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Werner Güth
Kerstin Pull
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Alexandra Zaby

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Friedrich Schiller University Jena
Carl-Zeiss-Str. 3
D-07743 Jena
www.uni-jena.de

Max Planck Institute of Economics
Kahlaische Str. 10
D-07745 Jena
www.econ.mpg.de

Endogenous Price Leadership - A Theoretical and Experimental Analysis

Werner Güth*, Kerstin Pull♭, Manfred Stadler♮, and Alexandra Zaby♯

Abstract

We present a model of price leadership on homogeneous product markets where the price leader is selected endogenously. The price leader sets and guarantees a sales price to which followers can adjust according to their individual supply functions. The price leader then clears the market by serving the residual demand. Firms with different marginal costs would induce different prices if they were price leaders. Somewhat counter-intuitively, lower marginal costs of the leader imply higher prices. We compare two mechanisms to determine the price leader in a between-subjects design, majority voting and competitive bidding. The experimental data of later rounds support our theoretical finding that experienced price leaders with lower marginal costs choose higher prices. In the majority voting treatment, participants with higher marginal costs more often establish the lowest cost competitor as price leader in order to induce a higher sales price.

Keywords: Price leadership; majority voting, bidding, experimental economics

JEL Classification: D43, D74, L11

* Max Planck Institute of Economics, Strategic Interaction Group, Kahlaische Straße 10, D-07745 Jena, Germany. e-mail: gueth@econ.mpg.de.

♭ University of Tübingen, School of Business and Economics, Nauklerstraße 47, D-72074 Tübingen, Germany. e-mail: kerstin.pull@uni-tuebingen.de.

♮ University of Tübingen, School of Business and Economics, Mohlstraße 36, D-72074 Tübingen, Germany. e-mail: manfred.stadler@uni-tuebingen.de.

♯ University of Tübingen, School of Business and Economics, Mohlstraße 36, D-72074 Tübingen, Germany. e-mail: alexandra.zaby@uni-tuebingen.de.

1. Introduction

In many situations, individual group members elect one member from among themselves as their leader, authorizing him to make decisions affecting all of them. Leadership is often associated with positive attributes. But what is good for the group, may not be as good for the leader and vice versa. Furthermore, heterogeneous group members usually perform differently as leaders. Whether the best candidate is selected when the leader is determined endogenously, will be analyzed theoretically and experimentally in this paper.

For an exogenously determined price leader our industrial economics model of price leadership with seller firms as group members ensures clear incentives for voluntary cooperation via leadership. We enrich this setup by two mechanisms to endogenously select the price leader, namely majority voting and competitive bidding. By implementing the enriched model experimentally, we can relate the empirical findings to the theoretical predictions.

The price leader sets a price to which all other competitors, the followers, can adjust their sales amount optimally according to their individual supply functions. To guarantee his price choice, the leader serves the residual demand.[1] Obviously, followers are interested in a high price. Although intuition suggests higher prices for higher marginal costs, the highest price occurs when the lowest cost competitor acts as price leader. Asking a competitor to act as price leader is justifiable since the price leader is not forced to choose a higher than competitive price.[2] Furthermore, followers could reward the price leader by smaller than optimal quantities in case of higher than competitive prices. In line with the endogenous leadership literature, we assume that the leader is able to credibly commit to his price, i.e., once he announces the price, he cannot change it anymore.[3]

More basically, leadership refers to a more or less hierarchical structure of interaction. In modern market economies, entrepreneurs or chief executive officers mostly play the role of a decisive leader. Other examples are technological leaders or simply sellers who, as in our model, precommit before the others. Whereas

[1]Rather than justifying quantity setting by tatonnement adjustment or fictitious auctioneers or, more ingeniously, by first-capacity-then-price-setting models (see Kreps and Sheinkman, 2013), the model of price leadership justifies quantity competition by all but one seller (e.g., Güth et al., 1989).

[2]Choosing the competitive price allows the leader to sell his optimal quantity at this price.

[3]For models of duopolistic price leadership, see, e.g., Deneckere et al. (1992) and Furth and Kovenock (1993), and for an experimental test, see, e.g., Kuebler and Mueller (2002).

our model assumes that leader and followers determine different action variables, namely the uniform price respectively their sales quantities, most other leadership models rely on the same type of choices by leaders and followers, e.g., on markets with quantity competition or in public good experiments with “leading by example” (see Capellen et al., 2013 and the references cited therein). In the latter type of experiments, unlike in our scenarios, the benchmark solution, which is based on common opportunism, fails to predict voluntary cooperation via leadership.

We compare two mechanisms to award the leadership role in price setting, one where no other reciprocation is possible than via sales reduction and one that allows to monetarily reward the price leader, majority voting (the firm with the most votes becomes price leader with unbiased random assignment as default), and competitive bidding, with sellers determining monetary compensations for competitors becoming price leader. Although both mechanisms suffer from a multiplicity of equilibria, this does not question the intuition that a lower cost competitor is the more likely price leader. Using these mechanisms to endogenously determine the price leader, we can shed light on voluntary, deceived, and forced price leadership as discussed, for example, by Ono (1982).

The remainder of the paper is structured as follows: In Section 2, we introduce a triopoly model of price leadership. In Section 3, we endogenize price leadership and derive our main hypotheses. Section 4 describes the experimental protocol. The main findings are presented in Section 5. Section 6 concludes.

