Experimental Tests of Consciously Parallel Behaviour in Oligopoly¤

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Abstract

This research examines, in experimental oligopoly markets, (a) whether parallel pricing patterns emerge when communication among players is limited to cheap talk announcements; (b) whether such pricing patterns, if they emerge, lead to payo¤s that exceed those players would receive in Nash equilibrium of the one-shot game. Results indicate that announcements and price matching lead to larger price-cost margins than in static Nash equilibrium, while falling well short of joint pro…t maximization.

¤Louis Phlips was o¤ered the opportunity to assert co-authorship of this paper, which his contributions would have justi…ed. We are grateful to the European University Institute for …nancial support, to Klaus Abbink and Abdolkarim Sadrieh for providing us with their RatImage computer program (Abbink and Sadrieh, 1995), to Professor Henning Bunzel, to the Department of Economics at the University of Aarhus, to Charles Holt, and to seminar participants at George Washington University, Michigan State University, and the University of Edinburgh. Responsibility for errors is our own.

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1. Introduction

Economists' concern with the possibility that …rm conduct might allow businesses to collect economic pro…t over the long run goes back at least to Smith's (1937, p. 128) oft-quoted observation that

> People of the same trade seldom meet together, even for merriment and diversion, but the conversation ends in a conspiracy against the public, or in some contrivance to raise prices.

From that time forward, industrial economists have analysed structure–conduct–performance relationships and o¤ered advice to policy makers on the kinds of rules for business behaviour that are conducive to good market performance. Consistent with this advice, competition policy for most market economies declines to enforce collusive agreements and prohibits a variety of types of conduct thought to facilitate collusive outcomes.[1]

Although the infusion of industrial economics by game theory has been marked by great technical advances, this precision is of limited use for the purpose of advising policy-makers about rules for business behaviour. In the kind of imperfectly competitive market that characterizes major industries in modern economies, the best equilibrium market performance obtainable is that of the Nash equilibrium of a nonrepeated game (henceforth, for conciseness, we will refer to this as the static Nash equilibrium). Game theoretic models of markets as repeated games are plagued by a multiplicity of equilibria, many of which yield …rms greater pro…t than they would earn in static Nash equilibrium. Indeed, the Folk Theorem states that in an in…nitely repeated game non-cooperative behaviour can sustain any strategy yielding …rms individual payo¤s that exceed non-cooperative payo¤s from the stage game, provided that the interest rate used to discount future pro…ts is su¢ciently low.[2] Theory alone cannot guide policy prescriptions.

The purpose of this study is to examine, in a laboratory situation, one type of …rm conduct that is often alleged to worsen market performance. We consider a kind of signalling that has been the subject of policy concern in both the European Union and the United States: parallel pricing that emerges in an environment of public announcements of prices and price changes (Phlips, 1995, Chapter 7). Such behaviour has been attacked in the United States as a violation of the Sherman Act Section 1 prohibition against contracts, combinations, and conspiracies in

[1] An older approach, which permitted collusion and sought to regulate its consequences, has generally fallen into disfavor. See Martin (1997).

[2] Strategies yielding such payo¤s may also be an equilibrium in …nitely repeated games (Benoit and Krishna, 1985; Harrington, 1987; Basu, 1992).

restraint of trade,[3] in the European Union as a violation of the Treaty of Rome Article 85 prohibition of agreements and concerted practices that distort competition within the common market.[4] In both jurisdictions, enforcement authorities' early inferences of collusion from parallel conduct by enforcement authorities were sustained by the courts, but later cases met the judicial objection that in imperfectly competitive markets outcomes that gave …rms collusive payo¤s might result from conduct that was not collusive in a legal sense:[5]

> concertation is not the only plausible explanation for parallel conduct. To begin with, the system of price announcements may be regarded as constituting a rational response to the fact that the pulp market constituted a long term market and to the need felt by both buyers and sellers to limit commercial risks. Further, the similarity in the dates of the price announcements may be regarded as a direct result of the high degree of market transparency, which does not have to be described as arti…cial. Finally, the parallelism of prices and the price trends may be satisfactorily explained by the oligopolistic tendencies of the market and by the speci…c circumstances prevailing certain periods. Accordingly, the parallel conduct established by the Commission does not constitute evidence of concertation.

We seek to observe, in stylized experimental markets that capture the main structural characteristics of important oligopoly markets,

- whether parallel pricing can emerge in a market that excludes explicit collusion by design;
- whether such pricing patterns, if they emerge, lead to market performance approaching that resulting from explicit collusion.

2. Conscious Parallelism and the Conscious Parallelism Game

Back-and-forth price announcements, sometimes implemented and sometimes not, are a hallmark of many industries. The US steel industry is one example. The

[3] Leading cases are Interstate Circuit, Inc. et al. v. U.S., 306 U.S. 208 (1938); American Tobacco Co. et al. v. U.S., 328 U.S. 781 (1946); Theater Enterprises, Inc. v. Paramount Film Distr. Corp. et al., 346 U.S. 537 (1953).

[4] See among other references Dyestu¤s Commission Decision of 24 July 1969 JO L 195/11 [1969] CMLR D23 and Italian Flat Glass Commission Decision of 7 December 1988 OJ No L33/44 4 April 1989.

[5] Re Wood Pulp Cartel: A. Ahlström oy and others versus E.C. Commission [1993] 4 CMLR 407 at 582-3; emphasis added. On the distinction between the legal and economic notions of collusion, see Baker (1992) and Martin (1992).

experiment described here, which permits such behaviour, is patterned in a general way after MacLeod's (1985) formal model of consciously parallel price changes.[6]

The market is one in which each …rm sells a single variety of a di¤erentiated product. The model is one of a repeated game, in which each period has two stages. In the …rst stage, …rms play an announcement game, announcing prices or price changes and reacting to the announcements of other …rms. The announcement stage is followed by a second stage in which …rms set actual prices.

2.1. The announcement stage

Let P be the vector of announced prices. MacLeod imposes three axioms on function $r_{ji}(P; ¢P_i)$ that gives the response by …rm j to a price change $¢P_i$ announced by …rm i:

- r_{ji} is continuous and continuously di¤erentiable;
- r_{ji} is independent of scale changes: $r_{ji}(®P; ®¢P_i) = ®r_{ji}(P; ¢P_i)$
- response functions are symmetric, in the sense that relabelling …rms does not alter responses.

MacLeod (1985, Proposition 3) shows that the unique response function satisfying these axioms is a matching function,

$$r_{ji}(P; ¢P_i) = ¢P_i; \tag{2.1}$$

a result that implies behaviour of the kind observed in conscious parallelism cases. He interprets this as a socially acceptable rule of thumb of the type that might be expected to emerge if pro…t functions are not common knowledge (1985, p. 32).

This price matching strategy is then embedded in an equilibrium strategy for the announcement game; this strategy speci…es

- a …rm will match an announced price increase if it is individually pro…table to do so, assuming all other …rms match the increase, and if all other …rms match the increase;
- a …rm will match an announced price decrease;
- defection triggers reversion to the Nash equilibrium prices of the one-shot game.

[6] The discussion that follows is heuristic; for a comprehensive presentation, see MacLeod (1985).

Informational requirements are minimal: each …rm is able to observe the announcements of other …rms, knows the Nash reversion prices, and knows whether or not the increase, if matched by all …rms would be pro…table for itself. It does not know whether or not the increase would be pro…table for rivals.[7]

2.2. The price-setting stage

The announcement game is followed by a pricing game. The conscious parallelism strategy requires …rms to set the equilibrium prices from the announcement game. The strategy is sustained by the threat that if any …rm defects from announced prices, all other …rms will revert to the noncooperative equilibrium prices of the underlying stage game. The conscious parallelism equilibrium prices exceed these static Nash prices by the same amount for all …rms (this is a consequence of the matching rule (2.1)), and are such that further matched increases will be unpro…table for at least one …rm.

3. The Experimental Market

MacLeod's analytical framework is quite general. Experimental implementation required us to select speci…c functional forms for demand and cost functions. We discuss the duopoly version here.[8]

We assume linear demand curves,

$$p_1 = a_1 - b(q_1 + \mu q_2) \tag{3.1}$$

$$p_2 = a_2 - b(\mu q_1 + q_2) \tag{3.2}$$

where $0 < \mu < 1$. Varieties are thus demand substitutes, and …rms' choice variables, prices, are strategic complements.

We assume that …xed costs are zero and that marginal costs c_1 and c_2, respectively, are constant. Without loss of generality, let

$$a_1 - c_1 \geq a_2 - c_2. \tag{3.3}$$

For simplicity and with some abuse of terminology we will refer to variety 2 as the higher-quality variety (strictly speaking this would require $a_2 > a_1$).

[7] One can conceive of a dual quantity-matching strategy, in which …rms would announce and react to announcements of output changes. For a discussion of quantity announcements in the US automobile industry, see Doyle and Snyder (1996).

