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Cournot or Stackelberg Competition?

A Survey on Experimental Evidence

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August 17, 2010

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Abstract

In this survey, I look into experimental studies on duopolistic quantity competition with homogeneous products and duopolistic price competition with heterogeneous products. The focus is on the sequence of competition. That is, I summarize and analyze experimental studies checking Cournot competition against Stackelberg competition. I find that while Stackelberg equilibrium outcomes are seldom under quantity competition, under price competition, the Stackelberg equilibrium prediction seems to be more appropriate. However, after discussing the experimental setups, I conclude that some methodological problems are present. Moreover, I make recommendations for further research.

Keywords: Cournot competition, simultaneous competition, simultaneous play, Stackelberg competition, sequential competition, sequential play, duopoly, homogeneous products, heterogeneous products, experiemtal economics.

Journal of Economic Literature Classification Codes: C720, C910, D430, L130.

1 Introduction

Although the *Cournot model* and the *Stackelberg model* of duopolistic quantity competition with homogeneous products and duopolistic price competition with heterogeneous products are part and parcel of every textbook on industrial organization,[1] only few experiments testing these models have been conducted yet. The same is true for so-called *endogenous competition models.*

An endogenous competition model is a model in which the sequence of competition is not exogenously given but endogenously determined by the firms' decisions. The two most often used endogenous competition models were built by Hamilton and Slutsky (1990): the *extended game with action commitment* and the *extended game with observable delay.* For example, van Damme and Hurkens (1999) apply Hamilton and Slutsky's extended game with action commitment to quantity competition between firms which are asymmetric with respect to marginal costs. Another endogenous competition model is Saloner's (1987) *extended game with two investment periods* which has been advanced by Ellingsen (1995).

Experimental studies on the two exogenous quantity competition models were done

[1] Most often, textbook authors speak of the *Bertrand model* when they refer to simultaneous price competition. Since Bertrand has argued with homogenous products exclusively and Cournot has applied his equilibrium concept not only to quantity competition but also to price competition, following Morrison (1998), I say Cournot quantity (price) competition when I refer to simultaneous quantity (price) competition with homogeneous (heterogeneous) products. The same logic is applied to sequential competition.

by Huck et al. (2001) and Fonseca et al. (2005). Saloner's model was experimentally examined by Müller (2006), and Hamilton and Slutsky's models were tested by Huck et al. (2002) and Fonseca et al. (2006). Further, Fonseca et al. (2005) also experimentally investigated van Damme and Hurkens's model. The only experimental study checking Cournot price competition against Stackelberg price competition was done by Kübler and Müller (2002). Moreover, none of the endogenous price competition models has been experimentally examined yet. For example, such models were published by Hamilton and Slutsky (1990), van Damme and Hurkens (2004), Pastine and Pastine (2004), and Amir and Stepanova (2006).[2]

In Cournot quantity competition markets, Huck et al. and Fonseca et al. (2005) find evidence for the Cournot equilibrium prediction. In contrast, Stackelberg equilibrium outcomes are seldom in Stackelberg quantity competition markets. In endogenous Stackelberg quantity competition markets, the Stackelberg equilibrium prediction is even worse. However, in Stackelberg price competition markets, the Stackelberg equilibrium prediction seems to be more appropriate.

Consequently, I raise the following four questions: (i) Has the Cournot quantity competition model been corroborated and the Stackelberg quantity competition model been falsified by Huck et al. (2001) and Fonseca et al. (2005)? (ii) Did Müller (2006), Huck et al. (2002), Fonseca et al. (2006), and Fonseca et al. (2005) falsify the endogenous

[2] Another endogenous price competition model was developed by Deneckere and Kovenock (1992) and experimentally investigated by Datta Mago and Dechenaux (2009). However, they deal with homogeneous products.

Stackelberg quantity competition models? That is, is it not possible to explain sequential quantity competition by these models? (iii) Did Kübler and Müller (2002) find evidence for the Cournot and the Stackelberg price competition model? (iv) What can we expect from further research on price competition? In particular, will it be possible to explain price leadership by the proposed endogenous Stackelberg price competition models? My aim is to stimulate further research in this area.

In addition to the models mentioned above, there is Bagwell's (1995) noisy leader game. Bagwell claims that the first mover advantage, which is present in Stackelberg quantity competition games under perfectly observable first mover actions, disappears if the action of the first mover is not perfectly observable by the second mover. That is, for Stackelberg quantity competition markets under noise, Bagwell predicts Cournot equilibrium outcomes. While Bagwell focuses on Nash equilibria in pure strategies, van Damme and Hurkens (1997) concentrate on Nash equilibria in mixed strategies. They prove that each noisy leader game exhibits a Nash equilibrium in mixed strategies. Further, van Damme and Hurkens show that the associated outcome converges to the Stackelberg equilibrium outcome when the noise goes to zero.