2. The price leadership model

We focus on a homogeneous product market with three asymmetric seller firms $i = 1, 2, 3$. Market demand is assumed to be linear

$$D(p) = \max\{0, \alpha - \beta p\} \; ; \qquad \alpha,\, \beta > 0,$$

with $D(p)$ denoting total demand at sales price p. We rely on firm-specific quadratic cost functions

$$C(q_i) = (c_i + dq_i)q_i \; , \quad c_i \geq 0 \; , \quad d > 0 \; ,$$

with q_i denoting the quantity produced and sold by firm $i = 1, 2, 3$. Of course, asymmetry of cost could also rely on different coefficients of the quadratic term,[4],

[4] For a generalization to $n \geq 3$ firms, see Güth et al. (1989).

what is avoided here to limit complexity for the sake of our participants. Profits are given by

$$\pi_i = pq_i - C_i(q_i) \ , \ i = 1, 2, 3.$$

For a given price each firm would like to sell according to its individual supply function

$$q_i(p) = (p - c_i)/(2d) \ , \quad i = 1, 2, 3.$$

Clearing the market by equating aggregate supply

$$S(p) = (3p - \sum_{i=1}^{3} c_i)/(2d)$$

and market demand determines the competitive price

$$p^c = \frac{\alpha + (\sum_{i=1}^{3} c_i)/(2d)}{\beta + 3/(2d)} \ .$$

From the perspective of methodological individualism, simply assuming that p^c will result is rather unsatisfactory. Price leadership does not only explain and justify market clearing prices but also allows all firms to earn more than by selling at the competitive price p^c.

Price leadership requires one seller, the price leader $\ell \in \{1, 2, 3\}$, to set the common sales price p^ℓ, thereby allowing all other sellers $i \neq \ell$ to freely adjust their sales quantities q_i. To guarantee his choice p^ℓ, the price leader has to clear the market by selling the residual quantity

$$q_\ell = D(p^\ell) - \sum_{i \neq \ell} q_i \ .$$

Proceeding by backward induction, i.e., by anticipating the optimal supply quantities $q_i(p) = (p - c_i)/(2d)$ of all followers $i \neq \ell$, the residual demand for the price leader is

$$q_\ell(p^\ell) = \alpha - \beta p^\ell - \frac{(2p^\ell - \sum_{i \neq \ell} c_i)}{2d} \ .$$

The price p^ℓ maximizing

$$\pi_\ell = p^\ell q_\ell(p^\ell) - C_\ell(q_\ell(p^\ell))$$

is

$$p^\ell = \frac{(3 + 2\beta d)\alpha + (\beta + 3/(2d)) \sum_{i \neq \ell} c_i + (\beta + 1/d)c_\ell}{2(\beta + 1/d)(2 + \beta d)} \ .$$

Since $p^\ell > p^c$ for all $\ell \in \{1, 2, 3\}$, followers $i \neq \ell$ gain from price leadership compared to competition. The same holds for any price leader due to the unique optimal price $p^\ell (\neq p^c)$, proving that all firms gain from price leadership.

In our experiment, we use the parameter values $\alpha = 400, \beta = 1, c_1 = 0, c_2 = 100, c_3 = 200, d = 1$, implying the competitive price $p^c = 220$, the corresponding sales amounts $q_1^c = 110, q_2^c = 60, q_3^c = 10$, and profits $\pi_1^c = 12100, \pi_2^c = 3600, \pi_3^c = 100$. In case of price leadership, the outcome depends on which competitor takes over the leader role. Table 1 summarizes the results for all three possible price leaders.[5]

leader	p^ℓ	q_1^ℓ	q_2^ℓ	q_3^ℓ	π_1^ℓ	π_2^ℓ	π_3^ℓ	$\pi_1^\ell - \pi_1^c$	$\pi_2^\ell - \pi_2^c$	$\pi_3^\ell - \pi_3^c$
$\ell = 1$	229	92.0	64.5	14.50	12604.00	4160.25	210.25	504.00	560.25	110.25
$\ell = 2$	225	1125.0	50.0	12.50	12656.25	3750.00	156.25	556.25	150.00	56.25
$\ell = 3$	221	110.5	60.5	8.00	12210.25	3660.25	104.00	110.25	60.25	4.00

Table 1: Numerical results for all possible price leaders $\ell = 1, 2, 3$

Each firm sells more when another firm becomes price leader. However, firms 1 and 2 prefer own leadership over seller 3 being leader. For firm 1 the disincentive to become price leader rather than firm 2 is only marginal, compared to what firms 2 and 3 gain by firm 1's price leadership. The price increase by firm 1 rather than firm 2 as price leader is as large as the price increase when firm 2 rather than firm 3 is leader.

3. Endogenizing price leadership

How can firms establish such a price leadership from which all firms gain? If $c_\ell < c_{\ell'}$ for $\ell, \ell' \in \{1, 2, 3\}$ with $\ell \neq \ell'$, then $p^\ell > p^{\ell'}$. Thus the usual intuition that a lower (marginal) cost induces a lower price does not extend to our price leadership model. One hypothesis to be tested with the experimental data is therefore whether participants learn that price leaders with lower (marginal) costs choose higher prices. Clearly, the two firms with higher marginal costs would like to establish their low cost competitor as price leader. Therefore they will probably vote for the low cost competitor in the

[5] For the experimental implementation we rounded prices to the next integer and used these integer numbers to calculate all other values. The precise values are $p^{\ell=1} = 229.167$, $p^{\ell=2} = 225.000$ and $p^{\ell=3} = 220.833$.