[8] Results generalize to the n-…rm case, as shown in an appendix available on request from Stephen Martin.

3.1. Static Nash equilibrium prices

If demand for both varieties is nonnegative,[9] the quantity demanded of variety 1 satis…es

$$b(1 - \mu^2)q_1 = (a_1 - c_1) - \mu(a_2 - c_2) + \mu(p_2 - c_2) - (p_1 - c_1); \tag{3.4}$$

with an analogous expression for variety 2. Firm 1's pro…t then satis…es

$$b(1 - \mu^2)\pi_1 = (p_1 - c_1)[(a_1 - c_1) - \mu(a_2 - c_2) + \mu(p_2 - c_2) - (p_1 - c_1)]: \tag{3.5}$$

The …rst-order condition for maximizing π_1 with respect to p_1 gives the equation of …rm 1's price reaction function,

$$2(p_1 - c_1) = (a_1 - c_1) - \mu(a_2 - c_2) + \mu(p_2 - c_2): \tag{3.6}$$

Solving the equations of the two reaction functions gives static Nash equilibrium prices, which satisfy

$$(4 - \mu^2)(p_1^N - c_1) = (2 + \mu - \mu^2)(a_1 - c_1) - \mu(a_2 - c_2) \tag{3.7}$$

$$(4 - \mu^2)(p_2^N - c_2) = (2 + \mu - \mu^2)(a_2 - c_2) - \mu(a_1 - c_1): \tag{3.8}$$

From these expressions it follows that the higher-quality variety has the greater static Nash equilibrium price-cost margin,

$$p_2^N - c_2 > p_1^N - c_1: \tag{3.9}$$

The equations of the reaction functions imply that the quantity demanded of each …rm in static Nash equilibrium is proportional to its price-cost margin,

$$b(1 - \mu^2)q_1^N = (p_1^N - c_1): \tag{3.10}$$

Hence equilibrium pro…t is proportional to the square of the price-cost margin,

$$b(1 - \mu^2)\pi_1^N = (p_1^N - c_1)^2; \tag{3.11}$$

and in static Nash equilibrium the higher-quality variety has the greater payo¤.

[9] In the n-…rm case, if one …rm prices so high that its sales are zero, the market becomes an $(n - 1)$-…rm oligopoly among the remaining …rms. Programming for the experiments included subroutines to deal with such events.

3.2. Conscious parallelism equilibrium prices

We now turn to a question that is critical for the conscious parallelism strategy of the MacLeod model, in which prices are raised until at least one …rm is unwilling to go along with additional increases. How high will price rise if …rms behave in this way?

From (3.4), if all prices are increased by ¢p from the noncooperative equilibrium level, the quantity demanded of variety 1 falls according to

$$q_1(p_1^N + ¢p - c_1; p_2^N + ¢p - c_2) = q_1^N - \frac{1}{1+\mu}\frac{¢p}{b} \tag{3.12}$$

Player 1's pro…t, if all prices are increased by ¢p from the noncooperative equilibrium level, is

$$¼_1 = ¼_1^N - \frac{1}{1+\mu}\left[¢p - \frac{\mu}{1-\mu}(p_1^N - c_1)\right]\frac{¢p}{b} \tag{3.13}$$

This is quadratic in ¢p and has a maximum at

$$¢p_1 = \frac{1}{2}\frac{\mu}{1-\mu}(p_1^N - c_1): \tag{3.14}$$

There is a similar expression for …rm 2. These expressions give the price increase that …rm i would prefer, assuming that the other …rm matches the increase. By (3.9), it is the lowest quality variety that will have the smallest Nash equilibrium price-cost margin. The conscious parallelism strategy therefore implies that it will be the producer of the lowest-quality variety that calls a halt to price increases.

3.3. Joint pro…t maximization

It is straightforward to show (and a standard result in this type of model) that joint pro…t maximisation requires each …rm to set the price that it would set if it were a monopolist not faced with the competition of substitute varieties:

$$p_1^J - c_1 = \frac{1}{2}(a_1 - c_1): \tag{3.15}$$

3.4. Discussion

The conscious parallelism equilibrium is illustrated graphically in Figure 3.4. The non-cooperative equilibrium (point N) is to be found in the intersection of the reaction functions $(R_1; R_2)$ of the two …rms. The dotted CP line is a 45± line with

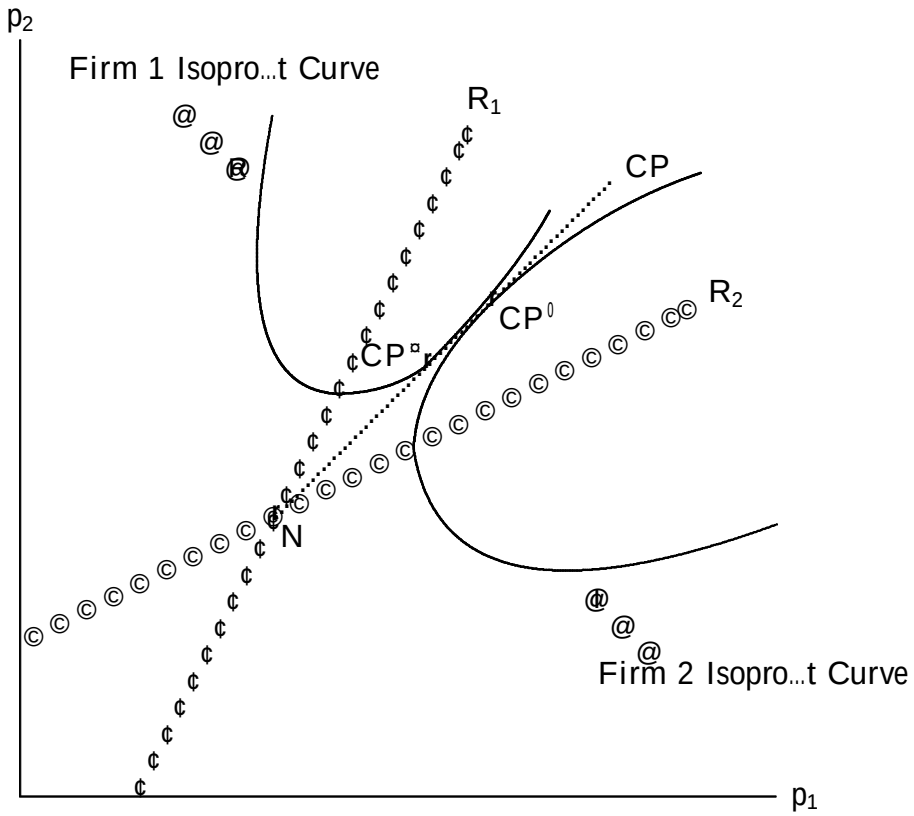

Figure 3.1: The Conscious Parallelism Equilibrium

N as the origin. It shows all possible conscious parallelism prices. The conscious parallelism prices preferred by …rm 1 and …rm 2 are found where isopro…t curves are tangent to the CP line: …rm 1 prefers prices corresponding to $CP^{¤}$, while …rm 2 could still gain from a further price increase to CP^{0} – given that this price would be matched by …rm 1. Since …rm 1 is worse o¤ at point CP^{0}, it does not match this price increase and $CP^{¤}$ is the conscious parallelism equilibrium.

4. Experimental Design

4.1. Treatments

Four treatments make up the overall experiment:

I. A control treatment in which players act as independent price-setters.

In each period, each player selects a price; each player is informed of the prices chosen by the other players, of its own quantity sold and its own payo¤; the experiment then proceeds to the next period. Subjects from this experiment do not participate in later experiments.

II. A treatment to examine whether consciously parallel behaviour emerges spontaneously from oligopoly interactions.

Each period consists of two stages. In the …rst stage, players may announce prices. Any announcements are communicated to other players via the computer network. Firms may make multiple announcements, retract announced changes and so on. When no announcement has been made for a speci…ed interval (initially two minutes, reduced to 30 seconds after subjects have acquired experience with the mechanics of the procedure), the period moves to the second stage, in which …rms select actual prices. Prices, own sales, and own payo¤s are communicated as in the …rst session. The session then proceeds to the next period. Subjects from this experiment will not participate in later experiments.

III. A treatment to examine the implications of consciously parallel behaviour for market performance.

As in treatment II, each period will consist of an announcement game and a pricing game. In the announcement game, players are constrained to match or to not match announced price changes. In other words, they are obliged to follow the MacLeod conscious parallelism strategy. The price-setting stage of the game is identical to that of treatment II.

IV. A treatment to examine the impact of socialisation on the sustainability of consciously parallel behaviour.

Subjects from treatment III participate in a follow-up session of treatment II. The hypothesis to be tested is that subjects who have had experience with price matching strategies in treatment III will tend to follow such strategies even when the experimental design does not force them to do so.