Huck and Müller (2000), Müller (2001) as well as Güth et al. (2006) experimentally investigate Bagwell's (1995) noisy leader game.[3] Contrary to Huck and Müller (2000) and Müller (2001), Güth et al. (2006) do not use a 2×2 but a 20×20 payoff bimatrix. That is, Güth et al. examine the standard Stackelberg quantity competition game in the

[3] O'Higgins et al. (2010) experimentally investigate a Stackelberg price competition market under noise. However, they do not have an underlying theory to test.

presence of noise. In the 2×2 payoff bimatrix experiments, the Stackelberg equilibrium prediction is nearly perfect. Güth et al.'s results largely coincide with those which have been derived by Huck et al. (2001) and Fonseca et al. (2005). Since I am particularly interested in testing current endogenous competition models, I will not deal with these experiments. However, for the further development of endogenous competition models, they should be kept in mind.

In the following section, I recapitulate the experiments on quantity competition. After that, I investigate Müller's (2006) experiment on price competition. The findings are discussed in section 4. In the last section, I conclude.

2 Quantity Competition

In a series of experiments, Huck et al. (2001) examine two markets for a homogeneous good. In every market, there are (many households and) two firms competing in quantities. Both firms face a linear inverse demand function; marginal costs are constant and identical:

$$p(q) = \max\{30 - q, 0\},\ q = q_1 + q_2;\ c_i(q_i) = 6q_i,\ i = 1, 2. \tag{1}$$

In the Cournot market, firms act simultaneously. In the Stackelberg market, firms move sequentially. The Cournot and Stackelberg equilibrium predictions as well as the predicted outcomes under collusion are shown in Table 1. The focus is on the Stackelberg market treatments, the Cournot market treatments serve as control treatments.

Prediction	Cournot	Stackelberg	Collusion
Quantities	$q_i^C = q_{3-i}^C = 8$	$q_i^L = q_{3-i}^L = 12,\ q_i^F = q_{3-i}^F = 6$	$q_i^J = q_{3-i}^J = 6$
Total quantity	$q^C = 16$	$q^S = 18$	$q^J = 12$
Profits	$\pi_i^C = \pi_{3-1}^C = 64$	$\pi_i^L = \pi_{3-i}^L = 72,\ \pi_i^F = \pi_{3-i}^F = 36$	$\pi_i^J = \pi_{3-i}^J = 72$
Total welfare	$TW^C = 256$	$TW^S = 270$	$TW^J = 216$

Table 1: Cournot and Stackelberg equilibrium predictions.

Source: Huck et al. (2001, p. 751).

The experiment was run in lecture halls with pen and paper. Overall, 134 students from various fields of study, mostly from economics and business administration as well as law, participated in 7 sessions. Every session consisted of 10 rounds and lasted between 60 and 75 minutes. Participants' average earnings were €8.01. For Cournot markets, Huck et al. find that, under random matching, average quantities per round are close to the Nash equilibrium quantities; under fixed matching, average quantities per round are lower because the collusive quantity is chosen more often. Further, there is a noticeable endgame effect under fixed matching: collusion breaks down in the last rounds. That is, the theoretical predictions are supported to a large extent. For Stackelberg markets, the picture is different: under random matching, leaders mostly supply less than predicted by the subgame perfect Nash equilibrium, and followers typically supply more; under fixed matching, firms compete less intensively at large. Thus, the experimental results differ from the theoretical predictions. However, as predicted, because of the higher total output, the Stackelberg markets are associated with a higher welfare than the Cournot

markets.

Huck et al. (2002) use the same 13×13 payoff bimatrix as Huck et al. (2001). In addition, to endogenize the order of moves, they extend the quantity-choosing game by a time-setting game. According to Hamilton and Slutsky's (1990) extended game with action commitment, firms are able to choose their quantities in one of two periods. If a firm commits to a quantity in the first period (moves early), it does not know whether the other firm also moves early or commits to a quantity in the second period (moves late, waits). By waiting until the second period, a firm is able to observe the other firm's action of the first period. The extensive form of the extended game with action commitment is depicted in Figure 1.

