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Publication date:
2003

Citation for published version (APA):
Müller, W. (2003). *Allowing for Two Production Periods in the Cournot Duopoly: Experimental Evidence*. (CentER Discussion Paper; Vol. 2003-42). Microeconomics.

CentER

Discussion Paper

No. 2003–42

ALLOWING FOR TWO PRODUCTION PERIODS IN THE COURNOT DUOPOLY: EXPERIMENTAL EVIDENCE

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April 2003

ISSN 0924-7815

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Allowing for two production periods in the Cournot duopoly: Experimental evidence*

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April 15, 2003

Abstract

In this study behavior in a Cournot duopoly with two production periods (the market clears only after the second period) is compared to behavior in a standard one-period Cournot duopoly. Theory predicts the endogenous emergence of a Stackelberg outcome in the two-period market. The results of the experiments, however, reveal that in both markets (roughly) symmetric outcomes emerge and that, after a short adaptation phase, average industry output in the two-period markets is the same as in the standard one-period markets.

Keywords: Cournot duopoly; Stackelberg; flexibility; experiments.

JEL classification numbers: C72; C91.

1 Introduction

In the standard Cournot duopoly both firms are assumed to decide once and simultaneously about their outputs before the market clears. Saloner (1987) analyzes an extended market game allowing for two production periods before the market clears. In this model, the initial outputs chosen in the first production period become publicly known before firms decide about their additional non-negative outputs in the second production period. Only after the second production period the market price is determined according to the total amount of output produced in both periods.

*I thank Dirk Engelmann and Arno Riedl for helpful comments. The author acknowledges financial support from the German Research Foundation, DFG. Furthermore, he thanks the Center for Experimental Social Science (CESS) at New York University (where part of this research was done) for its hospitality.

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Moreover, production costs are assumed to be the same in both periods. Saloner shows that in case of constant marginal costs and linear demand[1] any outcome on the outer envelope of the best-response functions between and including the firms' Stackelberg points[2] can be achieved in a subgame perfect Nash equilibrium of the two-period model. However, Ellingsen (1995) shows that only the Stackelberg points survive the elimination of weakly dominated strategies. Thus, the interesting feature of this model is that it predicts an asymmetric outcome even when firms are a-priori symmetric. As a consequence total quantity and welfare are higher than in a standard one-period Cournot market.

Another model in which duopolists are given more flexibility in the timing of moves is Hamilton and Slutsky's (1990) extended game with action commitment in which two firms may choose their action in *one* out of two periods. A firm may move early by committing itself to a quantity, or it may wait until the second period and observe the other firm's first-period action. Again, there are two endogenous Stackelberg equilibria with either firm as the Stackelberg leader.[3] While there also exists a simultaneous-move Cournot equilibrium in pure strategies, this equilibrium is in weakly dominated strategies.

This paper reports the results of an experiment designed to investigate Saloner's two-period model with quantity competition and identical firms. In the experiment, fixed pairs of subjects are repeatedly matched to play the game. The results in the two-period market are compared with results in standard one-period Cournot markets. Given the two models' predictions, I shall focus on three research questions: (1) Do we observe the endogenous emergence of Stackelberg outcomes in the two-period markets? (2) Will the two-period markets—as in theory—yield higher total outputs at smaller prices than standard Cournot markets, thus increasing total welfare?[4] (3) What is the actual behavior in the two periods of Saloner's model?

There are several reasons why in an experimental setting of the two-period model it is doubtful that one observes the endogenous emergence of a Stackelberg outcome. First, Ellingsen's result is based on iterated elimination of weakly dominated strategies. Earlier experiments, however, have demonstrated that subjects do not iteratively eliminate dominated strategies but stop

[1] Saloner actually allows for a much more general demand function. See Section 2 and especially footnote 9.

[2] This is set E indicated in Figure 1.

[3] See Matsumura (1999) for a more general version of this model, i.e., with more than two firms and with more than two production periods.

[4] In Huck, Müller and Normann (2001) in which Stackelberg markets with *exogenous* role assignment are compared with Cournot markets, it is found that—although "pure" Stackelberg outcomes are rarely observed—total output in the former markets are consistently higher than in the latter.

after one or very few rounds of reasoning.[5]. Second, there is a coordination problem as there are two Stackelberg outcomes with either firm evolving as the Stackelberg leader. In a symmetric setup it is not clear how subjects can overcome this coordination problem.[6] Third, both subgame perfect equilibria imply large payoff differences. The extensive experimental evidence on e.g. the ultimatum game shows that subjects display an aversion to disadvantageous inequality suggesting that Stackelberg outcomes are unlikely to evolve (see Fehr and Schmidt (1999) and Bolton and Ockenfels (2000)). Finally, Huck, Müller, and Normann (2002) experimentally investigate the extended game with action commitment of Hamilton and Slutsky (1990) mentioned above. The data does not confirm the theory. While Stackelberg equilibria are extremely rare, often endogenous Cournot outcomes and sometimes collusive play is observed.