Voting Treatment V: All three firms $i \in \{1, 2, 3\}$ suggest a price leader $\ell \in \{1, 2, 3\}$, and the only firm with a majority of votes becomes price leader. In case of no majority, the price leader is randomly selected with equal probabilities among all candidates with the highest number of votes.

Specifically, it is an equilibrium outcome that at least the two high cost sellers vote for the competitor with the lowest cost. If, for instance, the two high cost sellers vote for the low cost seller and the lowest cost seller votes for himself, no firm would gain by unilaterally deviating. As is typical for majority voting, other equilibrium outcomes exist:[6] whenever all three sellers unanimously vote for the same candidate ℓ, no individual seller i can gain by deviating from unanimity. For strict majorities (only two voters agree) the deviant seller should not induce a majority voter to join him. Thus there exists an abundance of (mixed) strategy equilibria featuring different sellers as price leaders. However, among all these equilibria, establishing the low cost type as price leader is clearly focal and obviously justifiable by equilibrium selection (see Selten and Güth (1982) for equilibrium selection in a related voting game).

We compare the Voting Treatment V with the

Bidding Treatment B: All firms $i \in \{1, 2, 3\}$ place a bid $b_i \in \mathbb{R}$, stating how much they would suffer as price leader, $i = \ell$. The seller placing the lowest bid becomes price leader with unbiased random selection among those with minimal bids. More formally, each seller $i = 1, 2, 3$ chooses a bid $b_i \in \mathbb{R}$, and the price leader $\ell \in \{1, 2, 3\}$ satisfies $b_\ell \leq b_j$, $j \neq \ell$. The two other sellers $j \neq \ell$ compensate the price leader by paying him the non-negative difference between their own bid and the bid of the price leader, $\Delta_\ell^j \equiv b_j - b_\ell$. Thus the price leader ℓ receives in total

$$\sum_{j \neq \ell} \Delta_\ell^j = \sum_{j \neq \ell} b_j - 2b_\ell.$$

For equality[7] between any seller $j \neq \ell$ and the price leader ℓ, it must hold that

$$\Delta_\ell^j = \Delta_j^\ell \quad \text{for all } j \neq \ell \,,$$

where Δ_j^ℓ is the compensation, price leader ℓ would have to pay to j if j substitutes him as price leader.

[6]See Güth et al. (1985) for applying the Harsanyi and Selten (1988) theory of equilibrium selection to resolve strategic uncertainty in such voting games.

[7]We postulate equality according to bids what is applicable even in case of privately known costs (see Güth, 2011 for another application and Güth and Kliemt (2013) for a more thorough justification.)

For this bidding mechanism the profit functions must include the transfer payments so that

$$\pi_j = p^\ell q_j(p^\ell) - C_j(q_j) - \Delta_\ell^j \qquad \text{for } j \in \{1,2,3\} \text{ with } j \neq \ell$$

and

$$\pi_\ell = p^\ell q_\ell(p^\ell) - C_\ell(q_\ell(p^\ell)) + \sum_{j \neq \ell} \Delta_\ell^j$$

for any leader $\ell \in \{1,2,3\}$. In the focal equilibrium outcome, the two high cost sellers h with $c_h > c_i$ for some $i \neq h$ establish their low cost competitor as price leader ℓ. More specifically, in the case of $\ell = 1$ such an equilibrium outcome requires that seller 1 underbids only marginally the lowest bid of the other two sellers and $\pi_\ell^1 = \pi_j$ for $j \neq 1$ submitting the second-lowest bid, i.e., by increasing his bid b_1 to the second-lowest bid to avoid leadership responsibility, seller 1 would not gain. There is a multiplicity of equilibrium bid vectors $b = (b_1, b_2, b_3)$ establishing the low cost seller as lowest bidder, resembling the multiplicity of equilibria in sealed-bid auctions with complete information.

One may object that both mechanisms, *voting* and *bidding*, do not require the consent of the chosen price leader ℓ, i.e., they do not grant veto power. However, the price leader is not forced to set a price p^ℓ higher than the competitive price p^c. Specifically, by setting $p^\ell = p^c$ each seller could guarantee via $p^\ell = p^c$ that he sells his most preferred amount at price p^c. In this sense, neither mechanism violates voluntariness since price leaders can always induce the competitive price.

When comparing the two mechanisms, it is crucial that *bidding* allows followers to directly compensate price leader ℓ for taking on the responsibility of price leadership. With the voting mechanism, followers $j \neq \ell$ can only reward the price leader ℓ by selling less than their optimal sales amount, $q_j < q_j(p^\ell)$.

According to these theoretical findings, we want to test the following hypotheses:

H1: Price leaders with lower marginal costs choose higher prices.

H2: The two sellers with higher marginal costs establish their lowest cost competitor as price leader.

H3: $q_i < q_i(p^\ell)$ is more frequent in the *voting* than in the *bidding* treatment.

H4: Optimal price choices p^ℓ are more likely with *bidding* than with *voting* where low cost price leaders may fear losing their payoff advantage.

H5: The sum of profits is larger in the *bidding* treatment since transfer payments might crowd in efficiency concerns.