Treatment I is a posted-o¤er market with simulated demand. Treatment II is similar to the announcement games examined by Holt and Davis (1990) and

	Price-cost margins		Single-period payo¤s	
	L	H	L	H
Static Nash	3.3125	4.4375	25.60	45.95
CP	13.250	14.375	58.52	101.22
J¦M	15.000	16.000	55.00	106.67

Table 4.1: Comparative Stage-Game Equilibrium Values

Cason (1995), although we use a di¤erent market structure. Grether and Plott (1984) impose speci…c market practices (in their case, advance notice of price changes and most-favoured nation clauses) on experimental markets, as we do in Treatment III, and examine the consequences for market performance. Our focus on experience in comparing Treatments III and IV is related to Benson and Faminow (1988), which uses a spatial di¤erentiation model.

4.2. Parameter values/market characteristics

Each session involved 4 experimental subjects. Demand intercepts and marginal cost parameters were chosen so that

$$a_H - c_H = 32 \tag{4.1}$$

for two players and

$$a_L - c_L = 30 \tag{4.2}$$

for the other two players. Each player knew its own demand intercept and unit cost, and did not know those of the other players.

The product di¤erentiation parameter μ was set equal to 2/3. This introduces enough di¤erentiation to avoid substantial shifts in sales in response to small price changes, but means that di¤erent varieties are close enough substitutes so that there are substantial potential gains from coordinating behaviour.

As might be suspected from the discussion of duopoly (and as is shown in the Appendix for the general case), it is only the di¤erences $a - c$ that matter for incentives and payo¤s. Adding/subtracting the same constant to/from all values of a and c in a session leaves the underlying game unchanged, although it does change equilibrium price levels. This aspect of the experimental market was used to vary the equilibrium price levels of di¤erent sessions while maintaining comparability of margins across sessions. Subjects could therefore honestly be told that any information they might have received about price levels from subjects of previous sessions was not relevant for their session.

Table 4.1 compares price-cost margins and single-period payo¤s in three alternative stage-game equilibria. It will be noted that the conscious parallelism

Experiment	Session	Rounds
1	1	20
1	2	20
1	3	23
1	4	34
1	5	27
2	1	24
2	2	21
2	3	27
2	5	23
2	6	23
3	1	22
3	2	20
3	4	21
4	1	22
4	2	22
4	3	26
Total		375

Table 4.2: Aarhus conscious parallelism experiments: descriptive statistics

margins and payo¤s are very close to the joint-pro…t-maximizing values, and that both are substantially greater than the corresponding static Nash values. The potential reward to successful coordination is large.

Equilibrium payo¤s for the H subjects are substantially greater than those for the L subjects. Di¤erential exchange rates were used to convert the experimental currency unit (ECU) to Danish kroner (3 ECU/kroner for L subjects, 6 ECU/kroner for H subjects), so that potential cash payments to H and L subjects were essentially the same. These values were chosen so that experimental currency unit (ECU)-Danish kroner exchange rates could be used that would make mental conversions by subjects during the course of the session straightforward, while leading to payo¤s within our budget constraint.

Subjects received a 60 kroner show-up fee as well as the kroner-equivalent of their experimental pro…ts. The …rst period was a practice session that did not count toward the subject's payo¤. Actual payments ranged from 180 to 540 Danish kroner (approximately $30 to $90) (before allowing for Danish income tax). Sessions lasted between 1.5 and 2 hours.

4.3. Organizational considerations

The experiments were carried out at the University of Aarhus. Subjects were mainly although not exclusively undergraduate economics majors.[10]

Each session lasted a minimum of 20 periods. We used a random stopping rule to determine the end of the session. At the end of period 20 and of each following period, a die was rolled in plain view of the experimental subjects. If the die came up 6, the experiment ended, otherwise it continued. The resulting ending probability makes the conscious parallelism strategy a noncooperative equilibrium.

The number sessions of each treatment, and the number of rounds in each session, are reported in Table (4.2).[11]

Experimental subjects were linked via a computer network. The programming language is Turbo-Pascal; we used the RatImage routines developed by Abbink and Sadrieh (1995), which were designed for computer-aided human behaviour experiments.

Instructions (reproduced in an appendix at the end of this paper) were scrolled across the computer screen. Options available through the menu included a calculator and a history option that allowed a player to review previous prices of all …rms as well as its own previous sales and pro…ts. This is illustrated in Figure 4.1, which shows a sample screen from treatment I.[12] In the event, experimental subjects consulted the price history for 1130 of the 1500 observations generated by the Aarhus sessions.

In treatment I, which involves price setting but no announcements, subjects saw a screen of the kind shown in Figure 4.2 at the end of each period. This shows all four prices, as well as own quantity sold, own pro…t, and accumulated pro…t.

Figure 4.3 shows …rm 1's screen appearance in treatment II, after …rm 2 has announced a price change and other …rms have had the opportunity to react to this announcement.

Figure 4.3 may be compared with Figures 4.4 and 4.5. These show …rm 1's screen in treatment III when a price change is announced (Figure 4.4) and after players have been able to react to the announced change (Figure 4.5). The information that is given to …rm 1 in Figure 4.4 is consistent with that required by MacLeod's formal model: under the conscious parallelism strategy, …rms are to match announced price increases if it is pro…table for them to do so and all other …rms match the announced increase. Somewhat more broadly, we intended to give subjects information that would replicate the kind of information real-world

[10] The subject who earned the largest payo¤ was majoring in Japanese.

[11] Session 4 of experiment 2 and session 3 of experiment 3 were terminated due to software problems.

[12] Additional screens from the various treatments are posted on the world wide web at url http://www.ibt.dk/www/samf/oko/cie/screens.htm.

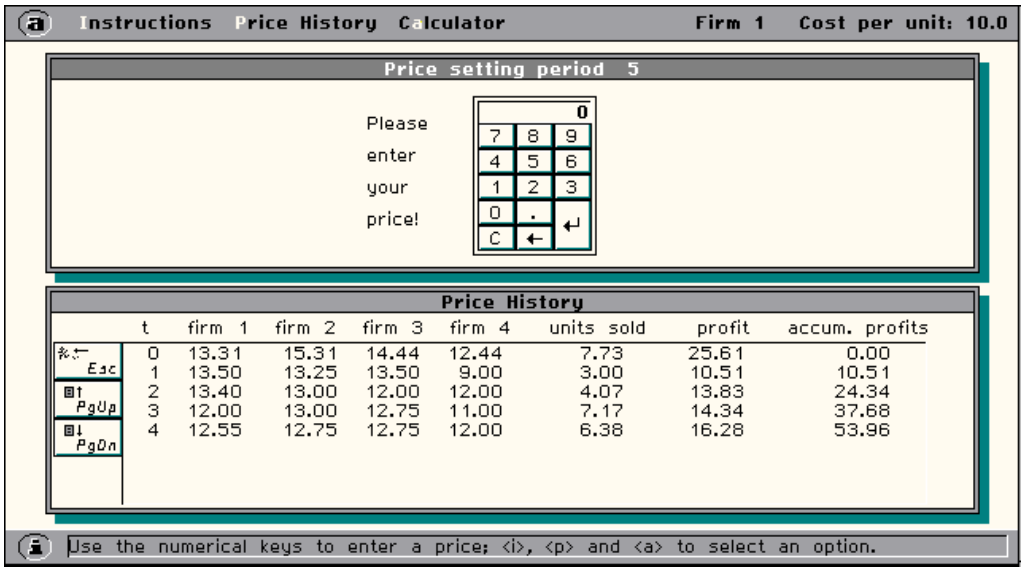

Figure 4.1: Price History Screen Image, Treatment I (price setting only)

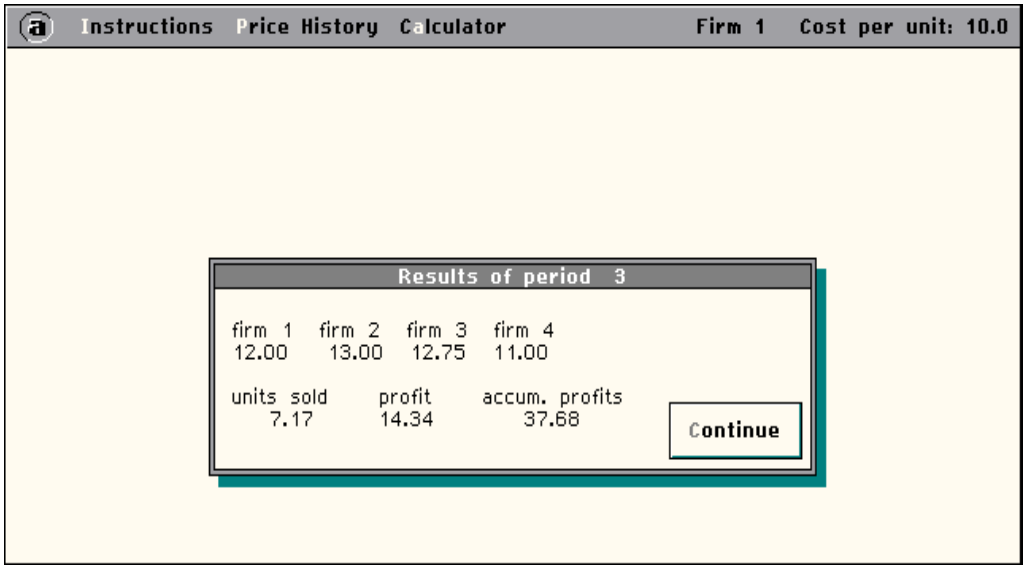

Figure 4.2: Results Screen, Treatment I (price setting only)