Notwithstanding these objections and those made elsewhere (e.g. in Pal, 1996) it seems interesting and useful to explore how experimental subjects behave in the two-period market. First of all, the two-period model seems to be more relevant than the one-period Cournot model as real-world firms do have more flexibility in the timing of decisions regarding e.g. quantities (or capacities), as in the current model, or prices. It is then only desirable to contrast theoretical results with empirical findings. Second, Saloner's model is part[7] of the growing theoretical literature dealing with the endogenization of market structures. Instead of exogenously assuming modes of play (either simultaneous or sequential), this literature tries to identify factors[8] that might lead to the endogenous emergence of leader-follower or simultaneous-move outcomes. It might then be fruitful to give theorists feedback about the behavioral relevance of such factors by providing empirical evidence. Third, Huck, Müller and Normann (2002) employed a random-matching scheme. One might argue that fixed matching is more appropriate as it might help subjects to overcome the inherent coordination problem. For example, with repeated interaction a player is more likely to successfully

[5] A stunning failure of subjects to go through longer chains of reasonings is reported in a recent paper by Kübler and Weizsäcker (in press) on informational cascades. For further evidence on subjects' depth of reasoning see, e.g., the seminal work by Nagel (1995) or the more recent paper by Costa-Gomes, Crawford, and Broseta (2001).

[6] Van Damme and Hurkens (1999) analyze Hamilton and Slutsky's extended game with action commitment in the presence of cost differences. Their model has two pure strategy Stackelberg equilibria, too. However, in order to solve the inherent coordination problem they apply the tracing procedure (Harsanyi and Selten, 1988). As a result, the Stackelberg equilibrium with the efficient firm as the Stackelberg leader is selected.

[7] In fact, it is one of the very first in this area.

[8] Besides more flexibility in the timing of moves, such factors are for example whether firms can engage in pre-play communication about the timing of moves or whether they can observe delay by rivals (Hamilton and Slutsky, 1999), different risk attitudes in the presence of demand uncertainty (Spencer and Brandner, 1992, and Kambhu, 1984) or different production capacities (Deneckere and Kovenock, 1992).

"teach" the other player. Also, practitioners might suggest that fixed matching is more relevant as in real-world markets firms interact repeatedly. Therefore fixed matching is employed in the experiments reported here. Finally, the two-period model might give rise to interesting dynamics and adaptation patterns.

The experiments yield the following answers to the three questions asked above: First, in both markets (roughly) symmetric outcomes emerge. Second, after a short adaptation phase average industry output is the same in both markets and lower than predicted by the traditional one-period Cournot model. Third, behavior in the individual two-period markets is quite diverse ranging from pure collusive behavior to behavior that leads to Cournot-Nash industry outputs. Furthermore, on average 83% of the total quantity in the two-period markets is produced in the first production period and 17% in the second period.

The remainder of the paper is organized as follows. Section 2 reiterates Saloner's model by means of the market parameters used in the experiments. Section 3 describes the experimental procedures. Sections 4 presents the experimental results, and, finally, Section 5 concludes.

2 Theory

In the following I reiterate Saloner's (1987) model along with its solution using the specific demand and cost functions implemented in the experiment. For the general result see Saloner's paper. For the sake of comparison, I shall use the notation adopted by Saloner.

Consider a duopoly market with two production periods and assume that the market clears only after the second period. Firms are assumed to have constant marginal costs of $c^i = 1$, $i = 1, 2$, respectively, no matter in which period production takes place. In the first production period firms 1 and 2 simultaneously choose outputs $q_1^1 \geq 0$ and $q_1^2 \geq 0$, respectively. These outputs become commonly known before, in the second production period, the firms simultaneously choose outputs $q_2^1 \geq 0$ and $q_2^2 \geq 0$. Firm i's total output is denoted by $q^i = q_1^i + q_2^i$. At the end of the second period, the market price is determined by the inverse demand function $P(q^1 + q^2) = 100 - \left(q^1 + q^2\right)$. Firm i's best-response function is given by

$$R^i(q^j) = \arg\max_{q^i} \left(99 - (q^i + q^j)\right) q^i = \frac{1}{2}\left(99 - q^j\right). \tag{1}$$

(Recall that firms have constant marginal costs of one.)

It is straightforward to show that in the standard Cournot model with only one production period there exists a unique Nash equilibrium which is given by $(N^1, N^2) = (33, 33)$.

