E C O N O M I C S   B U L L E T I N

Reciprocal strategies and aspiration levels in a Cournot−Stackelberg experiment

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Abstract

We examine behavior in Cournot and Stackelberg markets in a simple experiment where participants experience both market forms. Moreover, Stackelberg followers have to submit full response strategies. Our main finding is that Stackelberg followers employ rather flat, reciprocal response function, i.e., they punish leaders in who try to exploit their strategic adavantage and are willing to cooperate with cooperative leaders. Also, it turns out that prior exposure to a symmetric market makes followers more aggressive which hints at the role of aspiration levels in markets.

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1 Introduction

In a recent paper Huck, Muller, and Normann (2001, henceforth HMN) report a first experimental comparison of Stackelberg and Cournot duopolies. They replicate previous results for Cournot markets, finding stable equilibrium play for random matchings and some collusion for fixed matchings. For the Stackelberg case, their main finding is that behaviour did not settle down to the theoretical prediction, with leaders producing less and followers producing more than is predicted by theory. Both shifts imply significantly lower market concentration than theoretically predicted.

This result appeared mainly to be driven by followers playing according to reaction curves that were much flatter than predicted by theory. Flat reaction functions can be interpreted as reciprocal as they are "nasty" to greedy leaders and "nice" to cooperative leaders. Given such reaction curves, a leader's best response is to produce less than in the unique subgame perfect equilibrium. However, HMN did not observe full response strategies as their subjects played sequentially. Hence, their estimates of response functions are potentially biased by the uneven distribution of leaders' quantities.

In this paper we test the robustness of HMN's results by employing a different method of eliciting choices. While HMN studied sequentially taken decisions (repeated over ten rounds in either random or fixed-pairs matching)[1] we employ the so-called strategy method (Selten 1967). Each subject plays both games, but only once each. The obvious advantage of the strategy method is that we can gather much more data in otherwise seldomly reached information sets. This allows us to present estimates of followers' response functions that are less biased than HMN's.

Our main finding is that Stackelberg followers indeed employ rather flat, reciprocal response function, ie, they quite calmly plan to punish leaders in case they try to exploit their strategic adavantage and, at the same time, they are willing to not to exploit cooperative moves by the leader. Moreover, it turns out that prior exposure to a symmetric market makes followers more aggressive which hints at the role of aspiration levels in markets. Both results might be of relevance to explaining (endogenous) market structures in the field.

The remainder of the paper is organized as follows. In Section 2 we briefly present the theory and then the experimental design. Section 3 presents the data and their analysis. Section 4 concludes.

2 Theory and experimental design

As with HMN, we study two duopoly markets, Cournot and Stackelberg, using quantity competition, with both firms facing linear inverse demand

$$p(Q) = \max\{30 - Q, 0\}, Q = q_1 + q_2$$

[1] As with the Cournot case, behaviour became less competitive when pairs were fixed.

	Cournot first	Stackelberg first
Stackelberg leader	LeCo 11	LeSt 10
Stackelberg follower	FoCo 12	FoSt 11

Table 1: Design of the experiment and number of subjects.

and where linear costs are given by

$$C_i(q_i) = 6q_i, i = 1, 2.$$

In the experiment only quantities from the finite grid $\{3, 4, ..., 15\}$ were feasible.[2]

Stackelberg and Cournot markets differ in the timing of the decision. In the Cournot market, both firms decide on quantities *simultaneously*, but in the Stackelberg market one firm, the leader, decides on its quantity, q_L, then the other firm, the follower, knowing the leader's quantity decides on its quantity, q_F. Theory predicts $q_1 = q_2 = 8$ in the Cournot case and $q_L = 12$, $q_F = \frac{1}{2}(24 - q_L) = 6$ in the Stackelberg market.

HMN studied both of these two markets with repeated experiments, using two treatments, fixed matching and random matching, over ten periods. We take an alternative experiment, where we get each subject to write down either their Stackelberg follower response function or their Stackelberg leader quantity. We also get each subject to decide on their Cournot quantity. The order in which a subject decides (either Stackelberg first or Cournot first) affords four different positions in the experiment and enables us to gain further information on attitudes to competitiveness. See table 1 for experimental design and numbers participating in each experiment.