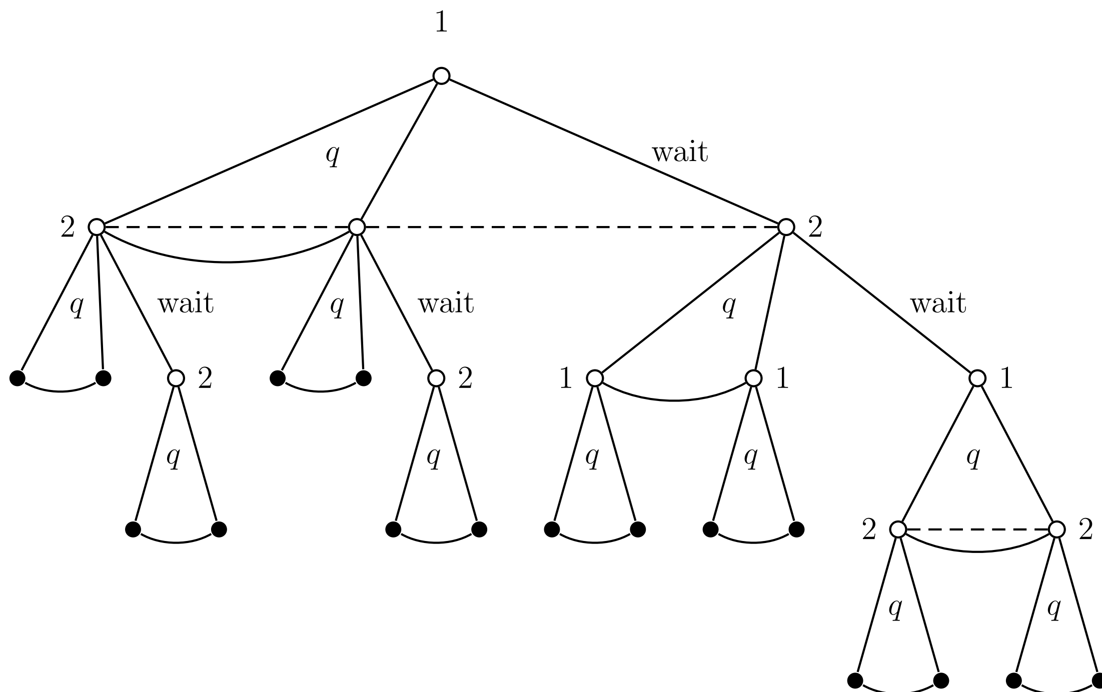

Figure 1: Extensive form of the extended game with action commitment.

Source: On the basis of Hamilton and Slutsky (1990, p. 35).

The market is assumed only to exist in the second period, therefore, profits from simultaneous play in the first period are the same as profits from simultaneous play in the second period. After the elimination of weakly dominated strategies, the extended game exhibits two subgame perfect Nash equilibria in pure strategies: one of the two firms moves early and the other one moves late. In particular, Huck et al. are interested in checking Hamilton and Slutsky's prediction of endogenous Stackelberg competition.

The computerized experiment was run at Humboldt University Berlin. Overall, 70 students from various fields of study, mostly from economics and business administration as well as law, participated in 7 sessions: 4 sessions with a small version of the payoff bimatrix and 3 sessions with a large version. Every session consisted of 10 rounds. The 3 sessions with the large bimatrix, each consisting of 30 rounds, lasted about 90 minutes; the 4 sessions with the small bimatrix, each consisting of 10 rounds, lasted about 50 minutes. Participants' average earnings were €10.53 in the sessions with 30 rounds and €8.80 in the sessions with 10 rounds. For the large bimatrix, consisting of 13 rows and 13 columns, Huck et al. find that, under random matching, endogenous Stackelberg equilibria are extremely seldom, and their frequency does not increase with experience. Further, participants have problems in coordinating their actions: in about 25 percent of all rounds, they find evidence for coordination failures. Over time, the frequency of collusive quantities increases because endogenous Stackelberg followers reward cooperation/punish exploitation more often. However, Cournot equilibria are the most frequent outcomes. For the small bimatrix, consisting of 3 rows and 3 columns, the picture is the same. Huck et al. conclude that the failure of Hamilton and Slutsky's theoretical

prediction of endogenous Stackelberg competition is not due to the complexity of the large bimatrix. Further, they record that subjects seem to prefer symmetric outcomes to asymmetric outcomes. Beyond, they are sceptical whether this result is the same for markets with asymmetric firms or price competition.

Hamilton and Slutsky's (1990) extended game with action commitment is also used by Fonseca et al. (2005). Adopting the idea of Huck et al. (2002), firms are asymmetric with respect to marginal costs:

$$p(q) = \max\{30 - q, 0\},\ q = q_1 + q_2;\ c_1(q_1) = 6q_1,\ c_2(q_2) = 8q_2. \tag{2}$$

For this setup of the game, van Damme and Hurkens (1999) predict sequential play with a specific order of play: since committing early is risky, the firm for which committing early is less risky is expected to be the leader. Using Harsanyi and Selten's (1988) risk dominance criterion, van Damme and Hurkens show that committing early is less risky for the low-cost firm, that is, only the Stackelberg equilibrium, in which the low cost firm leads, survives the refinement. The Cournot and Stackelberg equilibrium predictions are shown in Table 2.