Given the timing and the information conditions of the two-period game, a player's strategy must specify an output for period 1 and an output for period 2 where the latter is a function of q_1^1 and q_1^2, i.e., of the two firms' first-period outputs. A firm's strategy is denoted by $\sigma^i \equiv \{\sigma_1^i, \sigma_2^i(q_1^i, q_1^j)\}$.

Firm i's unique Stackelberg leader output will be denoted by

$$\mathbf{S}^i = \arg\max_{q^i} \left(99 - q^i - R^j(q^i)\right) q^i = 49.5$$

which implies that firm j's unique Stackelberg follower output is 24.75. Denote the outer envelope of R^1 and R^2 by R and define $E = \{(q^1, q^2) \mid (q^1, q^2) \in R,\ q^1 \leq \mathbf{S}^1 \text{ and } q^2 \leq \mathbf{S}^2\}$. Saloner shows that the elements of E are the only outcomes that can be sustained by subgame perfect Nash equilibria. To see this, consider the following strategy:

$$\sigma_1^i = a^i, \tag{2}$$

$$\sigma_2^i(q_1^i, q_1^j) = \begin{cases} 0 & \text{if } q_1^i \geq R^i(q_1^j) \text{ and } q_1^j \geq R^j(q_1^i) \quad \text{(I)} \\ N^i - q_1^i & \text{if } q_1^i \leq N^i \text{ and } q_1^j \leq N^j \quad \text{(II)} \\ 0 & \text{if } q_1^i \geq N^i \text{ and } q_1^j \leq R^j(q_1^i) \quad \text{(III)} \\ R^i(q_1^j) - q_1^i & \text{if } q_1^i \leq N^i,\ q_1^j \geq N^j \text{ and } q_1^i \leq R^i(q_1^j) \quad \text{(IV)} \end{cases} \tag{3}$$

where $(a^1, a^2) \in E$.[9] In the following I will illustrate why the strategies given in (2) and (3) constitute subgame perfect equilibria. To understand why there are no other subgame perfect equilibrium outcomes, see Saloner (1987, p. 186). Refer to Figure 1 which shows the best response functions of the two firms along with the set E. The different areas denoted by I through IV (and made visible by different shading) correspond to the four cases of second-period behavior of the subgame-perfect equilibrium in (3). Consider first second-period behavior as prescribed by (3). If (q_1^i, q_1^j) lies in area (I), both firms' first-period outputs are already higher than what (1) prescribes in response to the other firms first-period output. Thus, both firms are best off by ceasing production. If (q_1^i, q_1^j) lies in area (II) meaning that both firms have produced less than their Cournot-Nash output, both firms produce up to the Cournot-Nash output in the second period. If (q_1^i, q_1^j) lies

[9] Note that Saloner (1987) assumes next to constant marginal costs, a general demand function such that a firm's best-reponse function satisfies $0 > dR^i(q^j)/dq^j \geq -1$. This ensures that the standard one-period market has a unique Cournot-Nash equilibrium. However, with a more general demand function, the set S^i of firm i's $(i = 1, 2)$ Stackelberg points may contain more than one element. Therefore, the more general result proven in Saloner (1987) is that the elements of $E = \{(q^1, q^2) | (q^1, q^2) \in R, q^1 \leq \mathbf{S}^1 \text{ and } q^2 \leq \mathbf{S}^2\} \cup S^1 \cup S^2$ (where $\mathbf{S}^i$ is the infimum of the set S^i, $i = 1, 2$) are the subgame perfect Nash equilibria of the two-period game.