4. Experimental design and setup

We implemented both mechanisms, *voting* and *bidding*, as separate between-subjects treatments and included a control treatment where price leadership was established randomly. The experimental instructions differ only in the paragraph on how to determine the price leader (see the instructions in Appendix A). To allow for learning, the game is played 10 times using a random strangers matching protocol. More specifically, in each session 27 participants took part, divided into three matching groups of 9 participants each. Since we assigned constant roles (participants were assigned constant marginal costs, called "z-values," 0, 100, and 200, respectively), a matching group contained three participants for each of the three z-values. Participants were not informed about the restricted rematching within matching groups to weaken possible repeated game effects. Throughout the experiment, payoffs were calculated in Experimental Currency Units (ECU), which were converted into euros at a given exchange rate (500 ECU = 1 euro) at the end of the experiment. Participants were informed about the exchange rate in the experimental instructions.

According to our theoretical model, each of the 10 rounds consisted of three successive stages: In the first stage, price leadership was established (participants chose one participant to take over "role X"). In the *voting* treatment, participants simply indicated which z-value participant they wanted to take over role X, i.e. price leadership. In the *bidding* treatment, we imposed $b \in [0, B]$ with $B = 2000$ to reduce the multiplicity of the equilibrium bid vectors $b = (b_1, b_2, b_3)$. Immediately after bidding or voting, participants were informed which z-seller was established in role X. Additionally, in the *bidding* treatment, the compensations that the participant in role X had received from the other two participants were displayed. In the second stage, the price leader chose the price ("x-value") within range $p^\ell \in [210, 240]$. The software allowed the price leader to calculate the payoffs for hypothetical quantity choices by the other participants. In the third stage, the followers ("role Y") chose their sales quantity ("y-value") within range $q \in [0, 115]$. Followers could also compute their payoffs before submitting their definitive decision to help them cope with the nonlinear profit functions.

All sessions started with a set of control questions concerning *(i)* the different decision tasks in the three stages of the experiment and *(ii)* how to calculate payoffs. The experiment started when all participants had answered all control questions correctly. After completion of the 10 rounds, participants were asked to fill out a post experimental questionnaire designed to collect demographic information about them and assess their risk tolerance and decisiveness[8] (see Holt and Laury, 2002).

Besides a show-up fee of 2.50 euros, participants received the payoff earned in one randomly chosen round of the experiment as well as the reward for the lottery question in the post experimental questionnaire. The experiment was programmed in z-tree (see Fischbacher, 2007). We ran 9 sessions (3 for each treatment) with 27 participants each, i.e., 9 independent matching groups for each treatment. On average, one session lasted about 110 minutes, and the average payment of participants amounted to 15.28 euros.

5. Experimental results

Before comparing the treatments *voting* and *bidding*, we explore the general hypotheses regarding price leadership.

Hypothesis 1 proposes that price leaders with lower marginal costs choose higher prices. The mean price choices of leaders, given their respective cost type, support our theoretical findings at least qualitatively: Pooling the data from all three treatments, we find that for price leaders with lowest marginal costs the mean price is 227.38, while price choices of leaders with intermediate marginal costs are on average 225.91, and mean prices of leaders with highest marginal costs are 222.86. While only the price choices of leaders with low and median marginal costs are not significantly different (p-value > 0.05, Mann-Whitney ranksum test),[9] the other differences, i.e. , between low and high and between median and high marginal cost leaders, are strongly significant in a statistical sense (p-value < 0.001, Mann-Whitney ranksum test). Comparing the price choices of experienced players (last three rounds) for the three different types of price leaders, we find all differences to be statistically significantly different from each other (p-value < 0.01, Mann-Whitney ranksum test). This leads to

Result 1. *Experienced price leaders with lower marginal costs choose a higher price.*

Hypothesis 2 predicts that the two sellers with higher marginal costs try to establish their low cost competitor as price leader. In the *voting* treatment, the low

[8] Since the model is deterministic, these questions serve to identify personality traits and should not be interpreted as assessing risk attitude in the sense of expected utility theory.

[9] Considering all price choices as independent in spite of possibly many price choices of the same participant and the dependence of price choices within matching groups.

cost competitor (marginal costs of 0) is established as price leader in 38.2% of cases. Further, in 32.2% of cases price leaders were of the high cost type (marginal costs of 200) and in 29.6% of cases price leaders were of the medium cost type (marginal costs of 100), see Table 2. Considering again only the last three rounds, the low cost type is established as price leader substantially more often (49.4%), while the median and the high cost type each receive just about half as many votes. This clearly supports Hypothesis 2.

	All rounds ($\Sigma = 270$)	Last three rounds ($\Sigma = 81$)
Cost type 0	103 (38.2%)	40 (49.4%)
Cost type 100	80 (29.6%)	22 (27.2%)
Cost type 200	87 (32.2%)	19 (23.4%)

Table 2: Absolute (and relative) frequency of cost types in the role of the price leader in the *voting* treatment

For the *voting* treatment the experimental data provide information on the voting behavior of the different cost types (see Table 3 with the numbers in parentheses only for the last three rounds).