The experiment was run in lecture rooms with pen and paper. Overall, 60 students participated in 6 sessions.[4] Every session consisted of 20 rounds.[5] Participants' average earnings were €13.63.[6] Fonseca et al. find that, under random matching, endogenous

[4]Fonseca et al. do not divulge the fields of study.

[5]The duration of the sessions is not divulged either.

[6]Fonseca et al. report £8.30. Since they did not mention the date when the experiment was run, the exchange rate of December 28, 2001 was used for the calculation.

Prediction	Cournot	Stackelberg: LF	Stackelberg: FL
Quantities	$q_1^C = \frac{52}{6}, q_2^C = \frac{40}{6}$	$q_1^L = \frac{78}{6}, q_2^F = \frac{27}{6}$	$q_1^F = \frac{42}{6}, q_2^L = \frac{60}{6}$
Total quantity	$q^C = \frac{92}{6}$	$q_{LF}^S = \frac{105}{6}$	$q_{FL}^S = \frac{102}{6}$
Profits	$\pi_1^C = \frac{5408}{72}, \pi_2^C = \frac{3200}{72}$	$\pi_1^L = \frac{6084}{72}, \pi_2^F = \frac{1458}{72}$	$\pi_1^F = \frac{3528}{72}, \pi_2^L = \frac{3600}{72}$
Total welfare	$TW^C = \frac{17072}{72}$	$TW_{LF}^S = \frac{18567}{72}$	$TW_{FL}^S = \frac{17532}{72}$

Table 2: Cournot and Stackelberg equilibrium predictions.

Source: Author.

Stackelberg equilibria are seldom: only in 31 percent of all rounds, the low-cost firm emerges as the endogenous leader; the high-cost firm is observed to be the leader in 18 percent of all rounds. In the residual rounds, simultaneous play occurred – mostly in the first period. Further, there is no trend towards the risk-dominant equilibrium over time. Compared with the experimental results of Huck et al. (2002), firms' timing decisions are nearly identical. Furthermore, firms' output decisions are not in accordance with van Damme and Hurkens' prediction: when a firm, no matter which type, commits in the first period, on average, it produces approximately the Counot output. Thus, low-cost firms are not able to exploit their efficiency advantage to become Stackelberg leaders.

The payoff bimatrix generated by Huck et al. (2001) is also used by Fonseca et al. (2006). To endogenize the order of moves, in contrast to Huck et al. (2002), they employ Hamilton and Slutsky's (1990) extended game with observable delay. The extensive form of the extended game with observable delay is depicted in Figure 2.

Firms simultaneously announce a production period and then they produce in the an-

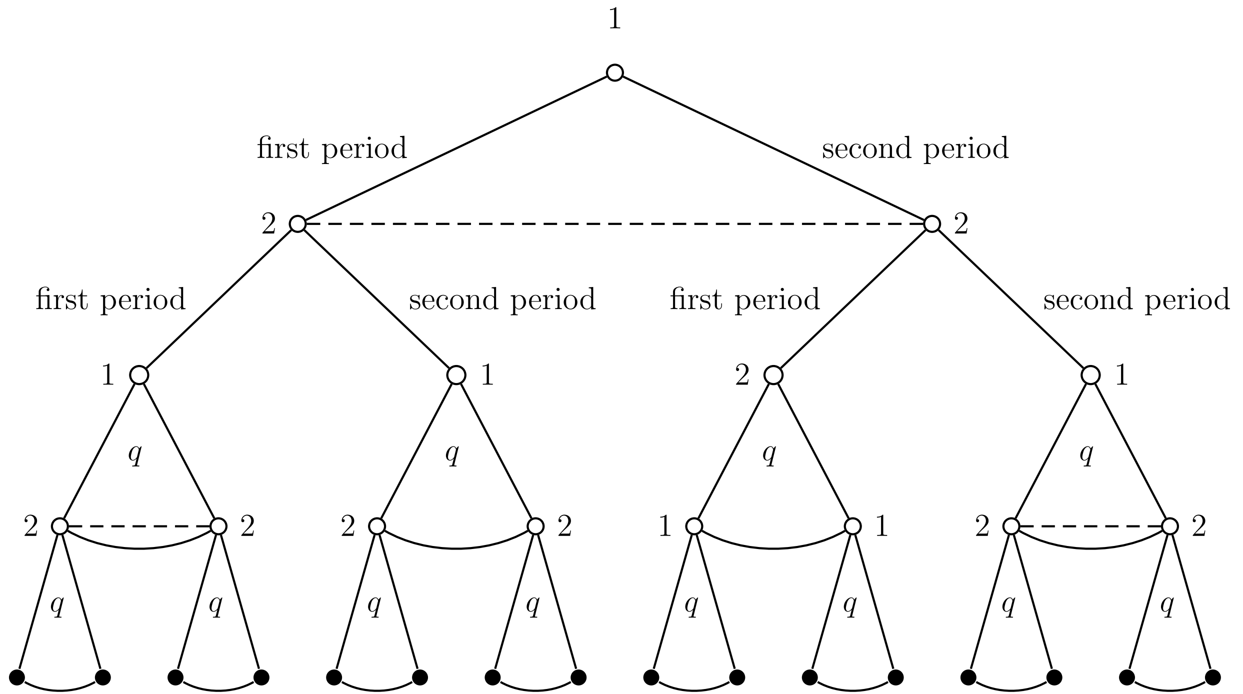

Figure 2: Extensive form of the extended game with observable delay.