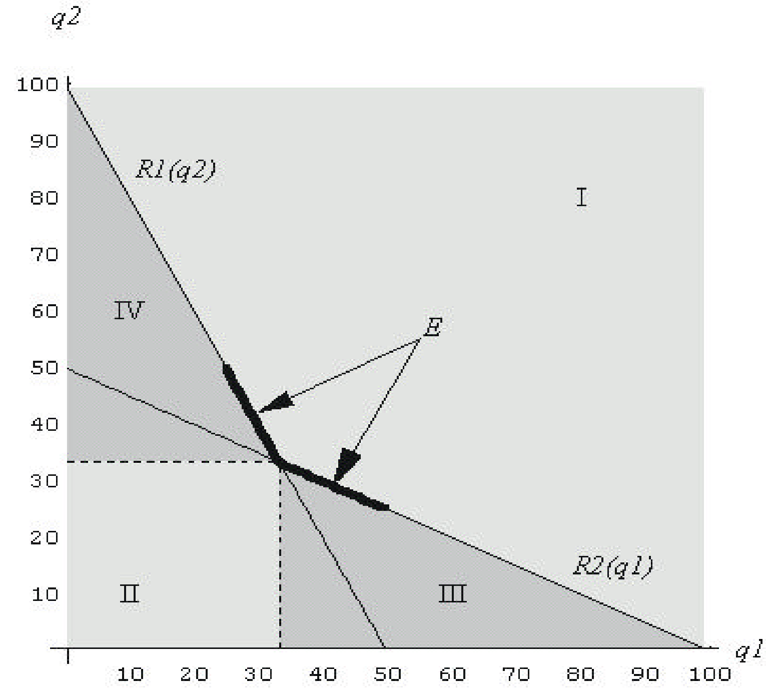

Figure 1: The firms' best-response functions

in area (III), then firms i's first-period output is again already higher than what this firm's best-response function prescribes to firm j's first-period output. Thus, again, firm i is best off by ceasing production. Finally, if (q_1^i, q_1^j) lies in area (IV), firm j will cease production while firm i produces up to it's best response to firm j's first-period output. Thus, the second-stage strategy described in (3) is part of every subgame perfect Nash equilibrium.

Consider next the first period decision. First, it is clear that neither firm has an incentive to produce more than what is prescribed by (2) since this would result in an output that lies outside the outer envelope of the best-response functions. Second, consider the case in which, say, firm 2 produces $q_1^2 < a^2$ while firm 1 produces $a^1 = R^1(a^2)$. According to (3), final output will then be $\left(R^1(q_1^2), q_1^2\right) \in R$ which is a worse outcome for the deviating firm 2. The reason being that for outcomes in R with $q^2 < \mathbf{S}^2$, firm 2's preferences are increasing in q^2.

Note that along the equilibrium path prescribed by (2) and (3), it holds that $\sigma_2^1(a^1, a^2) = \sigma_2^2(a^1, a^2) = 0$. That is, in this equilibrium production takes place only in the first period. However, this need not be the case in a subgame perfect equilibrium. Since production costs do not vary across periods, it is also possible that firm i produces a quantity in the interval $[N^i, \mathbf{S}^i] = [33, 49.5]$ in the first period whereas firm j chooses $q_1^j \geq 0$ and $q_2^j \geq 0$ such that $(q^i, q^j) \in E$.

However, as Ellingsen (1995) notes, only the Stackelberg points survive the elimination of weakly dominated strategies. As Saloner (1987, p. 186) notes, intuitively, it is the threat that the follower will respond optimally in the second period in case the leader underproduces in the first period, that sustains the Stackelberg outcomes.

3 Experimental design

The computerized[10] experiments were conducted at Humboldt University Berlin and at Royal Holloway College (University of London) in November and December 2000.

Upon arrival in the lab subjects were assigned a computer screen and received written instructions. After reading them, questions could be asked in private. All experiments consisted of 25 rounds.

Subjects could choose quantities from a finite grid between 0 and 100 with .01 as the smallest step. Hence, the action space had a sufficiently fine grid such that continuous action spaces were approximated. Therefore, the above benchmarks are also valid in the experiment. The fine grid also has the advantage that multiple Nash equilibria due to the discretization of the action space (Holt, 1985) can be avoided.

There were two treatments. In treatment "Two" the two-period duopoly as described in the previous section was implemented. Additionally, as a control treatment, a standard one-period Cournot duopoly (treatment "One") was run. In both treatments fixed matching was used. For each treatment, ten markets were conducted: six two-period and six one-period markets were conducted at Humboldt University and four two-period and four one-period markets were conducted at Royal Holloway College. In all, forty subjects participated in the experiments.

In treatment One subjects had to decide about the single quantity they wanted to produce in each round. In treatment Two, however, subjects were informed that each round would consist of two production periods in which production may take place. They were informed that in the first production period both firms would simultaneously decide which quantity they want to produce in this production period and that, then, each firm would be informed about the quantity the other firm has produced in the first production period. Then both firms would decide (again simultaneously) which additional quantity they want to produce in the second production period. Furthermore, they were informed that also in the second production period only non-negative quantities could

[10] We used the software tool kit *z-Tree*, developed by Fischbacher (1999).

be chosen. That is, it was only possible to increase the total quantity (or to leave it constant). But it was not possible to withdraw some of the quantity that was produced in the first production period.

Subjects had qualitative information about demand and cost conditions and were able to determine the best reply to the quantity of the other firm. This information was provided verbally (see the Appendix) and in the form of a 'profit calculator'. The profit calculator worked as follows. When fed with data regarding the other firm (total quantity of the other firm), the calculator allowed to try out the consequences of own actions. Note that a profit calculator gives qualitatively the same information as a profit table which is often provided in Cournot experiments (e.g., Holt, 1985). Moreover, the profit calculator might help to avoid a bias due to limited computational capabilities of subjects. In the second production period of treatment Two, subjects were asked to fed the profit calculator with an additional quantity of their own firm and an additional quantity of the other firm. The profit calculator would then compute the profit that results from the total quantities of both firms.