... voted for ...	Cost type 0	Cost type 100	Cost type 200	Σ
Cost type 0	66	117	87	270
	(22)	(37)	(22)	81
Cost type 100	122	40	108	270
	(39)	(10)	(32)	81
Cost type 200	133	96	41	270
	(50)	(30)	(1)	81

Table 3: Votes for different cost types in the *voting* treatment

Interestingly, the main diagonal has the lowest frequency row- and column-wise, i.e., participants seem to understand that becoming price leader is a burden rather than a blessing. Instead, we find both high cost type competitors to vote mostly for the low cost type as price leader: 45.2% of participants with medium marginal costs and 49.2% of participants with high marginal costs voted for the low cost type as price leader, thereby supporting Hypothesis 2.

Result 2a. *In the* voting *treatment, sellers with higher marginal costs try to establish their low cost competitor as price leader.*

Surprisingly, in the *bidding* treatment the high cost type is established as price leader in most of the cases (47.4%), while only 16.7% of the low cost type participants are elected as price leaders. If we account for learning effects, this result remains nearly unchanged (see the second column of Table 4).

	All rounds ($\Sigma = 270$)	Last three rounds ($\Sigma = 81$)
Cost type 0	45 (16.7%)	13 (16%)
Cost type 100	97 (35.9%)	30 (37%)
Cost type 200	128 (47.4%)	38 (47%)

Table 4: Absolute (and relative) frequency of cost types in the role of the price leader in the *bidding* treatment

Comparing the average bids placed by the respective cost types, we find the mean bid of 178.7 of the high cost participants to be far (slightly) below the mean bid of 539.47 (189.56) of the low (medium) cost type participants. This leads to

Result 2b. *In the* bidding *treatment, sellers with higher marginal costs do not establish their low cost competitor as price leader.*

We explain these puzzling findings by (*i*) participants of the high cost type being unwilling to become price leader, (*ii*) low cost participants not minding whether to become price leader or to establish the medium cost type as price leader,[10] and (*iii*) the bidding mechanism overburdening participants cognitively and being less intuitive than majority voting.

Regarding the behavior of followers, Hypothesis 3 predicts that quantity choices below the theoretical optimum are more frequent in the *voting* treatment than in the *bidding* treatment due to attempts to reward the price leader.[11] Pooling all cost types, 42.6% in the *voting* treatment choose quantities below the optimum, while 45.9% of followers do so in the *bidding* treatment, thus contradicting Hypothesis 3. When conducting the same analysis for the different cost types separately, the experimental data confirm Hypothesis 3 only for the low cost type: In the *voting* treatment 51.5% of low cost type participants choose quantities below the optimum,

[10]Similar to the results of the theoretical model, the mean payoffs in treatment B for the low cost type are 11557.17 if he is price leader and 12561.13 if the medium cost type is established as price leader.

[11]Interestingly, residual demand is sometimes negative due to suboptimal behavior of the price leader (setting too high a price) or the followers (choosing too large sales quantities). See Appendix B for a thorough investigation of this experimental result.

whereas only 44.9% do so in the *bidding* treatment. For the medium and the high cost types this relation is reversed.

Experienced participants (rounds 8 to 10), however, support Hypothesis 3 for the low and high cost type: While in the *voting* treatment, 61.9% of the low cost type participants choose quantities below the optimum, this only holds for 44.1% of the low cost type participants in the *bidding* treatment. Further, in the *voting* treatment, 55% of the high cost type participants choose quantities below the optimum as compared to 39.5% of the high cost types in the *bidding* treatment. Thus, when becoming more experienced, the high and low cost types compensate the price leader by lower than optimal quantities more frequently in the *voting* treatment than in the *bidding* treatment, as predicted by Hypothesis 3. Therefore we state

Result 3. *Experienced players of the high and low cost type choose quantity choices below the optimum more frequently in the* voting *than in the* bidding *treatment.*

According to Hypothesis 4, optimal price choices p^ℓ should occur more often in the *bidding* than in the *voting* treatment. In order to capture noise in measuring whether the optimal price is chosen or not, we follow the notion of ϵ-equilibria (Radner (1980)) and allow for a 3% variation around the optimum. For the three possible scenarios (low, medium, or high cost type is price leader), this 3% variation has to be calculated separately. In case of the medium cost type as price leader, the optimal price choice ($p_\ell = 225$) would lead to a profit of 3,750 for the price leader, and a 3% tolerance of deviations from optimality would render the range of profits between 3,637.5 and 3,750 as nearly optimal. This range is reached for price choices between 220.7 and 229.3, which we therefore consider as (nearly) optimal price choices in the following analysis.