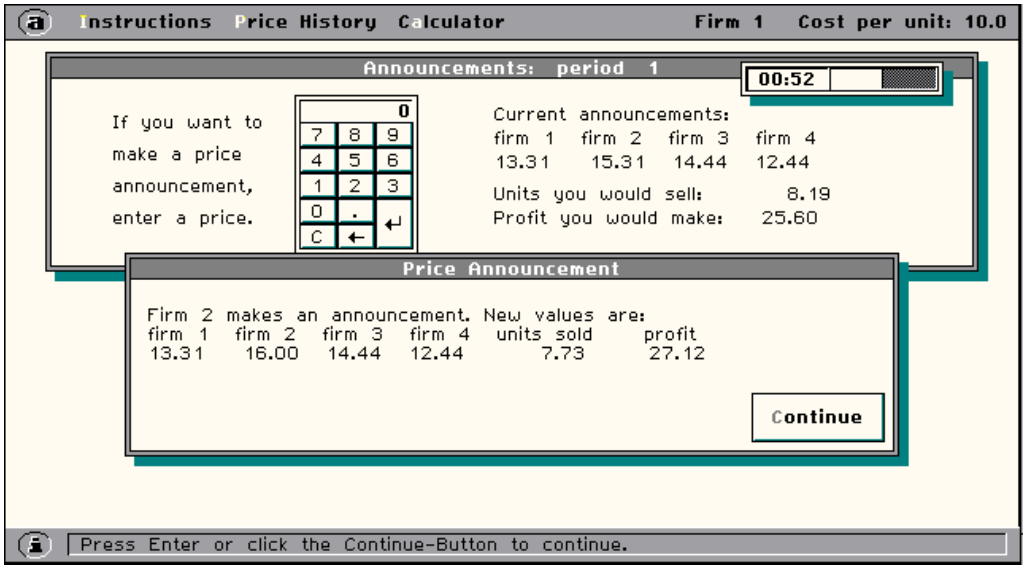

Figure 4.3: Treatment II, screen after an announcement is made

…rms might be expected to have if direct communication among competitors is ruled out. This includes own cost and own and rivals' prices, as well as what realistically would be estimates of expected own sales and own pro…t.

5. Results

Table 5.1 gives a general description of the 16 sessions. Table 5.2 reports the average di¤erence, subject by subject and session by session, between actual and static Nash price-cost margins. Negative values indicate that the subject set below-Nash prices, on average. The conscious parallelism values would be 9.9375 for L and H subjects; the joint-pro…t maximizing values would be 11.6875 and 11.5625, for L and H subjects respectively.

5.1. Treatment I

Figure 5.1 shows the development of price-cost margins in the 5 sessions of treatment I (price-setting without announcements). What is shown in Figure 5.1 are the arithmetic di¤erences between the actual and the static Nash price-cost margins, averaged over the 4 subjects in the session (two with low-quality, two with high-quality varieties).

In sessions I–1, I–2, and I–3 margins are below static-Nash levels early in the session. Margins in session I–1 rise steadily throughout the session. Margins

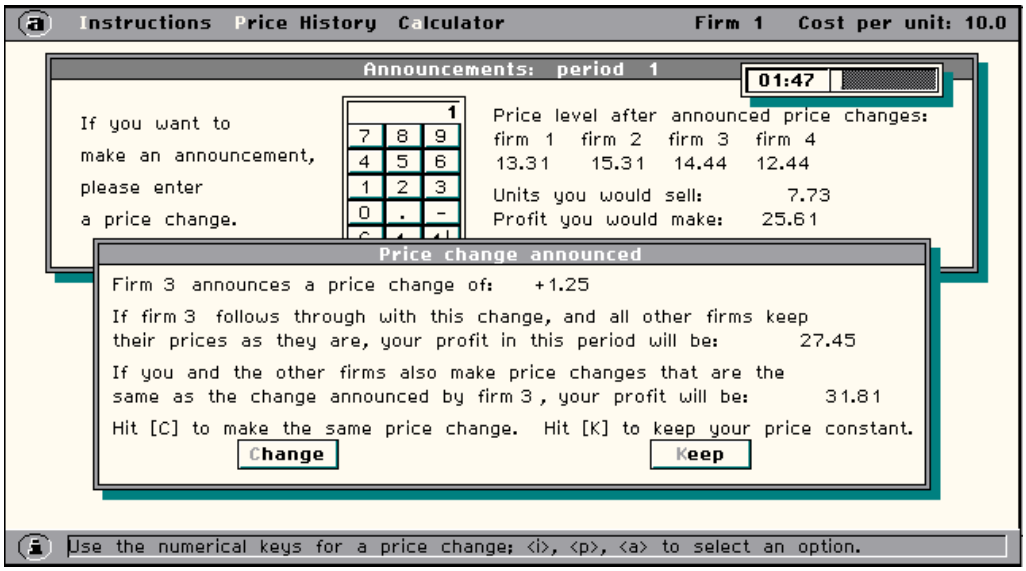

Figure 4.4: Treatment III, price change announced

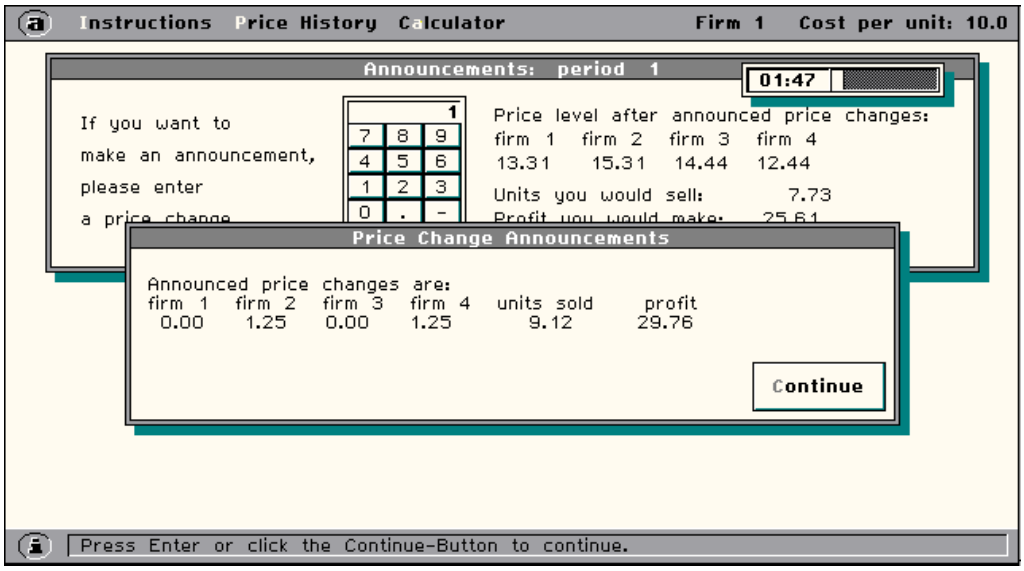

Figure 4.5: Treatment III, after all players have responded to an announced price change

Session	Comments	$\bar{p} = \bar{p}^N$ (%)
I-1	3 …rms progressively move to above-static Nash prices; …rm 2 a maverick	83
I-2	all …rms above Nash price in second half of the session	96
I-3	1 and 4 prices above Nash in middle periods; 2 and 3 Nash from period 7 on; endgame e¤ects	90
I-4	3 Nash from period 5 on; other players persistently above Nash prices	135
I-5	above Nash throughout; apparent tacit collusion breaks down periods 16–22, then resumes 23–25	141
II-1	prices essentially always above Nash level; 2 and 3 usually near best response prices, 1 and 4 above best response prices	130
II-2	1 and 4 persistently price above Nash, 3 slightly below Nash, 2 mostly above but with two episodes of low prices	101
II-3	1 and 4 persistently price above Nash, 2 and 3 price at Nash level throughout	104
II-5	signalling by 4, periods 11–17, all prices then above Nash; otherwise, prices at Nash level	124
II-6	prices at or above Nash levels, periods 8–14; player 2 never above Nash level; slow decline from period 15	107
III-1	prices rise sharply through period 6, decline slowly thereafter, above Nash levels throughout	151
III-2	prices ‡uctuate above Nash level …rst 10 periods, then rise sharply	121
III-4	prices above Nash throughout, substantially so periods 7–14, decline thereafter	145
IV-1	prices rise continuously through period 18, fall to Nash levels period 20, begin to rise again	181
IV-2	prices ‡uctuate substantially around an average above Nash levels	142
IV-3	prices rise through period 10, decline thereafter, end around Nash level	111