After each round in treatment One, subjects were informed about their own quantity and profit and the quantity of the other firm. In treatment Two, they were informed about their own and the competitor's first-period output before deciding about second-period outputs. After the whole round (consisting of two periods) was completed, subjects were informed about their own quantities and their own profit and the quantities of the other firm.

Whereas one-period market sessions lasted about 45 minutes, two-period market sessions lasted about 1 hour and 20 minutes. On average subjects earned about $15.

4 Experimental results

Recall that theory predicts that a Stackelberg outcome will emerge in treatment Two. As a result the firm emerging as a leader should produce a quantity of 49.5 whereas the firm emerging as a follower is expected to produce a quantity of 24.75 resulting in total output of 74.25. In contrast to this, in treatment One both firms are expected to produce a quantity of 33 resulting in a total output of 66. As a consequence, the two-period market in treatment Two yields higher total welfare when compared to the standard Cournot duopoly market in treatment One. So the first two questions I will answer in this section are:

Question 1 Do we observe the endogenous emergence of Stackelberg outcomes in treatment Two?

Treatment	1st bloc rounds 1-8	2nd bloc rounds 9-16	3rd bloc rounds 17-24	last round round 25	all rounds
ONE	**60.24**	**60.62**	**60.06**	**65.79**	**60.53**
	(19.23)	(12.10)	(13.68)	(7.55)	(15.05)
TWO	**65.16**	**60.93**	**59.54**	**66.40**	**62.06**
	(14.51)	(13.05)	(8.59)	(4.14)	(12.30)

Table 1: Summary of experimental results: Total quantities

Note: Standard deviations in parentheses.

Question 2 Will the two-period markets in treatment TWO yield higher total outputs at smaller prices than standard Cournot markets in treatment ONE, thus increasing total welfare?

Finally, I will answer

Question 3 What is the actual behavior in the two periods of Saloner's model?

Question 1. Do we observe the endogenous emergence of Stackelberg outcomes in treatment TWO? Recall that the Stackelberg outcome has one firm producing a quantity of 49.5 while the other firm produces a quantity of 24.75 which in a experimental setup is clearly to rigid. Allowing for about 10% deviation in action space, an observed outcome $(q^L, q^F) = (q_1^L + q_2^L, q_1^F + q_2^F)$ will be classified as a Stackelberg outcome if $q^L \in [45, 55]$ and $q^F \in [22, 27.5]$. Applying this criterion, it turns out that only 8 out of 250 cases can be classified as Stackelberg outcomes. These 8 cases, stemming from 7 different markets, all occur in the first 10 rounds and not later.[11] Thus it appears that subjects did not even seriously attempt to establish themselves as Stackelberg leaders. In sum, it seems fair to conclude that the answer to the first question is "No".

Question 2. Will the two-period markets in treatment TWO yield higher total outputs at smaller prices than standard Cournot markets, thus increasing total welfare? The answer to this question is no, they do not. Table 1 shows summary statistics for the two treatments classified by blocs of rounds. Inspecting Table 1 and concentrating on inexperienced behavior as represented in rounds 1 to 8 we observe the following: Though average total quantity in treatment TWO is with 65.16 higher than in treatment ONE (60.24), these differences turn out not be statistically significant

[11] Inspecting the data regarding the question whether many outcomes would fall only slightly short of this criterion, it turns out that there are only two more cases that might be classified as a Stackelberg outcome: (50, 29) and (45, 21). Each of these outcomes stem from one of the 7 markets mentioned in the text.

	1st bloc rds. 1-8	2nd bloc rds. 9-16	3rd bloc rds. 17-24	last rd. rd. 25	all rds.
1st Period	**26.27**	**25.71**	**24.86**	**26.90**	**25.66**
	(52.54)	(51.41)	(49.71)	(53.80)	(51.32)
2nd Period	**6.31**	**4.76**	**4.91**	**6.30**	**5.37**
	(12.63)	(9.51)	(9.82)	(12.60)	(10.73)
Both Periods	**32.58**	**30.46**	**29.77**	**33.20**	**31.03**
	(65.16)	(60.93)	(59.54)	(66.40)	(62.06)

Table 2: Individual quantities in treatment Two

Note: Total quantities in parentheses.

at a reasonable level ($p = 0.241$, two-tailed Mann-Whitney U-test).[12] Note that according to Table 1, behavior in treatment One is remarkably stable over time. In contrast, in treatment Two we observe that average quantities drop from a level close to the Nash equilibrium prediction during the first bloc to about the same level as in treatment One in blocs 2 and 3. And indeed, employing again a Mann-Whitney U-test this time to experienced behavior, i.e., to total quantities in bloc 3 in both treatments, confirms what seems to be obvious to the naked eye: Industry output in both treatments is indistinguishable from one another ($p = 0.88$, two-tailed Mann-Whitney U-test).