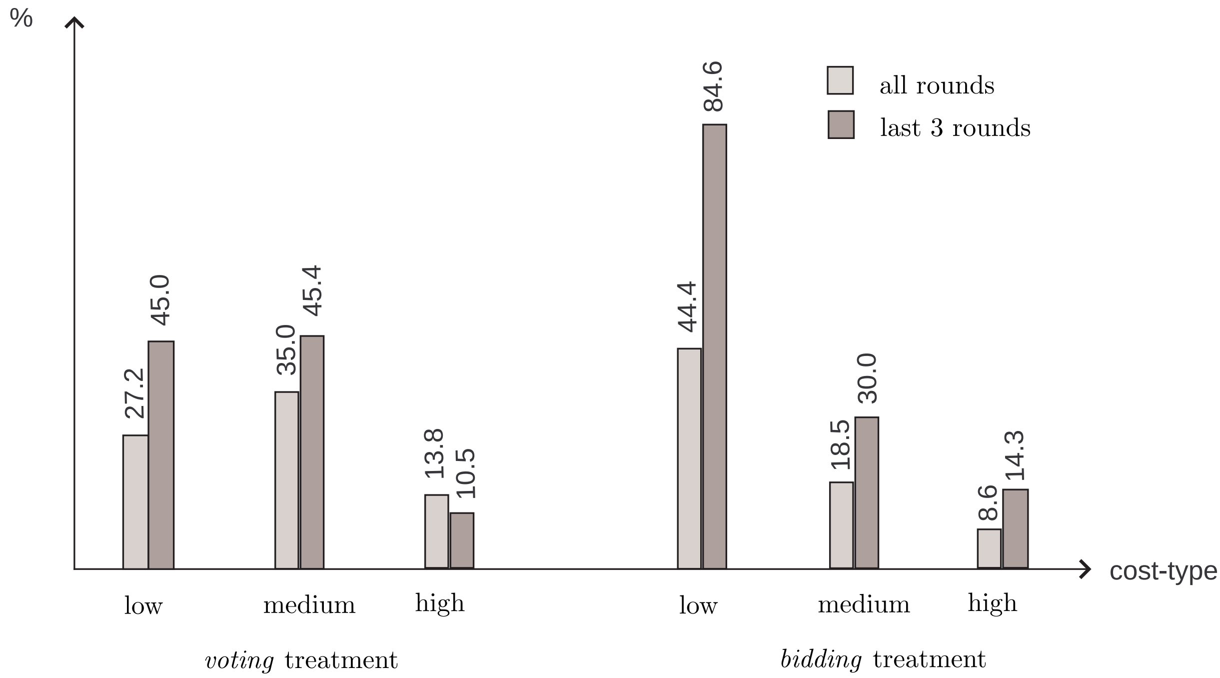

Figure 1: Percentage of price leaders with nearly optimal price choice (with 3% tolerance for deviations from optimality)

Figure 1 displays the percentage of leaders with a nearly optimal price choice given their cost type. The difference between the treatments is greatest for the low cost type: Taking learning effects into account by considering only the last three rounds, 84.6% of all leaders of this cost type make nearly optimal price decisions in the *bidding* treatment as opposed to 45% in the *voting* treatment. Even without learning effects, the propensity to choose an optimal price for the low cost type is higher in the *bidding* than in the *voting* treatment, thereby supporting Hypothesis 4.

Result 4. *For low cost price leaders optimal price choices p^ℓ are more frequent in the* bidding *than in the* voting *treatment. For experienced participants the same is also true for high cost price leaders.*

Finally, Hypothesis 5 expects the sum of profits to be larger in the *bidding* treatment since transfer payments might crowd in efficiency concerns. We find only partial support for this prediction by disentangling the sum of profits into the sum of price leader profits and follower profits, respectively. The sum of follower profits is larger in the *bidding* treatment than in the *voting* treatment. The intuition behind this result seems to be that since only followers make transfer payments, this mechanism is more thoroughly analyzed by them and therefore found to be more appealing. This is indeed what the data show. Hence, finding support for Hypothesis 5 we state

Result 5. *The sum of follower profits is larger in the* bidding *treatment where transfer payments strengthen the sellers' efficiency concerns.*

6. Conclusion

Price leadership in oligopolistic product markets is an appealing approach to explain and justify market clearing prices in the tradition of methodological individualism according to which social phenomena are based on individual choice making. It also allows for moderate cooperation enabling firms to earn higher profits than when selling at the competitive price. By inducing a moderate price increase, price leadership may not arouse suspicion by the antitrust authorities. Even if detected, it would most certainly not be assessed as illegal. What should prevent one competitor from setting a price to which all other competitors react so that the price leader has to serve residual demand? To the best of our knowledge, such behavior is not illegal and, even if so, it could hardly be verified by antitrust authorities.

We have analyzed price leadership on a homogeneous market with three asymmetric competitors determining endogenously who takes over the role of the price leader. According to our experimental data, price leaders with lower marginal costs choose higher prices when becoming more experienced.

Comparing the two mechanisms for selecting the price leader, majority voting and competitive bidding, we found that experienced participants of the high and low cost type reward price leaders for inducing higher than competitive prices by choosing quantities below the optimum level more frequently in the voting than in the bidding treatment. On the one hand, in the voting but not in the bidding treatment, firms with higher marginal costs try, and mostly succeed, to establish the lowest cost competitor as price leader. On the other hand, experienced participants with low or high costs more frequently choose optimal prices in the bidding treatment, with positive transfer payments rewarding the price leader. In the voting treatment, we found that low cost price leaders lose their relative advantage and therefore refrain from choosing the optimal price. This is in line with the finding that the sum of follower profits is greater in the bidding treatment, suggesting that allowing for transfer payments crowds in efficiency concerns.

Thus, although some experimental outcomes differ from the theoretically predicted ones, the main predictions are confirmed, at least qualitatively. Most importantly, we find that – in line with the somewhat counterintuitive prediction – lower marginal costs of price leaders indeed result in higher market prices when participants are more experienced with the quite demanding experimental scenarios.