Table 5.1: Aarhus conscious parallelism experiments: qualitative descriptions

Session	L1	L2	H1	H2
1-1	-0.01	-1.52	-0.76	0.06
1-2	-0.32	-0.06	0.80	1.20
1-3	0.40	-0.34	-0.74	1.37
1-4	2.47	3.09	1.05	3.04
1-5	2.99	3.40	2.28	3.57
2-1	2.64	1.79	2.00	2.82
2-2	0.26	0.25	-0.13	0.24
2-3	0.44	-0.13	-0.13	1.07
2-5	1.49	2.00	2.15	3.73
2-6	0.49	-0.15	0.59	1.22
3-1	3.13	2.65	3.19	3.15
3-2	1.47	1.80	1.14	1.75
3-4	3.48	2.47	3.72	3.38
4-1	6.31	4.98	6.01	7.14
4-2	1.20	1.73	1.06	2.29
4-3	0.97	1.72	0.97	0.43

Table 5.2: Aarhus conscious parallelism experiments: average $(p \text{ ¡ } c) \text{ ¡ } (p \text{ ¡ } c)^N$, by subject and session

Notes: For treatments I, II, and II, L1 is player 1, L2 is player 2, H1 is player 3, H4 is player 4; for experiment IV, L1 is player 3, L2 is player 4; H1 is player 1, H2 is player 4; periods 16 and 17 omitted from sample for player 4, experiment 2, session 5 (see text).

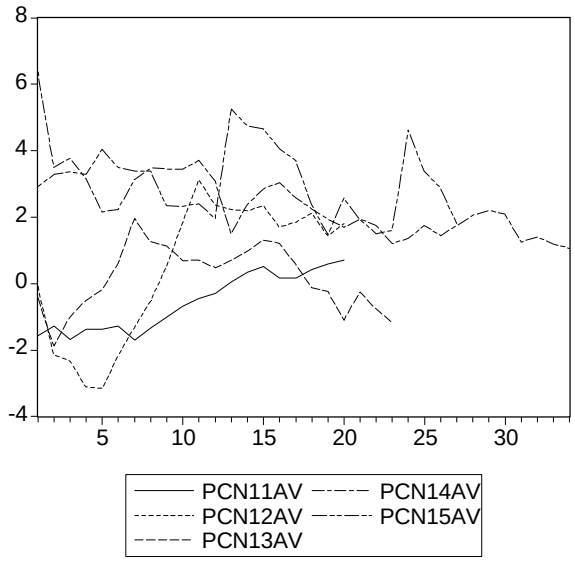

Figure 5.1: Treatment I, sessions 1–5, average (p ¡ c) ¡ static Nash (p ¡ c), by session

in session I–2 fall quite low though period 5, rise sharply through period 12, then decline slightly thereafter. Margins in session I–3 rise above static-Nash levels through period 8, level o¤ for about 9 periods, then decline. The latter may appears to be endgame e¤ects, which were evident in many of the sessions. Despite the continuation probability implied by the random stopping time, the …rst period in which the experiment might stop (period 20) seemed to be a focal point around which behaviour became more rivalrous.

5.1.1. History matters

One aspect of the MacLeod conscious parallelism model is that the static Nash equilibrium is known at the start of the game (1985, p. 34). With this in mind, the instructions included a set of "period 0" prices that were in fact the static Nash equilibrium prices. They were not described as such to the experimental subjects, who were told without editorial comment that the period 0 prices were based on previous experimental experience.

In treatment I, session 4, the period 0 prices were the joint-pro…t maximizing prices (without identifying them as such). In treatment I, session 5, no period 0 prices were given. It is evident from Table 5.2 that price-cost margins in sessions 4 and 5 were consistently higher than in sessions 1 and 3. The …nal column of Table

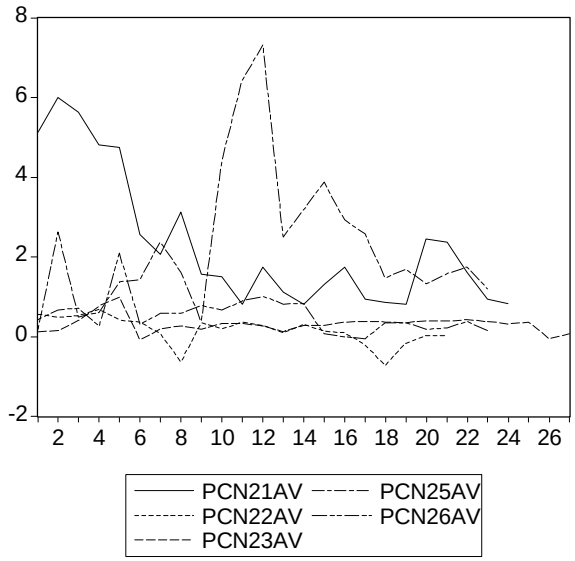

Figure 5.2: Average (p ¡ c) ¡ static Nash (p ¡ c), Treatment II, by session

5.1 indicates that payo¤s in these sessions were similarly higher than the other sessions of treatment I. In session 4, price-cost margins average 3.5 ECU above Nash levels in period 2 and declined slowly through 34 sessions to an average 1.1 ECU above the Nash level.

In treatment I, session 5 margins never fall below static Nash levels. There seem to be two relative breakdowns in coordination, once in period 12 and once over periods 19 through 23. The latter appears to be an endgame e¤ect. When the game continues through several rolls of the die, prices rise again.

5.2. Treatment II

Treatment II allows players to communicate via cheap-talk announcements. Average excess price-cost margins for Treatment II are shown in Figure 5.2.[13]

Sessions 2, 3, and 6 ‡uctuate around and converge to roughly the static Nash level. Results for these sessions are consistent with those for related speci…cations that have been reported in the literature (for example, Holt and Davis, 1990).

Sessions II-1 and II-5 exhibit di¤erent types of behaviour. Average margins in session II-1 decline over the initial periods, but stay consistently above static Nash levels. The same is true for average margins in session II-5, which exhibit

[13] For session II-5, periods 16 and 17, the average margin is calculated for …rms 1, 2, and 3 only.

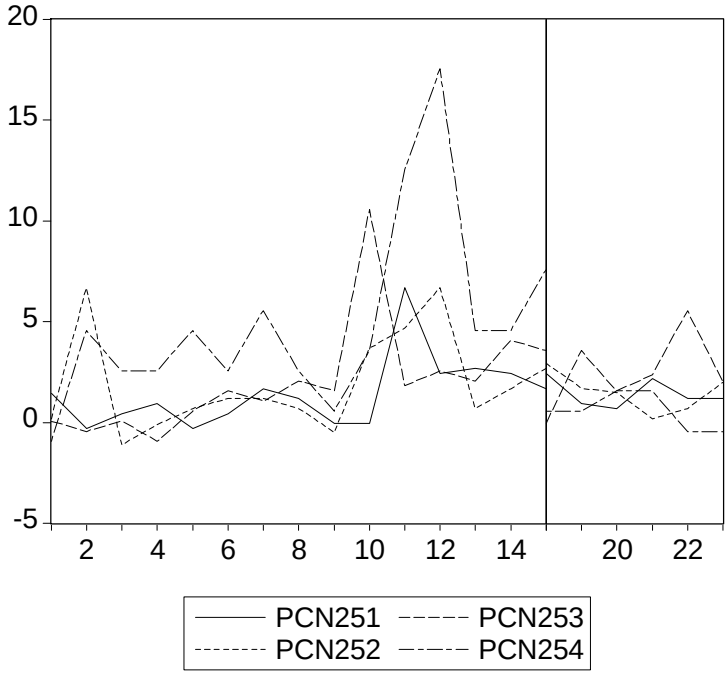

Figure 5.3: Treatment II, session 5, (p ¡ c) ¡ static Nash (p ¡ c); periods 16 and 17 omitted.

greater ‡uctuation. The e¤ect of price announcements for these two sessions recall the results reported by Brown-Kruse, Cronshaw, and Schenk (1993) for location communications.

Treatment II, session 5 merits separate attention. Its time path of price-cost margins is shown in Figure 5.3.

It will be noted that player 4 set very high prices in periods 11, 12, and 15. In periods 16 and 17, which are omitted from Figure 5.3 for reasons of scale, player 4 set a price of 400. An interview after the session established that these high prices were an attempt to signal to other players and lead them to raise prices. This e¤ort was abandoned in and after period 18, but the net result was relatively high margins and payo¤s for the session as a whole.