One more fact seems to be worthwhile noting, namely that in both treatments there is a notable endgame effect: total outputs clearly rise in the last period and are close to the Cournot-Nash industry output of 66 units.

Question 3. What is the actual behavior in the two periods of Saloner's model? To answer this question let us first concentrate on aggregated data. Table 2 shows average individual quantities in the two production periods along with total individual quantities in both periods again for blocks of rounds separately. Let us consider experienced behavior as observed during rounds 17 to 24. According to Table 2, a subject produces on average a quantity of 24.86 in the first period. Note that this quantity is very close to the symmetrically collusive individual quantity of 24.75. According to subgame perfect behavior as described by (3), in this case this average subject is expected to produce a quantity in the second production period such that the total quantity in both periods equals the Nash equilibrium quantity of 33. That is, on average we should observe a quantity of

[12] Here one group's average total output over the rounds of the considered bloc of the experiment was taken as one observation.

$33 - 24.86 = 8.14$. However, we observe that an average subject produces a quantity of only 4.91 in the second production period.

However, instead of trying to explain this average pattern, let us inspect each of the ten individual markets separately. As it turns out, the average pattern as described above is the superposition of quite different behavior in the individual markets ranging from purely collusive behavior to Cournot-Nash behavior.

Table 3 displays mean data as observed in rounds 17 to 24 in each individual market (ordered according to increasing total output). Here, as in the formulation of the two-period model above, q_1^i (q_2^i), $i = 1, 2$, denotes the individual quantity produced in period 1 (period 2), $q^i = q_1^i + q_2^i$ denotes total individual quantity and $Q = q^1 + q^2$ denotes industry output at the end of the second production period. Inspecting Table 3 the markets can be classified as follows:

Markets 1 and 2: These two markets are purely collusive. Firms produce the (very close to) collusive quantity of 25 in the first period and cease production in the second period. *Market 3:* Again an almost purely collusive market with an interesting pattern: Whereas both firms produce the collusive quantity in period 1, they almost always produce exactly one unit in the second period.[13] *Market 4:* Again a collusive market with substantial production also in the second period. *Market 5:* This market is clearly much closer to collusive behavior than to Cournot-Nash behavior: average industry output equals 55.13. Again both firms produce in both production periods. (Note that firm 1 produces always a quantity of 20 in the first period as can be inferred from the standard deviation of zero indicated in parentheses.) *Market 6:* According to industry output a Cournot-Nash market. Worthwhile noting is the fact that production in the second period is rather asymmetric. *Market 7:* A Cournot-Nash market, though with an interesting pattern: Whereas the two firms always produce a quantity of 20 or 30, respectively, in the first period, they always produce a quantity of 10 or 5, respectively, in the second period to (roughly) equal market shares. *Market 8:* Although a Cournot-Nash market (according to average industry output), the actual behavior in both periods does not follow a clear and settled-down behavior. *Market 9:* This is an almost pure Cournot-Nash market in which firms, interestingly, produce roughly the Nash quantities in period 1 and (almost) cease production in period 2. *Market 10:* Again a Cournot-Nash

[13] Firm 1 deviates from this behavior in period 24 by producing 12 units. To understand this, note that in the standard Cournot game, the best response to a quantity of 26 is to produce a quantity of 36.5. Thus, to produce a quantity of $12 \approx 36.5 - 25$ means the breakdown of the silent collusion agreement which usually happened only in the last period.