Source: On the basis of Hamilton and Slutsky (1990, p. 33).

nounced sequence. Since duopolistic quantity competition is associated with decreasing reaction functions, each firm prefers its Cournot equilibrium payoff to its Stackelberg equilibrium follower payoff. Thus, in equilibrium, both firms annonce the first period and achieve Cournot payoffs.

The computerized experiment was run at the University of London. Overall, 70 students from various fields of study participated in 7 sessions: 5 sessions with random matching and 2 sessions with fixed matching. In order to allow for learning, the random-matching sessions consisted of 30 rounds. The fixed-matching sessions consisted of 10 rounds. Every session lasted between 60 and 90 minutes. Participants' average earnings were €21.38. Fonseca et al. find that, under random matching, there is a trend towards equi-

librium timing behavior. However, the relative frequency of decisions for the first period does not exceed 72 percent. Further, the equilibrium prediction that both firms decide for the first period only occurs in 55 percent of the cases. In these simultaneous quantity choosing subgames, firms' quantity choices are almost identical and move towards the Cournot prediction. In the sequential quantity choosing subgames, first movers' outputs are smaller than the Stackelberg prediction, but larger than the Cournot prediction. That is, both leaders' and followers' payoffs are smaller than Cournot players' payoffs. Under fixed matching, the relative frequency of decisions for the first period is lower: about 50 percent. The equilibrium prediction that both firms decide for the first period only occurs in 32 percent of the cases. In all quantity choosing subgames, average outputs are lower than in the random-matching treatments, indicating a tendency to collude. That is, firms' payoffs are higher than in the random-matching treatments. Compared with the results above, the findings of Fonseca et al. are puzzling: although there is a unique symmetric equilibrium (coordination failures or inequality aversion are no problems), the experimental result does not sufficiently support the theoretical prediction.

As Huck et al. (2001), Müller (2006) experimentally investigates two markets for a homogeneous good. In every market, there are (many households and) two firms competing in quantities. Both firms face a linear inverse demand function; marginal costs are constant and identical. In one market, the Cournot market, firms act simultaneously. In the other market, the order of moves is endogenous. According to Saloner (1987) and Ellingsen (1995), there are two periods in which firms are able to produce their

outputs. The outputs simultaneously chosen in the first period are public information in the second period. That is, in the second period, firms simultaneously choose their additional (nonnegative) outputs fully aware of the actions in the first period. After the second period, the market clears. As in Hamilton and Slutsky's (1990) extended game, production costs are assumed to be the same in both periods. Saloner shows that any outcome on the outer envelope of the reaction functions between and including the firms' Stackelberg outcomes constitutes a subgame perfect Nash equilibrium. Ellingsen rounds Saloner's model out by eliminating weakly dominated strategies iteratively. He shows that only the Stackelberg outcomes survive this procedure. That is, he predicts that one of the two Stackelberg outcomes will occur.

The computerized experiment was run at Humboldt University Berlin and the University of London. Overall, 40 students participated in 20 sessions: 10 sessions with a Saloner-Ellingsen-Cournot duopoly treatment and 10 sessions with a standard Cournot duopoly treatment.[7] Every session consisted of 25 rounds. The 10 sessions with the Saloner-Ellingsen-Cournot duopoly treatment lasted about 80 minutes; the 10 sessions with the standard Cournot duopoly treatment lasted about 45 minutes. Participants' average earnings were €17.44. Müller finds that, under fixed matching, Stackelberg equilibrium outcomes are extremely rare in the Saloner-Ellingsen-Cournot duopoly treatment: only 8 out of 250 quantity combinations are classified as Stackelberg outcomes.[8] Further, compared with the outcomes in the standard Cournot duopoly treatment, these out-

[7]Müller does not divulge the fields of study.

[8]Since participants choose quantities from a finite grid, outcomes are classified as equilibrium outcomes if they do not deviate more than 10 percent from the equilibrium prediction.

comes are not associated with higher total quantities. Furthermore, an endgame effect is observed in both treatments: total quantities rise in the last rounds – and are close to the Cournot equilibrium prediction. With experienced subjects, average total outputs in the Saloner-Ellingsen-Cournot duopoly treatment are the same as in the Cournot duopoly treatment. That is, the experimental result does not support the theoretical prediction.