5.3. Treatment III

In treatment III, players were able to make announcements, but they were obliged to follow the price-matching element of the conscious parallelism strategy. Margins and payo¤s were high in all three sessions. The time paths of prices in the three

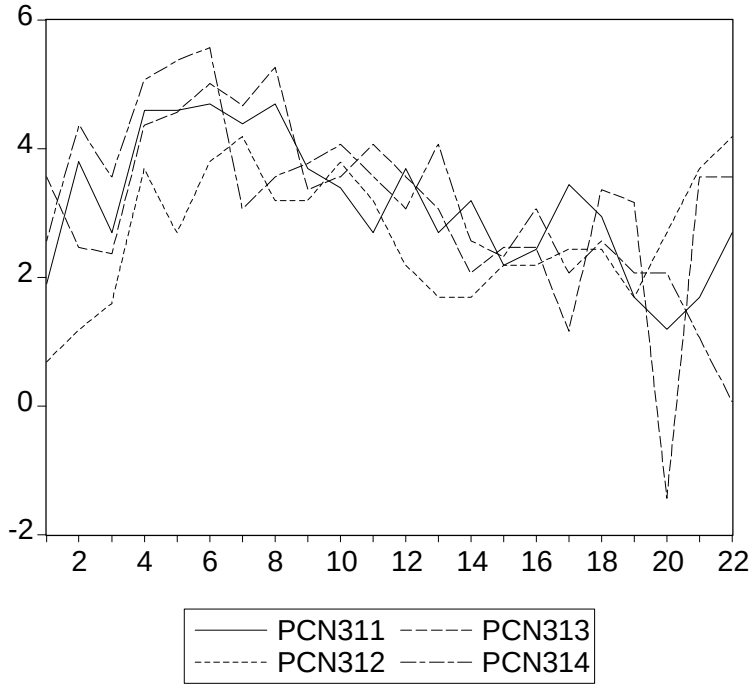

Figure 5.4: Treatment III, session 1, (p ¡ c) ¡ static Nash (p ¡ c)

sessions di¤ered, however.

In treatment III, session 1, price-cost margins rose for the …rst 6 periods, then fell slowly for the rest of the session (Figure 5.4). There is only 1 instance in which one player set a price below the Nash level, and this occurred in period 20. One might interpret this as an early comprehension of the private bene…ts of refraining from vigorous competition, more or less sustained by the conscious parallelism announcement mechanism.

The sharp price increase in the session occurs in period 4, with further smaller increases in periods 5 and 6. These periods are marked by many announcements (10 in periods 4 and 5, 14 in period 6), mostly of small positive or negative changes.

In period 4, 5 of the 10 announced changes were matched by all players (Table 5.3). All of these 5 announcements were increases. 2 of the announcements in period 5 and 2 of the announcements in period 6 (all increases) were matched by all players.

In treatment III, session 2, on the other hand, price-cost margins ‡uctuated around Nash levels for more than half of the session (Figure 5.5). In period 13, however, margins rose sharply, and they remained at this higher level for the rest of

Period 3 prices	16.00	16.90	16.80	16.00
3	0.50	0.50	0.50	0.50
3	0.00	-0.30	-0.30	-0.30
4	0.00	-0.50	0.00	-0.50
2	0.10	0.10	0.00	0.10
3	0.00	-0.30	-0.30	-0.30
4	0.00	-0.30	-0.30	-0.30
3	0.20	0.20	0.20	0.20
4	0.50	0.50	0.50	0.50
1	1.00	1.00	1.00	1.00
1	1.00	1.00	1.00	1.00
Period 4 prices	17.90	19.00	18.80	17.50

Table 5.3: Session III-1, period 4: price change announcements
Note: First column identi…es the player announcing a price change.

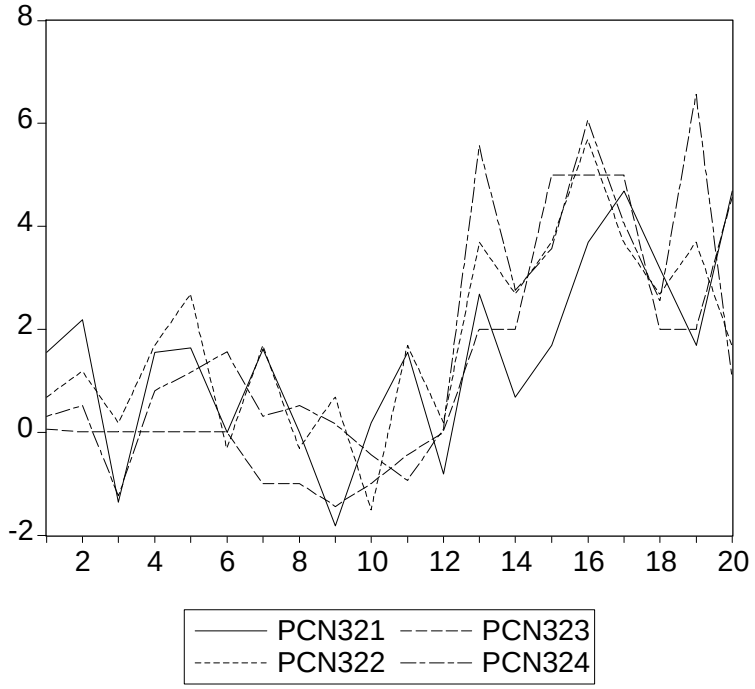

Figure 5.5: Treatment III, session 2, (p ¡ c) ¡ static Nash (p ¡ c)

Period 12 prices	13.50	16.50	15.44	13.50
1	2.00	2.00	2.00	2.00
1	2.00	2.00	2.00	2.00
1	2.00	2.00	2.00	0.00
1	2.00	2.00	0.00	2.00
Period 13 prices	17.00	20.00	17.44	19.000

Table 5.4: Session III-2, period 13: price change announcements
Note: First column identi…es the player announcing a price change.

Period 6 prices	18.25	18.50	16.89	15.90
3	0.00	0.00	2.00	0.00
1	1.00	1.00	1.00	1.00
1	1.00	1.00	1.00	1.00
1	1.00	1.00	1.00	1.00
3	0.00	0.55	0.55	0.55
2	1.00	1.00	1.00	1.00
Period 7 prices	22.00	20.00	20.95	18.50

Table 5.5: Session III-4, period 7: price change announcements
Note: First column identi…es the player announcing a price change.

the session. In the announcement segment of period 13, player 1 announced a price increase of 2 ECU 4 times in a row (Table 5.4). The …rst two times, all three of the other players matched the increase. The …nal two times, two of the other three players matched the increase. Actual prices that were set were somewhat below the announced levels, but substantially above the levels of previous periods.[14]

The path of price-cost margins in treatment III, session 4 (Figure 5.6) resembles that of treatment III, session 1 in some ways. Prices start at and rise to a higher level in session 4 than in session 1. In session 4, the peak of prices comes in the middle of the session, not the beginning. In session 4, the sharp increase in prices occurs in period 7.

6 price change announcements were made in the announcement segment of period 7 (Table 5.5). First player 3 announced an increase of 2 ECU; no other player matched this increase. Player 1 then successively announced 3 price increases of 1 ECU each. Each time, all three other players matched the announcement. Player 3 then announced an increase of .55 ECU, which was matched by players 2 and 4

[14] That posted prices fell short of announced levels is generally characteristic of the announcement treatments. This is functionally equivalent to undertaking transactions at discounts from list price.

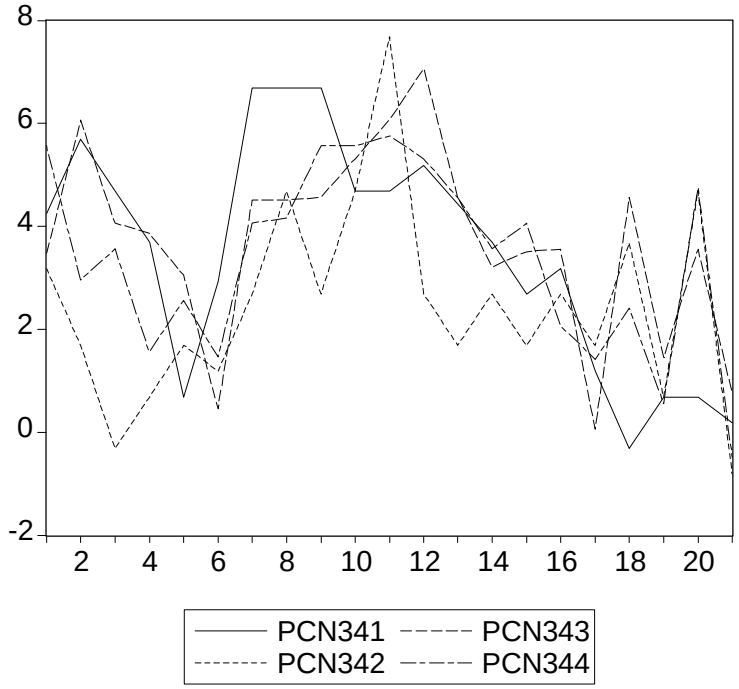

Figure 5.6: Treatment III, session 4, (p ¡ c) ¡ static Nash (p ¡ c)