Market	1st period		2nd period		both periods		total
	q_1^1	q_1^2	q_2^1	q_2^2	q^1	q^2	Q
1	**25.00**	**25.00**	**0.00**	**0.00**	**25.00**	**25.00**	**50.00**
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
2	**25.00**	**25.00**	**0.00**	**0.00**	**25.00**	**25.00**	**50.00**
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
3	**25.00**	**25.00**	**2.38**	**1.00**	**27.38**	**26.00**	**53.38**
	(0.00)	(0.00)	(3.89)	(0.00)	(3.89)	(0.00)	(3.89)
4	**16.13**	**18.75**	**13.13**	**6.25**	**29.25**	**25.00**	**54.25**
	(10.56)	(5.18)	(13.74)	(5.18)	(7.44)	(0.00)	(7.44)
5	**20.00**	**21.00**	**9.25**	**4.88**	**29.25**	**25.88**	**55.13**
	(0.00)	(2.88)	(3.81)	(2.70)	(3.81)	(2.10)	(4.61)
6	**26.25**	**23.38**	**3.50**	**9.00**	**29.75**	**32.38**	**62.13**
	(5.55)	(8.23)	(4.93)	(8.11)	(2.76)	(0.92)	(3.52)
7	**20.00**	**30.00**	**10.00**	**5.00**	**30.00**	**35.00**	**65.00**
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
8	**28.00**	**30.00**	**7.38**	**2.50**	**35.38**	**32.50**	**67.88**
	(3.16)	(8.45)	(4.14)	(3.78)	(4.50)	(5.98)	(9.69)
9	**33.13**	**34.63**	**0.00**	**0.50**	**33.13**	**35.13**	**68.25**
	(0.64)	(0.74)	(0.00)	(0.93)	(0.64)	(0.83)	(1.04)
10	**22.88**	**23.00**	**12.25**	**11.25**	**35.13**	**34.25**	**69.38**
	(12.81)	(4.54)	(11.17)	(4.17)	(2.23)	(2.19)	(3.16)

Table 3: Average quantities in each market in rounds 17 – 24 in treatment Two

Notes: Standard deviations in parentheses.

Class of	Rounds 1-24			Rounds 17-24		
Subgame	av. obs. q_2	av. opt. q_2	(N)	av. obs. q_2	av. opt. q_2	(N)
I	2.52	0.00	(44)	0.63	0.00	(16)
II	5.38	9.78	(364)	5.59	9.95	(132)
III	3.39	0.00	(36)	0.00	0.00	(6)
IV	10.21	7.15	(36)	6.33	3.42	(6)

Table 4: Average quantities in the four classes of subagmes in treatment Two

market with about symmetric quantities within each period. Notice that behavior in the second period is roughly and on average consistent with subgame perfect behavior: the two firms produce a quantity in the second period such that total individual quantity roughly equals the Cournot level of 33.

According to this classification, there are 5 markets displaying collusive behavior and 5 markets displaying Cournot-Nash behavior in the last third of the experiment.

Comparing total individual quantities of the two firms in a market as shown in Table 3, it seems fair to conclude that on average roughly equal market shares evolve. However, in some of the groups market shares are quite different. This is particularly so in market 7 and—to a lesser degree—in market 4. In market 7 for example firm 1 earns in all rounds of the third bloc 14.3% less than firm 2. Although, as it is evident by now, there are almost no outcomes that resemble Stackelberg market shares, one might ask whether market shares in treatment Two are on average more uneven than in treatment One. To answer this question, I assign to each of the individual markets (for each round separately) the number $s := \max\{q^1, q^2\} / \min\{q^1, q^2\}$.[14] As it turns out, in rounds 1-24 the average s for treatment One is only slightly higher than the average s in treatment Two: 1.29 vs. 1.17 (standard deviation: 0.67 vs. 0.26). In rounds 17-24 similar numbers emerge: 1.20 vs. 1.10 (standard deviation: 0.77 vs. 0.13). In fact, applying a Mann-Whitney U-test to each round (neglecting non-independence across rounds) reveals that the differences are insignificant in each round. Note, furthermore, that differences across markets are smaller within treatment Two as standard deviations in this treatment are smaller than in treatment One.

[14] There are two rounds in treatment One, in which one firm produced 0. Therefore, these two cases are excluded.

Let us finally and briefly explore actual behavior in the second production period in treatment Two. Recall form (3) that behavior in the second stage depends on the individual quantities produced in the first stage: Whereas a firm should cease production in classes I and III, it should produce up to the Cournot-Nash output (i.e., up to it's best response to the other firm's first-period output) in class II (IV). Table 4 shows average observed 2nd-period quantities in all of these four classes along with the average quantity that would have been optimal according to the subgame perfect equilibrium, separately for rounds 1-24 and rounds 17-24 (experienced behavior). Several observations are in order. First, in accordance with what was said above, most observations belong to class II, i.e., to the case in which both firms have produced less than the Cournot-Nash output in the first period: 364 out of 480 cases (rounds 1-24) and 132 out of 160 cases (rounds 17-24). Second, no matter which time interval one considers, on average firms produce less than what would have been optimal in class II: 5.38 vs. 9.78 (rounds 1-24) and 5.59 vs. 9.95 (rounds 17-24). That is, as we already know, on average firms do not produce up to the Cournot-Nash quantity as it is required by subgame perfect behavior in this class. In other words, firms act somewhat collusively. Third, again independent of the time interval considered, on average firms produce more than what would have been optimal in class IV: 10.21 vs. 7.15 (rounds 1-24) and 6.33 vs. 3.42 (rounds 17-24). Note that in class IV, the other firm's first-period output can be much higher than the first-period output of the own firm. Thus, an output beyond of what would have been optimal, can be interpreted as an attempt to balance market shares. Fourth, subjects appear to have learned over time to cease production in classes I and III: Average observed quantities in periods 17-24 are (close to) 0 in these cases whereas this is not the case in the first two thirds of the experiment as becomes apparent by looking at the respective numbers in periods 1-24. In all, it appears that learning leads to second-period behavior that over time moves closer to the subgame perfect equilibrium prediction.