3 Price Competition

Kübler and Müller (2002) experimentally examine two markets for a heterogeneous good. In every market, there are (many households and) two firms competing in prices. Both firms face a linear demand function; marginal costs are constant, identical, and zero:

$$q_i(p_i, p_{3-i}) = \max\{16 - 2p_i + p_j, 0\},\ i = 1, 2. \tag{3}$$

In the Cournot market, firms act simultaneously. In the Stackelberg market, firms move sequentially. The Cournot and Stackelberg equilibrium predictions as well as the predicted outcomes under collusion are shown in Table 3. From a methodological point of view, Kübler and Müller use the same experimental setup as Huck et al. (2001), that is, they carry the experiemtal setup over to price competition.

The computerized experiment was run at Humboldt University Berlin in June 2000 and in January and May 2001. Overall, 120 students, undergraduates as well as graduates, from various fields of study, mostly from economics and business administration,

Prediction	Cournot	Stackelberg	Collusion
Prices	$p_i^C = p_{3-i}^C = 4$	$p_i^L = p_{3-i}^L = 6,\ p_i^F = p_{3-i}^F = 5$	$p_i^J = p_{3-i}^J = 8$
Profits	$\pi_i^C = \pi_{3-1}^C = 53$	$\pi_i^L = \pi_{3-i}^L = 58,\ \pi_i^F = \pi_{3-i}^F = 68$	$\pi_i^J = \pi_{3-i}^J = 65$

Table 3: Cournot and Stackelberg equilibrium predictions.

Source: Kübler and Müller (2002, p. 1442).

participated in 10 sessions. Every session consisted of 15 rounds and lasted about 50 minutes. Participants' average earnings were €8.69. For Cournot markets, Kübler and Müller find that, under random matching, median prices of the last 5 rounds match the Nash equilibrium prices; under fixed matching, median prices of the last 5 rounds are higher. That is, the behavior is more collusive under fixed matching than under random matching. This result also holds for the mean prices. That is, the theoretical predictions are supported to a large extent. For Stackelberg markets, the picture is similar: under random matching, median prices of the last 5 rounds match the subgame perfect Nash equilibrium prices; under fixed matching and a sequential course of action (in contrast to the strategy method), the median prices of the last 5 rounds are identical to the median prices under random matching. Under fixed matching and Selten's (1967) strategy method, the leader's median price of the last 5 rounds equates to the follower's median price. However, for all treatments, mean leader prices (no matter whether all rounds or only the last 5 rounds are considered) exceed mean follower prices, and mean follower profits exceed mean leader profits. Thus, the experimental results widely match the theoretical predictions in the Cournot market treatments as well as in Stackelberg

market treatments.

4 Discussion

First of all, it is surprising that only a handful of experiments checking Cournot competition against Stackelberg competition have been published yet. It is also surprising that only one of these experiments involves price competition. That is, although the Cournot model and the Stackelberg model are part and parcel of every textbook on industrial organization, and there is a long history of characterizing oligopolistic industries by models of price competition, in particular by price leadership models,[9] an extensive experimental investigation has not been performed yet.

A reason for this may be that experimental methods in this field of research are seen as inappropriate. That is, echoing Friedman (1953), that the domain of the theory is seen to exclude the laboratory. To investigate whether using the laboratory is feasible, following Cubitt (2005), I start from identifying the formal objects of the theory. These are players, actions, payoffs, and information. Players act simultaneously or sequentially. They are assumed to be rational and to maximize their payoffs. The domain, which is the set of real phenomena to which the theory is intended to apply, consists of firms that compete duopolistically in quantities or prices for profits. Now, the question is: Is it

[9] For the classical price leadership models, see Forchheimer (1908) in conjunction with Zeuthen (1930), Stigler (1947), and Markham (1951). For a survey of these models, see Scherer and Ross (1990, p. 248–261).

possible to find an experimental design within the domain of the theory? Presuming that the theory is general, the answer is yes. Participants can be told that they represent firms, choose quantities or prices under a given sequence of competition, and receive profits subject to their chosen actions.

In addition, Binmore (1999) insists that economic theory is only expected to predict in the laboratory if the experimental design is not only in the domain of the theory but also provides "simple" tasks, "sufficient" time for learning, and "adequate" incentives. All published experiments fulfill these criteria to a lagre extent. Experimental designs seem to be in the domain of the theory. The judgement of simplicity of tasks, the sufficiency of time for learning, and the adequacy of incentices depends on the quantification of simple, sufficient, and adequate. In all mentioned experiments, tasks seem to be simple. Participants are told that they represent firms,[10] choose quantities or prices under a given sequence of competition, and receive profits subject to their chosen actions. Except for Müller's (2006) experiment, participants choose quantities or prices from a bimatrix. In Müller's experiment, participants choose quantities from a finite grid. Contemplating the time for learning, the picture is mixed. Some sessions consist of 30 rounds. Others only have 10 rounds. Incentives seem to be adequate. Payoffs are chosen to reflect opportunity costs, therefore, an adverse selection among potential participants is avoided.

