you choose your price (P1).

Production stage

At the beginning of each period you decide how many units of the good to produce (Q1). You make your decision by entering a number in the box on the left hand side of the screen and then press OK. **Any positive number between 0 and 90**, **with up to 2 decimals** is acceptable. (Example: 10, 20.6, and 33.33 are valid but -12, 50.123 are not). Please use a dot (.) as the decimal separator.

The amount you produce has consequences for your profit in that period, since you have to pay a production cost of 30 e-dollars for each unit; regardless of how much you sell. Note that no inventories can be carried to future periods.

Before you enter your quantity you should think carefully about your choice. You can use the calculator displayed on the right hand side of the computer screen. There you can enter hypothetical production quantities and prices for your firm and its competing firm, press CALCULATE and observe the results in the Table on the lower right hand side. Table 3 explains the columns.

Table 3: Calculator table legend

Q1	Your production
Q2	Competitor's production
X1	Your sold quantity
X2	Competitor's sold quantity
P1	Your price
P2	Competitor's price

Price stage

When all participants have entered their production levels you will automatically go to the price stage. On the left hand side you can see your own chosen production level as well as your competing firm's production level. You enter a price of your choice in the box below this information and press OK when you are ready. **Any positive number between 0 and 120, with up to 2 decimals** is acceptable. (Example: 10, 20.6, and 33.33 are valid but -12, 50.123 are not). Please use a dot (.) as a decimal separator. You may want to do some more calculations before you set your price. You still have the calculator on your right

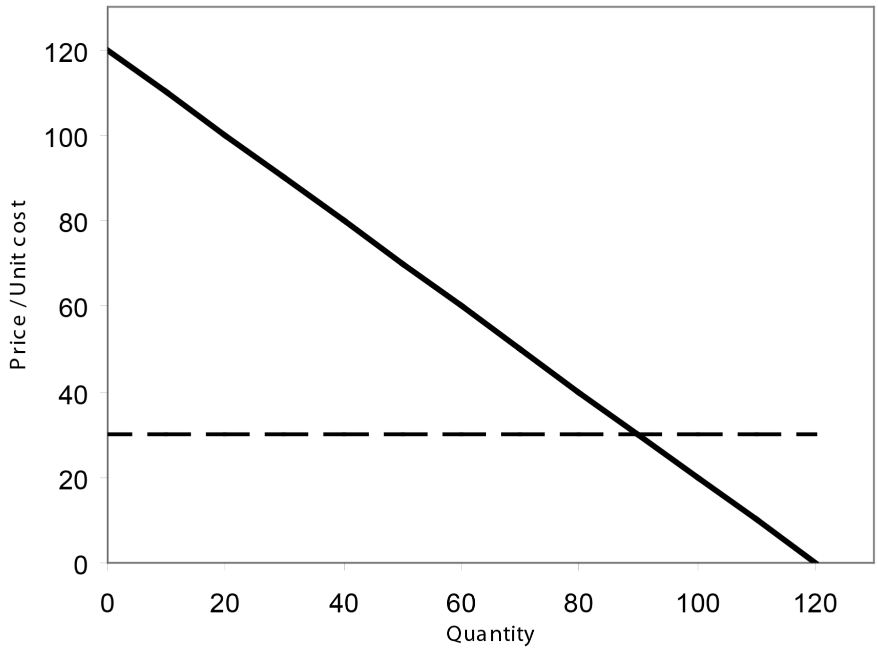

Figure 6: The demand function (solid line) and the unit cost function (dotted line)

hand side, but this time you can only alter the prices (P1 and P2). The previously chosen quantities (Q1 and Q2) are fixed at this stage.

How much you sell is determined by your price (P1) and its relation to your competitor's price (P2). Consumer demand is calculated by a computer program and follows a simple equation

$$D = 120 - P.$$

where D is demand and P is a price. This means for instance that at the price 0 consumers are willing to purchase 120 units of the product. At the price of 25.5 consumers are willing to purchase 94.5 units. There is no demand for the product at price levels equal to or greater than 120. Figure 6 illustrates demand and unit cost.