5 Discussion

Giving firms more flexibility with regard to the timing of decisions, Saloner (1987) studies an extension of the standard Cournot model by allowing firms to produce in each of two periods before the market clears. As a result, a continuum of equilibria arises in this model: All points in the outer envelope of the best-response functions between and including the Stackelberg points can be sustained as subgame perfect Nash equilibria. However, as noted by Ellingsen (1995), only the Stackelberg points survive the iterated elimination of weakly dominated strategies. Thus, even a-priori symmetric firms are predicted to end up in asymmetric positions. Contrary to this prediction, the main result reported in this paper is that about symmetric outcomes emerge in the experimental two-period markets. Moreover, when subjects are experienced, average industry outputs in two-period markets are the same as in one-period Cournot markets. Also, the bulk of the industry output—namely on average 83%—is produced during the first production period.

The endogenous emergence of Stackelberg outcomes in experimental duopoly markets with flexible timing appears in the light of the experimental results presented here and elsewhere[15] as very unlikely. Subjects' aversion to disadvantageous inequality as conceptualized in, e.g., Fehr and Schmidt (1999) and Bolton and Ockenfels (2000) seems to be too strong to allow symmetric as well as asymmetric firms to end up in asymmetric positions.

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[15] As mentioned in the introduction, Huck, Müller and Normann (2002) test Hamilton and Slutsky's (1990) extended Cournot model with action commitment and symmetric firms. Fonseca, Huck and Normann (2002) test the same model with asymmetric firms. Van Damme and Hurkens (1999) predict for this case that the low-cost firm should emerge as the Stackelberg leader. However, Stackelberg outcomes are, again, extremely rare.

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Appendix

A Translated Instructions

Welcome to our experiment! Please read these instructions carefully! Do not speak to your neighbors and keep quiet during the entire experiment! In case you have a question raise your hand! We will then come to you.

In this experiment you will repeatedly make decisions. Doing this you can earn money. How much you earn depends on your decisions and on the decisions of another participant. All participants receive the same instructions. You will stay anonymous for us and for the other randomly chosen participant you get in touch with during the experiment.

In this experiment you represent a firm. You and another firm produce and sell identical products on the same market. Costs of production are 1 ECU per unit (for all firms).

[The following paragraph only in treatment One.] All firms will always have to make one decision, namely which quantity they wish to produce.

[The following paragraph only in treatment Two.] In every round each firm has to decide which quantity it wants to produce. Each round consists of two production periods in which production may take place. In the 1st production period both firms simultaneously decide which quantity they want to produce in this production period. Then, each firm will be informed about the quantity the other firm has produced in the 1st production period. Then both firms decide (again simultaneously) which additional quantity they want to produce in the 2nd production period. In the second production period you can only increase your total quantity (or you leave it constant). But you cannot withdraw some of the quantity you produced in the first production period. Your profit per round will be computed using the total quantities produced by your firm and the other firm.

The following important rule holds: The larger the total quantity of both firms, the smaller the resulting price. Moreover, the price will be zero if total output exceeds a certain threshold.

Your profit per unit of output will then be the difference between the market price and the unit cost of 1 ECU. Note that you can make a loss, in case the market price is below the unit costs. Your profit per round is thus equal to the profit per unit multiplied by the total number of units you sell.

In each round the outputs of both firms will be registered, the corresponding price will be determined and the respective profits will be computed.

Moreover, you can first simulate your decision in each production period. You can do that on the left hand side of your decision screen. You simply enter some own quantity and some quantity of the other firm into the boxes and then push the button “compute”. At the top left corner of your screen it will then be indicated which profit for you would result.

When you have come to a final decision in a production period, please enter this decision into the box on the right hand side of your screen and push the button “OK”.

The experiment consists of 25 rounds. You will be constantly matched with the same other participant.

Your total monetary earnings will be determined by the sum of your earnings per round. At the end of the experiment your earnings will be converted into DM (Pounds) where 900 ECU = 1 DM (3000 ECU = 1 Pound). At the beginning of the experiment you get a one-time endowment of 500 ECU.