The experiment was conducted in one large session, and run with pen and paper. Subjects were randomly split into the four groups as described, and given written instructions and a sheet where they marked their Cournot strategy, their Stackelberg leader quantity or wrote down their whole response function (ie their response for each possible quantity from a Stackelberg leader) if they were Stackelberg followers. Then we announced a second round of the experiment with new instructions. Subjects who had been playing in the Cournot treatment were randomly assigned the roles of Stackelberg leaders or followers, and subjects who had been playing in the Stackelberg treatment were now assigned roles in the Cournot market. There was no feedback information about what had happened in the first round.

The subjects were informed that, at the end of the experiment, for each round and treatment two pairs would be randomly matched and would receive payoffs given their performance. Payoffs were according to the above functions multiplied by £0.10. Average payoffs were around £6. The experiment lasted roughly 30 minutes.

[2]Moreover, payoffs were slightly manipulated to ensure unique best responses and a unique Nash equilibrium. See also HMN who used the same payoff matrix.

q_L	1	2	3	4	5	6	7	8	9	10	11	12	13
FoCo	10.17	10.17	9.83	9.17	8.33	8.25	8.00	7.42	7.00	6.83	6.92	6.58	6.42
	(2.08)	(1.59)	(1.27)	(1.27)	(1.61)	(1.76)	(2.41)	(1.93)	(1.76)	(1.99)	(1.83)	(2.50)	(2.61)
FoSt	8.91	8.36	8.45	7.18	7.36	7.00	7.36	6.82	6.36	5.91	5.73	5.73	5.91
	(3.75)	(2.69)	(2.38)	(2.35)	(2.87)	(2.45)	(2.84)	(1.99)	(2.84)	(2.34)	(2.10)	(2.10)	(3.39)

Table 2: Average Stackelberg followers quantities and standard deviations.

Expt	Stackelberg leader quantity	Cournot quantity
LeCo	9.64	7.55
	(1.96)	(1.97)
LeSt	9.60	7.60
	(3.17)	(1.35)
FoCo	-	7.67
		(2.06)
FoSt	-	8.60
		(2.95)

Table 3: Average Stackelberg leader and Cournot quantities

3 Results

We investigate two main questions: How do the findings compare to the theory? And how do they compare to HMN? In particular, we are interested in whether the use of the strategy method provides more information about the reaction curves employed by followers.

We provide summary statistics about quantity choices in Tables 2 and 3. And there are a few facts immediately emerging from the tables.

1. The Cournot equilibrium predicts behavior reasonably well for all subjects.[3]

2. Stackelberg leaders produce roughly 20% less than predicted.

3. Stackelberg followers' reaction curves are less steep than predicted. This holds for those who started with Stackelberg as well as for those who started with Cournot. The latter subjects are, however, more aggressive and produce, on average, one unit more than the former.

[3]Subjects who were Stackelberg followers in the first round produced on average more than all other groups. But these differences are not significant.

	γ_0	γ_1	γ_2	γ_3	R^2
FoCo & FoSt	10.490*	−0.344*	−1.571*	0.065	0.815
	(0.205)	(0.026)	(0.297)	(0.037)	

Table 4: Estimated response function.

Thus, at first glance we find behavior is very similar to what HMN observe. There are, however, additional effects of the order in which subjects encountered the two market environments. A possible explanation for this is discussed below.

In order to analyse follower behavior more closely we estimate reaction curves using a linear regression. We include treatment dummies and subject dummies (both, for intercept and slope).[4] More specifically, we estimate the following equation:

$$q_F = \gamma_0 + \gamma_1 q_L + \gamma_2 I + \gamma_3 q_L I$$

where I is an indicator variable taking the value 1 when the subject has played Cournot first and 0 otherwise. Table 4 presents the regression results. Figure 1 illustrates the estimated reaction functions for the two values of I (together with the theoretical reaction function).

The regression confirms what we have seen above with the naked eye: For both groups of subjects, the slope is less steep than theoretically predicted.[5] And as with HMN the estimated reaction curves cross the theoretically predicted one roughly at Cournot. That, of course, means that followers are, at least partially, cooperative when leaders produce less than Cournot. But, at the same time, they are more aggressive when leaders try to exploit their theoretical advantage. This confirms the results in HMN—but now on the basis of having observed *full strategies*. The estimates also confirm that followers who first played in a Cournot market are significantly more aggressive than those who start out as a follower in round 1 of the experiment.

The best response of a leader against the estimated reaction curve of followers who started as followers would have been 10.30, the best response against the curve of followers who started with playing Cournot would have been 10.46. Thus, the leaders in our experiment did a remarkably good job in predicting followers' behavior even though they had zero experience and no opportunities for learning.[6]

4 Discussion and conclusion

Before turning to a brief discussion of our main results we would like to make one observation from a methodological point of view. There has recently been a discussion about whether the

[4]Subject dummies are coded such that coefficients of treatment dummies present actual averages. See HMN for the same procedure.