Consumers strictly prefer buying from the firm offering the lower price. Hence, the firm with the lower price will sell all its production up to the demand level at that price. The firm with the higher price can only sell the product to consumers who are not supplied by the lower pricing firm, and never more than the demand level at its price, or its produced quantity. If both firms choose the same price, demand will be split equally between them up to the quantity limits (the respective production levels).

Example 1: Say that Q1 = 35, Q2 = 45, P1 = 45 and P2 = 55. Since demand at the lower price level is 75, you (firm 1) can sell all your produced quantity. Your revenue is $45 \times 35 = 1575$ and your total cost is $30 \times 35 = 1050$. Your profit is $1575 - 1050 = 525$. Your opponent (firm 2) can only sell 30 units. The demand for his product equals $120 - 55 = 65$, by the demand equation. From that we have to subtract what is already supplied by your firm, or 35 units. Hence, she sells $65 - 35 = 30$ units at the price of 55. His revenue is $55 \times 30 = 1650$, his total cost is $45 \times 30 = 1350$ and she makes a 300 e-dollar profit.

Example 2: Say that $Q1 = Q2 = 15$ and $P1 = P2 = 55$. Demand at this price is greater than the sum of the production levels but you can only sell what you produce. Your profit is $55 \times 15 - 30 \times 15 = 375$.

Result display

When all participants have entered their prices the result display will appear. You can then see a summary for that period, for yourself and your competitor. Press continue when you have studied the results.

Periods

To help you familiarize yourself with the computer interface and the calculations, you get to practice for two periods. *The result of these periods will not affect your payoff.*

{Then, you will play for 10 periods, once with each of the participants in your room. Then, after a short break, the experiment restarts, and now you play against inexperienced participants. Again you go through two practice periods (for the others) and then 10 periods, where you can earn money, against each of the inexperienced participants.}

[The result of these pratice periods will not affect your payoff. Then you will play for 10 periods, once with each of the experienced participants in the other room. Then, after a short break, the experiment restarts and now you play for

10 periods against participants sitting in your room, who have the same level of experience as you do]

Before you leave, we ask you to fill out a short questionnaire about the experiment. We will use the time while you complete it to calculate your earnings.

Everything described here is not only valid for you, but also for all other participants in this experiment.

Now you should be ready to start the experiment. Please raise your hand if you have any questions. We prefer to answer your questions privately. Good luck!

B Predictions with Symmetric Action Space

If players randomize completely, the average capacity is determined by the mean of the action space. In most conceivable configurations of the KS model, the average of all feasible capacity levels is higher than the Cournot output, while the opposite is true for prices. This might affect the prediction of the *logit*-AQRE model. It is therefore interesting to compare the predictions in section 2.2 to the case where the action space is symmetric around the Cournot outcomes, $A_k = \{0, 5, ..., 60\}$ and $A_p = \{30, 35...90\}$. In this setup the expected capacity and price chosen by a totally clueless player (with $\lambda = 0$) is simply the Cournot outcome. Figure 7 illustrates average capacity and price choices in the *logit*-AQRE equilibrium profile. With a symmetric action space, average capacity is no longer uniformly decreasing in own precision level (λ_1). For positive levels of λ_2 (opponent's precision level) it first increases and then decreases. Furthermore, capacity only converges to the Cournot output level when both λ_1 and λ_2 increase simultaneously. The case of prices is more complicated, as the average price is not monotonic with respect to λ_2 either. The comparison of these two configurations is helpful. It suggests that the presence of a bias towards larger capacities and lower prices does not seem to be caused by the choice of action space, although it is an important determinant of the shape of the bias with respect to the level of players' rationality and their perceptions about the rationality of others.