However, the slopes of the reaction curves are small in magnitude, that is, losses from playing a disequilibrium strategy, which is in the neighborhood of the equilibrium strategy, are low. This can be a problem. For instance, Goeree and Holt (2001) present an

[10] In fact, they are told to be entrepreneurs.

experiment on Basu's (1994) "traveler's dilemma" game. Two players simultaneously select an integer between and including 180 and 300. If they have selected different numbers, both players are paid according to the lower of the two numbers, and, in addition, a transfer $R > 1$ is added to the payoff of the player with the lower number and subtracted from the payoff of the player with the higher number. If they have selected identical numbers, both players are paid according to their numbers. In the unique Nash equilibrium, both players select the number 180. That is, the theoretical prediction is 180. Since R is the cost of being undercut, Goeree and Holt speculate that the behavior might depend on the value of R. In particular, they conjecture: the higher the value of R, the better is the Nash equilibrium prediction. To investigate their conjecture, they implement two treatments: a treatment with $R = R^h = 180$ and a treatment with $R = R^l = 5$. The experiment was run at the University of Virginia. Overall, 50 students from undergraduate economics classes participated. All participants made decisions in both treatments. In both treatments, the game was only played once. These two games were presented randomly arranged and separated by a number of other games. Goeree and Holt find that about 80 percent of all participants choose the Nash equilibrium strategy in the R^h treatment. However, in the R^l treatment, the Nash equilibrium strategy is only chosen by about 10 percent of all participants. Moreover, about 80 percent of all participants choose 300, that is, they choose the strategy which is at the opposite end of the strategy set.

Smith and Walker (1993) report on similar findings in 31 experiments: the higher the

payoffs are, the better is the prediction and the lower is the variance.[11] They argue that this is based on decision costs. Decision costs are caused by the effort to decide. In their eyes, the decision problem is one of balancing the benefit against the costs of reducing the deviation. If decision costs are assumed to decrease with increasing simplicity and experience, then it follows that revising the instructions and playing more rounds will increase the predictive power of a true theory. In addition, the predictive power of a true theory is increased by increasing the payoff level: this causes an increase in effort. Regarding the experiments mentioned above, although the payoffs are chosen to reflect opportunity costs, incentives for choosing the equilibrium strategy are low due to the payoff level in connection with the "flat" reaction curves. The role of decision costs could have been analyzed by Kübler and Müller (2002) without additional treatments. However, although undergraduates as well as graduates participate in their experimental study and decision costs are likely to be lower for graduates than for undergraduates, Kübler and Müller pass on a separate evaluation of the two groups.

Another argument for the poor results under quantity competition is mentioned by Huck et al. (2001, 2002) themselves: disadvantageous inequality aversion.[12] Since both reaction curves slope downward, none of them enters the Pareto superior set relative to the equilibrium of the Cournot game (see Figure 3, i). That is, a firm's Stackelberg leader profit exceeds its Cournot profit and its Cournot profit exceeds its Stackelberg follower

[11]There are experimental studies in which higher payoffs do not cause a better performance of the participants. For a survey, see Camerer and Hogarth (1999).

[12]For a discussion of disadvantageous inequality aversion in ultimatum bargaining games, see Güth et al. (1982). For a survey on ultimatum bargaining behavior, see Güth and Tietz (1990).

profit: Stackelberg competition disadvantages the following firm relative to Cournot competition.[13]

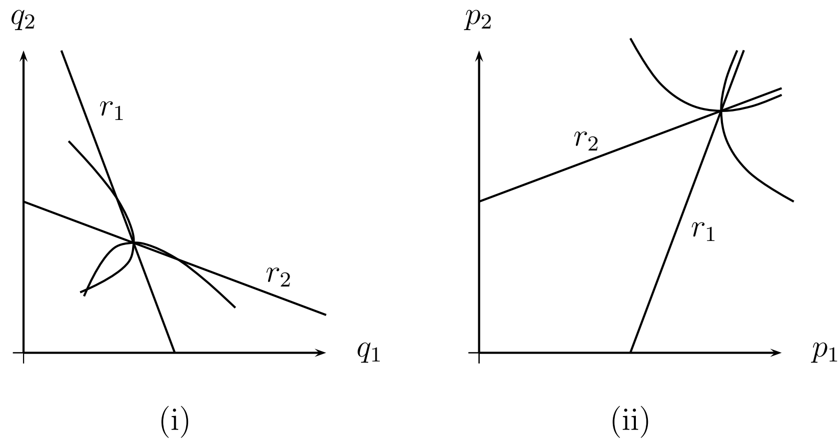

Figure 3: Reaction curves and Pareto superior sets.