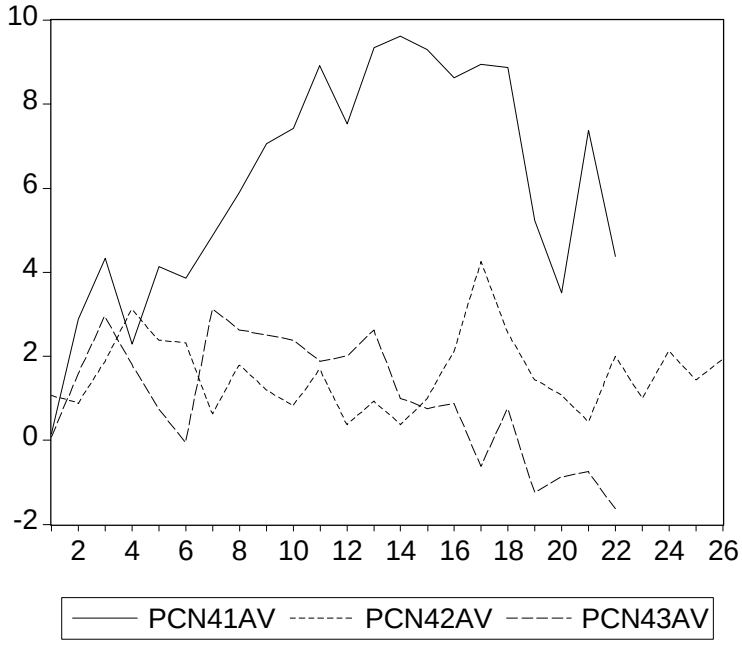

Figure 5.7: Average (p ¡ c) ¡ static Nash (p ¡ c), Treatment IV, by session

but not by player 1. Then player 2 announced an increase of 1 ECU, which was matched by all other players.

5.4. Treatment IV

Treatment IV is identical in structure to treatment II: players may make and react to cheap-talk price change announcements in the …rst half of each period. They are not constrained to follow the conscious parallelism announcement strategy. All subjects in treatment IV had experience with treatment III.

The di¤ering character of the three sessions is evident in Figure 5.7. The combination of experience and the possibility of making announcements yields very high margins in session IV-1 and comparatively high margins in session IV-2, but does not sustain margins above the static Nash level in session IV-3.[15]

Prices in treatment IV, session 1 rise steadily through period 14, level o¤ for another 4 periods, and then fall in periods 19 and 20. This last may be interpreted as an endgame e¤ect. Throughout this session, price-cost margins tended to move together.

[15] The average margin in session IV-2 is 1.02 ECU above the static Nash level.

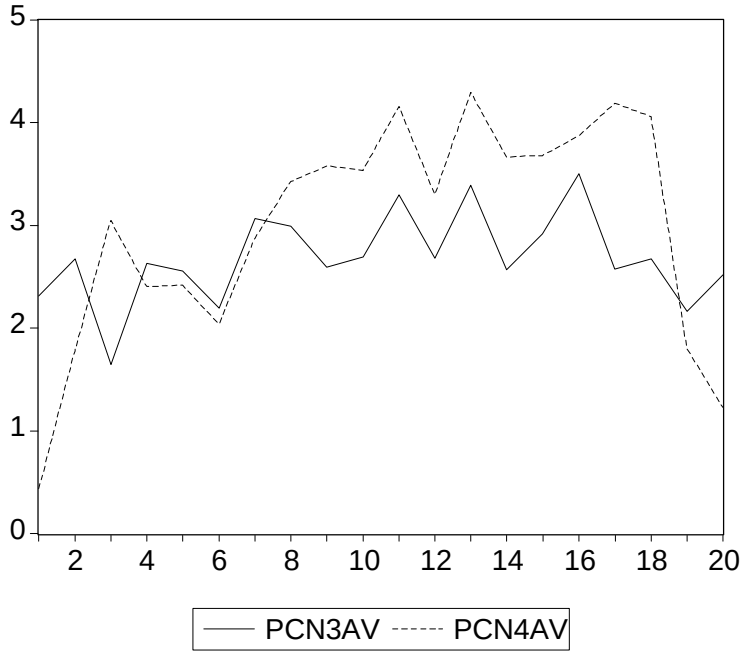

Figure 5.8: Average (p ¡ c) ¡ static Nash (p ¡ c), period by period, treatments III and IV, periods 1-20

In most of periods 1 through 14, many announcements were made. The general pattern was that announced prices were greater than prices that were actually set; Cason (1995) reports similar behaviour. However, the trend in both announced and posted prices was upward through period 14.

The time-path of price-cost margins in treatment IV, session 2 is much more level. Prices rise through period 4, decline slowly and with much ‡uctuation for about 10 periods, then rise somewhat.

In treatment IV, session 3, margins rise by period 3, ‡uctuate above Nash levels for 11 periods, then decline toward the end of the session.

5.5. Comparison of Treatments III and IV

It is instructive to compare treatments III and IV. Figure 5.8 shows the average price-cost margin, minus the static Nash margin, for the …rst 20 periods of all treatment III sessions and all treatment IV sessions. Each average is therefore taken over 12 experimental subjects, half with low-quality varieties and half with high-quality varieties. An average of zero means subjects are pricing at the static

Nash level. The average of the conscious parallelism margins is 13.8125, of the joint-pro…t maximizing margins 15.5 (Table 4.1).

Subjects price above static Nash levels for both treatments III and IV, although they approach neither the conscious parallelism nor the joint-pro…t maximizing level.[16] Margins are greater for treatment IV than for treatment III from period 9 through 18, at which point what should probably be interpreted as endgame e¤ects kick in.

5.6. Statistical Analysis

Table 5.6 reports the results of a regression analysis using the complete 1500-element sample. The dependent variable is the deviation between observed and static Nash price-cost margins. The …rst 20 observations in this sample are for treatment 1, session 1, subject 1; these are followed by 20 observations for treatment 1, session 1, subject 2; and so on. The …nal 26 observations in the sample are for treatment IV, session 3, player 4.

In Table 5.6, the coe¢cient of C is the constant term in the regression. F is a dummy variable that takes the value 1 for the …rst period in each session. This controls for the fact the subjects were told that they would not be paid for this period. H is a dummy variable that takes the value 1 for observations generated by subjects with high-quality varieties, and 0 otherwise. In static Nash equilibrium, high-quality varieties should exhibit larger margins. In conscious parallelism equilibrium, the excess of the margin over the static Nash level is the same for varieties of both types. The excess of the joint-pro…t maximizing margin over the static Nash level is slightly greater for low-quality varieties than for high-quality varieties. In any event, neither F nor H have signi…cant coe¢cients for any of the speci…cations reported in Table 5.6.

D24 is a dummy variable that takes the value 1 for treatments 2 and 4, which have the same structure, and 0 otherwise. Similarly, D3 and D4 are dummy variables keyed on treatments 3 and 4 respectively.

The residual category is therefore treatment 1. The coe¢cient of D24 should indicate the impact on margins of allowing subjects to make announcements, relative to the price-setting only treatment. The coe¢cient of D3 should indicate the di¤erential e¤ect of constraining subjects to follow the conscious parallelism strategy, and the coe¢cient of D4 should indicate the impact of experience with the conscious parallelism strategy on margins, over and above any e¤ect of the ability to make announcements pure and simple.

D400 is a dummy variable that takes the value 1 for the two observations from treatment 2, session 5 in which subject 4 set a price of 400. Inclusion of this

[16] In this respect, our results are similar to those of Grether and Plott (1984).

	(1)	(2)	(3)
C	1.1253	1.1343	-0.0907
	(4.5846)	(4.6315)	(0.3742)
D400	386.2814	378.2000	378.2000
	(1709.099)	(275.5513)	(275.3662)
F	-0.4572	-0.3971	-0.3253
	(1.3752)	(1.1960)	(1.0421)
H	0.2852	0.2624	0.2623
	(1.1446)	(1.0694)	(1.1653)
D24	-0.1294	-0.3156	0.9062
	(0.4762)	(1.2319)	(3.3491)
D3	1.3891	1.3887	2.6103
	(4.4520)	(4.4431)	(8.0897)
D4	1.7080	1.8938	1.8937
	(3.6185)	(4.0836)	(4.0798)
D14			2.3838
			(6.8418)
D15			2.6109
			(8.3719)
S251		2.0831	2.0863
		(4.009)	(4.0300)
S252		2.6026	2.6058
		(6.9875)	(7.0511)
S253		1.5186	1.5219
		(6.0682)	(6.2068)
S254		8.2815	8.2847
		(6.0405)	(6.0431)
R^2	0.9757	0.9771	0.9796

Table 5.6: Regression Results

Dependent variable: (p ¡ c) ¡ static Nash (p ¡ c); t-statistics in parentheses (based on Newey-West heteroskedasticity-consistent variance estimates).