Appendix A

INSTRUCTIONS

General Information

Thank you for participating in this experiment. You will receive 2.50 euros for showing up on time. Please remain silent and turn off your mobile phones. The instructions are identical for each participant. Please read them carefully. You are not allowed to talk to other participants during the experiment. In case you do not follow these rules, we will have to exclude you from the experiment as well as from any payment. The 2.50 euros show-up fee and any other amount of money you will earn during the experiment will be paid out to you in cash at the end of the experiment. All participants will be paid individually, i.e. no other participant will know the amount of your payment. All monetary amounts in the experiment are calculated in ECU (experimental currency units). At the end, all earned ECUs will be converted into euros using the following exchange rate: 500 ECU = 1 euro.

Experimental Procedure

The experiment consists of four control questions followed by ten experimental rounds and a final questionnaire. In each round you will interact with two other participants who will be randomly assigned each round anew. You will not be informed about the identity of these participants. It is unlikely that the same group constellation will occur twice. The interacting participants differ in a randomly assigned trait z. z can have one of three values: $z = 0$, $z = 100$ or $z = 200$. At the beginning of the experiment, you and the other participants in your group will be randomly assigned a trait z which you will keep throughout the whole experiment. In each round, three participants with the three possible traits will be randomly grouped together in such a way that each group consists of one participant with z -value 0, one participant with z-value 100 and one with z-value 200.

After each round, you will be shown the round's results. One of the rounds will be selected as relevant for the final payment which will be determined according to the rules displayed in the instructions. In case you receive a negative result in the selected round, the amount will be subtracted from your total payment. Regardless of the selected round, you will receive the amount of 2.50 euros for showing up on time. Thus your final payment cannot be negative. In addition, one of the questions from the questionnaire will be chosen as relevant to your final payment. Hence, your final payment is composed of the following parts:

Show-up fee (2.50 euros)

+ Earnings from a randomly selected round

+ Earnings from a randomly selected question from the questionnaire

Detailed Description of the Experiment

From now on, we will refer to the three different participants with their different values of z as z-value-0 participant, z-value-100 participant, and z-value-200 participant. The decisions taken by the participants will carry the z-value of their decision makers as an index. That way, every decision can be clearly associated to one z-value participant. As an example, x_0 is the value defined by the z-value 0 participant. The following three decision stages will be repeated ten times altogether, where the participants' assigned trait values $z = 0$, $z = 100$, and $z = 200$ stay the same throughout the whole experiment. Each round consists of three stages.

[next paragraph only in the voting treatment]

First Stage - Assignment of Role X

In the first stage, you will vote which one of the three z-value participants will take on role X. In the second stage, the participant in role X will decide on the value of x_z, which will have an impact on the payment of all participants in the group. During this round, the other two participants will take on role Y. In this voting procedure, all three z-value participants will cast their votes. In the event of a tie, it is randomly decided by the computer who will have role X. When voting about the assignment of role X, you can also vote for yourself. After all participants have voted, you will be informed about the voting results.

[next paragraph only in the bidding treatment]

First Stage - Assignment of Role X

In the first stage, it will be decided by placing of bids which one of the three z-value participants will take on role X. In the second stage, the participant in role X will decide on the value of x_z, which will have an impact on the payment of all participants in the group. During this round, the other two participants will take on role Y. All z-value participants will simultaneously place a bid g_z between 0 and 2000 (including the two numbers). The participant with the lowest bid will be assigned role X. The other two participants will take on role Y. We will refer to the minimal bid placed by the z-value participants with role X as $g_z^{\min}$. The z-value participant in role X will receive a payment P_z from both participants in role Y, amounting to the difference of their own bid and the bid placed by the z-value participant with role X, $P_z = g_z - g_z^{\min}$. g_z is the bid of the participant in role Y, $g_z^{\min}$ is the minimal bid of the participant in role X. In case of several identical minimal bids, the computer will randomly decide which one will take on role X. After all participants have placed their bid you will be informed about the assignment of role X.

[next paragraph only in the control treatment]
First Stage - Assignment of Role X
In the first stage, role X will be randomly assigned to one of the three z-value participants. In the second stage, the participant in role X will decide on the value of xZ, which will have an impact on the payment of all participants in the group. During this round, the other two participants will take on role Y.

[all treatments]
Second Stage - Defining the Value of x_z
The participant in role X will define the value of x_z, choosing any integer between 210 and 240 (including the two numbers). The two participants in role Y will be informed about the decision taken by the participant in role X.

Third Stage - Defining the Value of y_z
After being informed about the previously taken decision of value x_z, the two participants in role Y will independently define their value of y_z by choosing any integer between 0 and 115 (including the two numbers). This is the end of the interaction between participants in that round.

Information at the End of a Round
At the end of each round, you will receive the following information:
[only voting treatment]
The result of the vote on role X; i.e., which z-value participant will be assigned role X,
[only bidding treatment]
The result of the bid, i.e., which z-value participant will be assigned role X,
[only control treatment]
The result of the random assignment of role X to one of the z-value participants,

[all treatments]

The decision on the value of x_z by the participant in role X,
The decision on the value of y_z by both participants in role Y, and
The payment of all three z-value participants.