Source: On the basis of Hamilton and Slutsky (1990, p. 40).

Since both reaction curves slope upward under price competition, that is, each of them enters the Pareto superior set relative to the equilibrium of the Cournot game (see Figure 3, ii), a firm's Stackelberg follower profit exceeds its Stackelberg leader profit and its Stackelberg leader profit exceeds its Cournot profit: Stackelberg competition advantages both firms relative to Cournot competition. Hence, Huck et al. (2002) conjecture that endogenous Stackelberg price competition might be more likely to be observed in the laboratory than endogenous Stackelberg quantity competition. Their conjecture is supported by a partially successful application of Fehr and Schmidt's (1999) model of inequality aversion by Huck et al. (2001): on the one hand, their data suggest that Stackelberg followers are averse to disadvantageous inequality, on the other hand, Stack-

[13]For a detailed presentation, see Hamilton and Slutsky (1990).

elberg leaders seem to be advantageous inequality loving. Kübler and Müller's findings on exogenous Stackelberg price competition are in line with this conjecture.

5 Conclusion

I have summarized and analyzed experimental studies on duopolistic quantity competition with homogeneous products and duopolistic price competition with heterogeneous products. First, I find that only a handful of experiments checking Cournot competition against Stackelberg competition have been conducted yet and that only one of these experiments involves price competition. Second, I assert that Stackelberg equilibrium outcomes are seldom under quantity competition and that the Stackelberg equilibrium prediction seems to be more appropriate under price competition. Third, I get that experimental designs seem to be in the domain of the theory and that tasks seem to be "simple".

Contemplating whether there has been "sufficient" time for learning, the picture is mixed. Some sessions consist of 30 rounds. Others only have 10 rounds. Incentives seem to be "adequate" because payoffs are chosen to reflect opportunity costs, but losses from playing a disequilibrium strategy can be low. Following Smith and Walker (1993), I argue that this may be an argument for the poor results. Another reason is mentioned by Huck et al. (2001, 2002) themselves: disadvantageous inequality aversion. Their reasoning is supported by a partially successful application of Fehr and Schmidt's (1999) model of inequality aversion.

Due to the methodological problems mentioned above, I reason that the quantity competition models have not been falsified so far. However, doubts seem to be appropriate. Therefore, I suggest further research on the adequacy of incentives. This is of particular importance in experiments on endogenous competition models. Concerning the high complexity of those experiments, high decision costs are likely to be expected. Increasing the number of rounds solely may not suffice.

In consideration of the results of experiments on quantity competition models, Kübler and Müller's (2002) findings are surprising. Since decision costs are likely to be the same as those under quantity competition, incentives cannot be assumed to be stronger. However, according to Fehr and Schmidt's (1999) model of inequality aversion, as in the experiments on quantity competition, subjects seem to be advantageous inequality loving. Aside, many price competition models have not been tested yet (see Table 4 in the appendix). So far, I reason that there is not enough experimental research to speak of evidence for the price competition models.

Independent of the results of further experimental research, treating firms as economic agents with the sole objective of profit maximization seems to be problematic in the case of oligopolistic competition: if only few firms are present in a market, these firms are large and complex. Typically, they are characterized by a separation of ownership and management. This matter of fact is not taken into account in any model. However, such institutional arrangements may be important. For example, Vickers (1985), Fershtman and Judd (1987), and Sklivas (1987) show that strategic delegation can serve as

a commitment device in a Cournot oligopoly market.

Appendix

Variable	Model		Experiment	
	Author(s)	Order of moves	Author(s)	Course of action
Quantity	Cournot	exogenous	Huck et al. (2001) Fonseca et al. (2005)	pen and paper
	Stackelberg	exogenous	Huck et al. (2001)	pen and paper
	Saloner (1987) and Ellingsen (1995)	endogenous	Müller (2006)	computer
	Hamilton and Slutsky (1990): "action commitment"	endogenous	Huck et al. (2002)	computer
	Hamilton and Slutsky (1990): "observable delay"	endogenous	Fonseca et al. (2006)	computer
	van Damme and Hurkens (1999)	endogenous	Fonseca et al. (2005)	pen and paper
Price	Cournot	exogenous	Kübler and Müller (2002)	computer
	Stackelberg	exogenous	Kübler and Müller (2002)	computer
	Hamilton and Slutsky (1990): "action commitment"	endogenous	no experiments yet	
	Hamilton and Slutsky (1990): "observable delay"	endogenous	no experiments yet	
	van Damme and Hurkens (2004)	endogenous	no experiments yet	
	Pastine and Pastine (2004)	endogenous	no experiments yet	
	Amir and Stepanova (2006)	endogenous	no experiments yet	

Table 4: Models and experiments.

Source: Author.

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