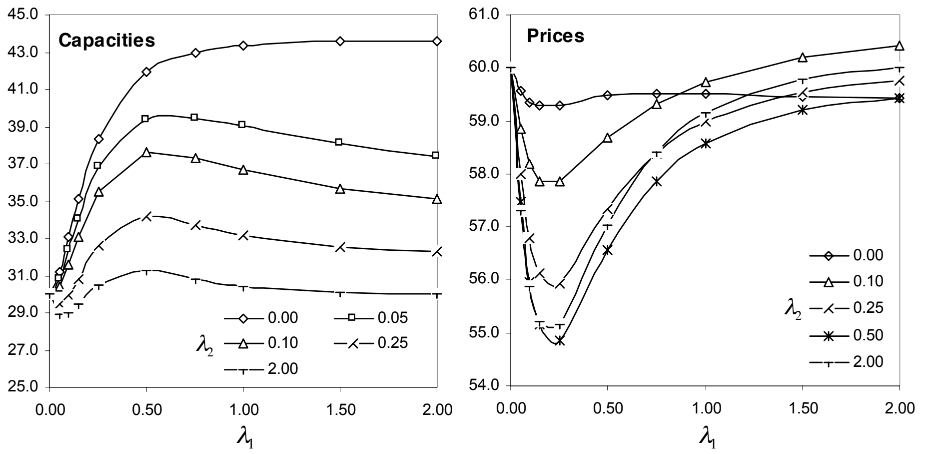

Figure 7: Mean capacities and prices in logit-AQRE equilibrium - Action space symmetric around Cournot outcome

C More experimental results

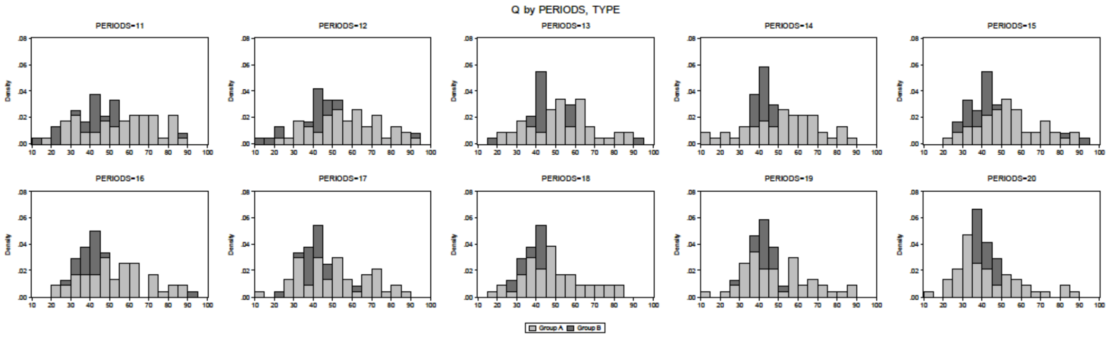

Figure 8: Distribution of capacity choices in group A in the first two sessions, each graph indicates a particular experience level (two periods)

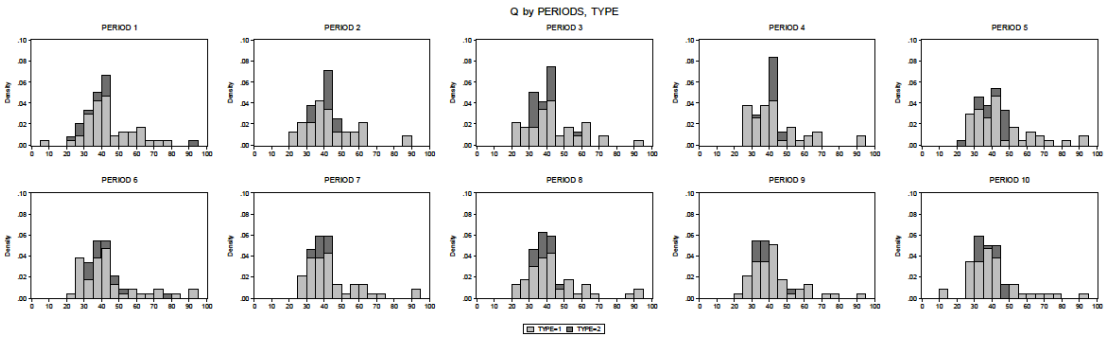

Figure 9: Distribution of capacity choices in group B in the first two sessions, each graph indicates a particular experience level (two periods)