Payments

The payments depend on your role (X or Y), your z-value, the decision on the value of x_z by the z-value participant in role X, and the decisions on y_z by the two participants in role Y. In the following, we will refer to the z-values of the participants as za, zb, and zc. Each of the variables can take on the values 0, 100, or 200. In case the participant in role X has got the z-value za and the participants in role Y have got the z-values zb and zc, the payments can be calculated as follows:

The participant in role Y with the z-value zb and the choice y_{zb} earns:
$(x_{za} - zb - y_{zb}) \cdot y_{zb}$

The participant in role Y with the z-value zc the choice y_{zc} earns:
$(x_{za} - zc - y_{zc}) \cdot y_{zc}$

The participant in role X with the z-value za and the choice x_{za} earns:
$(x_{za} - za - R) \cdot R$
R is determined as follows: $R = 400 - x_{za} - y_{zb} - y_{zc}$

[next paragraph only in the bidding treatment]

In addition, the participant in role X receives a payment from each of the participants in role Y amounting to $P_z = g_z - g_z^{\min}$, $g_z^{\min}$ being the minimal bid by the participant in role X.

This means the amount $P_{zb} = g_{zb} - g_{za}^{\min}$ will be subtracted from the payment of the participant in role Y with the z-value zb. The participant in role Y with the z-value zc will have the amount $P_{zc} = g_{zc} - g_{za}^{\min}$ subtracted from his payment. The amount $P_{zb} + P_{zc}$ will be added to the payment of the participant in role X with the z-value za.

[all treatments]

Example:

The z-value 100 participant in role X selects $x_100 = 223$. The z-value 200 participant in role Y selects $y_200 = 15$. His payment is determined by $(223-200-15)\cdot 15 = 120$. The other participant in role Y has z-value 0 and selects $y_0 = 100$. His payment results from $(223 - 0 - 100) \cdot 100 = 12,300$. To determine the payment of z-value 100 participant, R has to be calculated first; $R = 400 - 223 - 15 - 100 = 62$. As a result, the z-value 100 participant's payment is $(223 - 100 - 62) \cdot 62 = 3,782$.

[only bidding treatment]

Assuming the z-value participants' bids in the first round are z-value 0: $g_0 = 1,800$
z-value 100: $g_100 = 150$
z-value 200: $g_200 = 200$
the z-value 100 participant would be assigned role X. In addition to the amount above, he receives payments from the participants in role Y amounting to $(1,800 - 150) + (200 - 150) = 1,700$. However, the two z-value participants in role Y each have to subtract a certain amount from their initial payment. The z-value 0 participant pays $(1,800 - 150 =)1,650$ to the participant in role X. The z-value 200 participant pays $(200 - 150 =)50$ to the participant in role X.
The resulting total payments are
z-value 0: $(223 - 0 - 100)100 - 1,650 = 10,650$
z-value 100: $(223 - 100 - 62) \cdot 62 + 1,700 = 5,482$
z-value 200: $(223 - 200 - 15) \cdot 15 - 50 = 70$

[all treatments]

Before the start of the experiment, we ask you to answer some control questions which are designed to improve your understanding of the rules of the experiment. If you have any questions, please raise your hand.

Appendix B

Residual demand is sometimes negative due to suboptimal behavior of the price leader (setting too high a price) or the followers (choosing too large sales quantities).[12] Actually, in 132 out of the 140 cases with negative residual demand, this outcome is caused by too high prices.

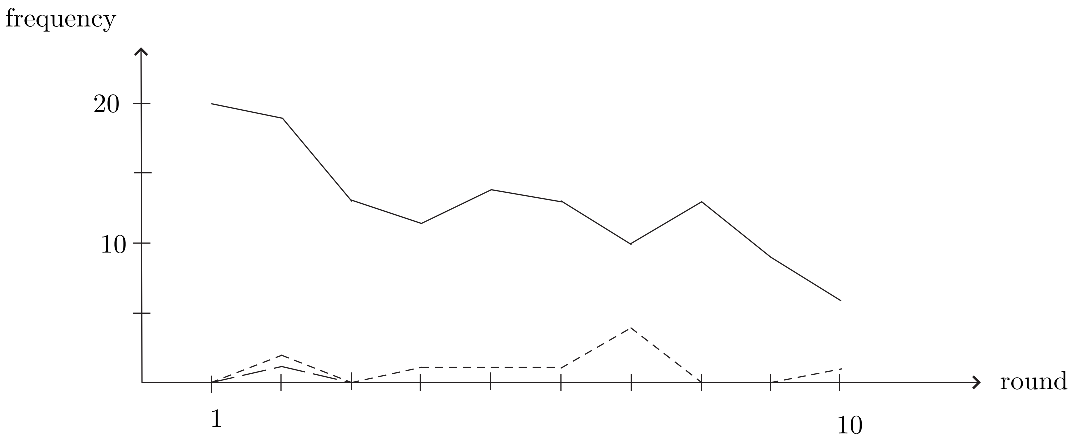

Figure 2: Frequency of negative residual demand

In Figure 2, we depict the frequencies of a negative residual demand for the respective cost types of price leaders across the 10 rounds of the experiment (the solid line representing the highest cost type, the dotted line the medium cost type, and the dashed line the lowest cost type). Thus this phenomenon mainly occurs when the highest cost type is chosen as price leader and could be explained by frustration of these high cost participants. Figure 2 additionally reveals that the frequency tends to decrease over time, meaning that learning takes place. When comparing treatments, the number of matching group outcomes with a negative residual demand is higher in the bidding treatment, confirming that this mechanism is less easily understood by our participants.

[12] In the instructions it was explained that this implies a loss for the price leader who has to buy the excess supply at his chosen price p^{ℓ}.

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