[5]In fact, looking at each persons' response function individually we find that not one of them is steeper than the theoretical prediction.

[6]Direct evidence on subjects capabilities of predicting choices of others is reported in Huck and Weizsacker (2001).

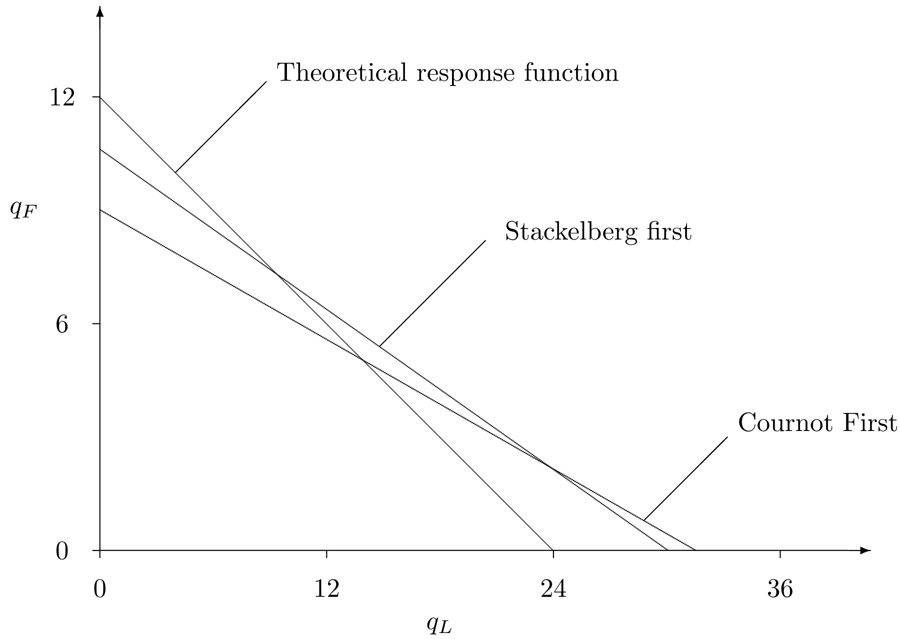

Figure 1: Illustration of Follower differences

strategy method can be seen as a reliable way of eliciting data or whether there are certain biases one must accept when using it. For example, Brandts and Charness (2000) provide evidence on a number of games where there are essentially no differences between sequential play ("hot") and the strategy method ("cold"). Guth, Huck, and Muller (2001), on the other hand, report data from mini ultimatum games where there is a huge difference between the two methods. This note adds to the evidence provided by Brandts and Charness (2000). In Stackelberg games it seems rather safe to use the strategy method. Potentially, this can make further experiments much cheaper.

Concerning the main questions raised in this note, we first of all conclude that reaction curves of Stackelberg followers are indeed much flatter than predicted and that this is, almost perfectly, anticipated by leaders. Subjects are able to put themselves into others' shoes which, in this case, avoids massive conflict and, moreover, renders markets much less concentrated than theoretically predicted. We think it would not be surprising to find similar patterns in actual industries. If strategically weaker firms act spitefully, firms that are strategically stronger, for example because of successful innovation, may not be able to exploit their advantage as one would expect from a naive game-theoretic analysis.[7]

Moreover, we find that subjects who start in a symmetric environment act more aggressively as Stackelberg followers than others who find themselves in a weak strategic position right at

[7]Rather, models that incorporate inequality aversion (as, for example, Bolton and Ockenfels 2000 or Fehr and Schmidt 1999) might also be tested for their usefulness for explaining industrial behavior.

the start. We conjecture that this is driven by aspiration levels.[8] Once subjects experience symmetric payoffs they are not easily forced into an unfavorable position. In other words, they are willing to bite back.[9] This fact, too, might have significant consequences for the evolution of actual market structures.

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[8] The theory of aspiration levels currently experiences a significant renaissance. See, for example Oechssler (2001).

[9] This is in line with very early empirical evidence on the role of aspiration levels in markets provided by Cyert and March (1956) who report that firms that have experienced a declining market share act more aggressively than others. Experimental evidence for the role of aspiration levels in mergers is provided in Huck, Konrad, Muller, and Normann (2001).