	Price-cost margins		Single-period payo¤s	
	L	H	L	H
Static Nash	3.3125	4.4375	25.60	45.95
Announcements + experience	6.0217	7.4090	38.86	59.07
CP	13.250	14.375	58.52	101.22

Table 5.7: Margins and One-shot payo¤s implied by Table 5.6, column 3 speci…cation

dummy variable does not a¤ect the other coe¢cient estimates; it is responsible for the high R^2-square statistics in Table 5.6.

Column 1 of Table 5.6 distinguishes the impact of the di¤erent treatments on price-cost margins (relative to static Nash levels). The coe¢cient of D24 is not statistically signi…cant — announcements as such do not generate increments in margins compared with treatment I — while D3 and D4 both have coe¢cients that are signi…cant and large, relative to the static Nash margins given in Table 4.1.

Column 2 in addition examines the impact of the signalling episode in treatment I, session 5. The variables S251, S252, S253, and S254 are dummy variables for each subject in this session that take the value 1 for periods in which player 4 appeared to follow a signalling strategy, and 0 otherwise. All 4 of these signalling variables have signi…cant positive coe¢cients.

Column 3 of Table 5.6 includes two additional dummy variables, one for treatment 1, session 4 and one for treatment 1, session 5. As noted above, session I-4 gave subjects the joint-pro…t maximizing prices as period 0 prices, while session I-5 gave no period 0 prices. Both variables have signi…cant positive coe¢cients.[17] In addition, when these variables that control for di¤erences in initial conditions are included as explanatory variables, the coe¢cient of D24 becomes positive and statistically signi…cant: controlling for other factors constant, the ability to make announcements along has a moderate positive e¤ect on price-cost margins.

The implications of the regression analysis for price-cost margins and payo¤s are summarized in Table 5.7.[18] In the experimental markets that we have examined, the possibility of making announcements increases margins, as does the use of the conscious parallelism mechanism and experience with announcements.

[17] These results may be contrasted with those of Mason, Phillips, and Redington (1991), who test for and reject the hypotheses that experience with practice periods anchored behavior in the session proper. Their treatments involved linear demand, two quantity-setting subjects (with constant but di¤erent unit costs), and a homogeneous good.

[18] The payo¤ estimates in Table 5.7 are from a separate regression, with dependent variable actual minus static Nash payo¤ and explanatory variables as in Table 5.6, column 3.

Margins nearly double, and payo¤s increase 30% (H varieties) and 50% (L varieties), compared with static Nash levels. While these are substantial increases, they remain below conscious parallelism and joint-pro…t-maximizing levels. Column 3 also indicates that either signalling or a history of high prices will sustain margins above those indicated in Table 5.7.

6. Summary

We have described imperfectly competitive experimental markets designed to explore the impact of price announcements and consciously parallel behaviour on market performance.

We have observed behavior under a single set of market conditions. As is traditional in experimental economics, focusing the design on research hypotheses has been assisted by the simplicities of linear demand and constant marginal costs. Also in accord with common practice, private information about demand intercepts and costs limited individual subjects to a proper subset of the minimal information for an explicit calculation of conscious parallelism or joint-pro…t-maximizing outcomes. All markets studied had each of four sellers produce a single variety of the commodity.[19] Perhaps the most important open question is the robustness of the results reported here to the degree of product di¤erentiation (μ); this is the subject of ongoing research.

Conditional on these elements of the speci…cation, the ability to make announcements is here su¢cient to sustain price-cost margins that are above static Nash levels. Margins are higher still if subjects are constrained to match or not match announced price changes, although for such treatments margins do not reach levels of the conscious parallelism equilibrium. In such treatments, periods of sharp price increases are also periods of substantial price-matching behaviour.

Experience with the matching strategy also leads to greater margins, as does attempts to assume a price leadership role and a history of higher prices.

The results reported here suggest that imperfectly competitive markets often can yield prices above and e¢ciencies below the static Nash equilibrium standard.

The kinds of signalling mechanisms that appear in treatments II, III, and IV of this experiment are available in real-world markets, are not condemned by mainstream competition policies, and support returns above static Nash equilibrium levels.

[19] Most of the simpli…cations just listed are standard; empirical evidence of the robustness of observations with respect to these simpli…cations is rare. Holt (1995) indicates that 4-seller markets have been seen to approximate behavior of markets with 5 up to perhaps 10 sellers.

7. Appendix: Instructions

7.1. Experiment I

GENERAL DESCRIPTION

Today we are going to set up an experimental market.
The market is supplied by four …rms.
Each of you will take the part of one …rm.
The pro…t or loss your …rm makes in the market depends on the decisions you make and on the decisions made by the other …rms, in a way that is explained below.
The pro…t or loss your …rm makes in the market determines the amount you will be paid IN CASH at the end of the experiment.
The experiment will last at least 20 periods. The precise ending time of the experiment will be determined randomly.
You are …rm number == i ==.
You do not know the …rm numbers of the other participants in the experiment, and they do not know your …rm number.

DESCRIPTION OF THE MARKET

Each …rm produces a product that is sold in competition with the products of other …rms.
The amount your …rm sells and the pro…t you make in each period depends on the price you set and the prices other …rms set in that period.
Each unit of output that you sell costs you c to produce. You do not know the cost per unit of the other …rms in the experiment and they do not know your cost per unit.
If your price is greater than your production cost, you will earn a pro…t on every unit of output that you sell.
If your price is less than your production cost, you will lose money on every unit of output that you sell.
The buyers in the market may consider products to be somewhat di¤erent. As a consequence of possible di¤erences in demand and cost, di¤erences in price may arise.

INFORMATION YOU WILL BE GIVEN

Before the …rst period starts you will be given information from previous experimental experience in this market. You will get to know prices of all …rms and the sales and the pro…t you would make if these prices were charged.
In every period, after all participants have entered a price for their …rm you will be shown the prices of all …rms and the sales and the pro…t you made in that period. You will also be given information about your accumulated pro…ts.
You will able to recall data from former periods (prices of all …rms, sales and pro…t you made) by using the 'Price History' option.

PRESS ESCAPE TO LEAVE THE INSTRUCTIONS

7.2. Experiment II

GENERAL DESCRIPTION

in addition to the instructions of Experiment I:
In every period there is an announcement phase and a price setting phase. These two phases are explained below.

DESCRIPTION OF THE MARKET

as in Experiment I.

DESCRIPTION OF THE ANNOUNCEMENT PHASE AND THE PRICE SETTING PHASE

During the announcement phase, …rms indicate the prices they may charge. Afterwards, in the price setting phase, each …rm will set the price that it will actually charge, and may choose a di¤erent price, higher or lower, than any price it announced.
Each …rm may make as many announcements as it likes to make.
If no …rm announces a price for two minutes, the announcement phase will be closed. Later in the experiment after you and the other participants have had some experience with the way the process works, the time period will be shortened to one minute and then to 30 seconds.
The experiment will then move to the price setting phase, in which you decide the price you will actually charge in that period.

INFORMATION YOU WILL BE GIVEN

in addition to the instructions of Experiment II:
Each …rm will learn the announced prices of all …rms. You will also be told how much sales and pro…ts you would make if the announced prices were actually …nalized.

PRESS ESCAPE TO LEAVE THE INSTRUCTIONS

7.3. Experiment III

GENERAL DESCRIPTION

as in Experiment II.

DESCRIPTION OF THE MARKET

as in Experiments I and II.

DESCRIPTION OF THE ANNOUNCEMENT PHASE AND THE PRICE SETTING PHASE

During the announcement phase, …rms indicate price changes they may make. Afterwards, in the price setting phase each …rm will set the price that it will actually charge, and may choose a di¤erent price, higher or lower, than the price resulting from announced price changes.
Note that the announcements are price CHANGES, i.e. …rms announce to increase or to decrease their price by a certain amount. In the price setting phase the ABSOLUTE prices which are charged in the market have to be set.
Each …rm may announce as many price changes as it wishes to make. When one …rm announces a price change, you will given the opportunity to announce and identical price change.
If no …rm announces a price change for two minutes, the announcement phase will be closed. Later in the experiment, after you and the other participants have had some experience in the way the process works, this time period will be shortened to one minute and then to 30 seconds.
The experiment will then move to the price setting phase, in which you enter the price you will actually charge in that period.

INFORMATION YOU WILL BE GIVEN

as in Experiment II, with one change:
Each …rm will learn the announced price changes of all …rms.

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