Table 4: Maximum likelihood estimation of the logit-AQRE model

Periods	λ_A	λ_B	$ln\mathcal{L}_{\text{AQRE}}$	$ln\mathcal{L}$
			a) Group A_1	
1-2	0.19		-205.9	-249.1
	(0.03)			
3-4	0.26		-201.2	-249.1
	(0.04)			
5-6	0.29		-187.5	-249.1
	(0.04)			
7-8	0.34		-196.9	-249.1
	(0.04)			
9-10	0.54		-171.5	-249.1
	(0.05)			
			b) Group A_2 vs. B_1	
1-2	0.73	0.40	-345.2	-509.1
	(0.10)			
3-4	0.75	0.48	-341.1	-509.1
	(0.09)			
5-6	0.86	0.65	-310.1	-509.1
	(0.10)			
7-8	0.81	0.69	-315.2	-509.1
	(0.10)			
9-10	0.81	0.69	-321.9	-509.1
	(0.10)			
			c) Group B_2	
1-2		0.86	-154.3	-260.0
		(0.11)		
3-4		0.82	-157.8	-260.0
		(0.09)		
5-6		1.01	-144.8	-260.0
		(0.12)		
7-8		1.02	-144.0	-260.0
		(0.11)		
9-10		1.141	-133.0	-260.0
		(0.12)		

Standard errors in parantheses, estimated by the BHHH method.

Table 5: Actual vs. predicted quantities and prices

	k_A		k_B		p_A		p_B	
	Actual	*Pred.*	*Actual*	*Pred.*	*Actual*	*Pred.*	*Actual*	*Pred.*
				a) Group $A_1 vs. A_1$				
1-2	53.9	38.0			40.7	48.5		
	(18.5)	(18.2)			(11.5)	(17.5)		
3-4	50.5	36.1			37.5	50.3		
	(16.2)	(16.3)			(8.6)	(16.4)		
5-6	48.9	35.3			37.5	51.2		
	(16.4)	(15.3)			(10.1)	(15.8)		
7-8	44.5	34.5			40.3	52.2		
	(14.0)	(14.3)			(12.2)	(15.2)		
9-10	38.4	32.3			47.5	55.8		
	(13.1)	(10.6)			(13.7)	(12.4)		
				b) Group A_2 vs. B_1				
1-2	37.7	31.5	45.8	33.3	44.1	56.5	42.9	54.7
	(9.2)	(9.0)	(16.6)	(12.6)	(9.7)	(12.2)	(10.0)	(13.2)
3-4	37.1	31.4	43.3	32.6	44.7	56.9	44.5	55.6
	(8.4)	(8.8)	(15.9)	(11.4)	(10.2)	(11.7)	(11.2)	(12.3)
5-6	37.0	31.1	41.7	31.6	46.1	57.9	46.4	57.3
	(8.6)	(8.0)	(16.5)	(9.5)	(10.2)	(10.5)	(10.3)	(10.8)
7-8	37.2	31.2	38.9	31.5	47.0	57.8	46.5	57.4
	(7.4)	(8.3)	(14.6)	(9.1)	(8.8)	(10.6)	(8.8)	(10.7)
9-10	36.7	31.2	39.6	31.5	46.6	57.8	46.7	57.4
	(8.0)	(8.3)	(12.7)	(9.1)	(8.3)	(10.6)	(8.6)	(10.7)
				c) Group B_2 vs. B_2				
1-2			37.4	31.0			46.8	58.2
			(11.5)	(8.0)			(7.5)	(9.9)
3-4			37.1	31.1			47.3	58.1
			(11.6)	(8.2)			(7.8)	(10.1)
5-6			36.5	30.7			48.2	58.8
			(11.8)	(7.3)			(8.0)	(9.2)
7-8			35.3	30.7			49.5	58.8
			(11.5)	(7.2)			(7.7)	(9.1)
9-10			35.2	30.5			51.1	59.1
			(11.7)	(6.8)			(8.4)	(8.7)