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Pricing Behavior of Cartel Outsiders in Incomplete Cartels

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Pricing Behavior of Cartel Outsiders in Incomplete Cartels

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Abstract

We analyze the pricing behavior of cartel outsiders when a partial cartel has formed in an experimental market. Using a repeated asymmetric capacity-constraint price game, we enable the two largest firms to communicate via chat to facilitate the formation of a partial cartel. Supporting common theory, we find that a partial cartel is sufficient to distort and increase market prices in general. However, in contrast to theory, we find that prices of insiders and outsiders in incomplete cartelised markets are not necessarily on the same level. Our data indicate that this particular market outcome depends greatly on the cartel's pricing strategy.

JEL Classification numbers: C91, C92, D03, L13, L41.

Keywords: partial cartels, umbrella effects, experiments, industrial organization

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1 Introduction

Although cartels are a highly debated phenomenon in economic theory, little is known about incomplete cartels. The majority of literature that includes incomplete cartels only focuses on cartel formation and stability where incomplete cartels are deemed as one possible outcome. Even less research has been conducted on the pricing of incomplete cartels. The pricing behavior of cartel members and non-cartel members is consistently considered as a consequence of the formation process in the respective economic model or market that the cartel is scrutinized in. More precisely, all contributions to this subject assert that if a subset of firms forms an incomplete cartel in a market, every firm in the market charges the price set by the cartel - even those who do not have explicitly agreed to anti-competitive behavior. This price increase of non-cartel members is linked to “umbrella effects” and considered as inevitable. We suspect this theoretical result and examine the pricing behavior of firms in cartelised markets experimentally.

Partial cartels base on restrictions such as switching costs, heterogeneous goods, heterogeneous marginal costs or heterogeneous capacities etc., whereby outsiders cannot compensate the intended effect of the cartel. The explanation of the umbrella effect can be different depending on the model, but eventually all models come to the same aforementioned conclusion.

In models of quantity competition, it is commonly assumed that when collusive firms reduce output, outsiders cannot compensate the entire reduction of supplied goods by the cartel due to increasing marginal costs of production. Therefore, the total supply decreases and prices increase accordingly, creating the aforementioned umbrella effect.¹ This causal connection has been shown in examinations of Cournot models (Selten, 1973; Escrihuela-Villar, 2004) as well as Stackelberg models in both static (Shaffer, 1995) and dynamic settings (Martin, 1990; Konishi & Lin, 1999; Zu et al., 2012; Escrihuela-Villar, 2009; Nocke, 1999; de Roos, 2004).

Research on partial cartels under price competition also shows that the prices of cartel outsiders and cartel members are identical. Based on a static price leadership model as defined by Markham (1951), it was shown that cartel members anticipate the outsiders’ reaction to a price increase and charge the monopoly price for the residual demand, also assuming increasing marginal costs of production (d’Aspremont et al., 1983; Donsimoni et al., 1986; d’Aspremont & Gabszewicz, 1986; Daskin, 1989; Donsimoni, 1985). Outsiders that are too small to influence the price, take this price as given and produce until their price equals marginal costs (Blair & Maurer, 1982).

We do not rely on marginal costs in our model but enable partial cartels to emerge by restricting capacities of firms. Bos & Harrington Jr. (2010) determined equilibrium prices in a model of price competition with capacity constraints in a dynamic setting. The authors show that in this case the cartel price serves as an umbrella for outsiders who set prices at the same level but free-ride by undercutting the cartel price by a minimal amount. We use this model as basis for our analysis, since firms have the biggest scope of strategic interaction in this setting.

¹see Inderst et al. (2014) for an extensive explanation

In previous experimental literature on incomplete cartels, Clemens & Rau (2013, 2014) focus on the formation process of partial cartels or antitrust policy. The pricing behavior of firms is modeled according to the aforementioned theory and is not part of the examination. The authors examine a Cournot game where insiders are assumed to set their joint-profit maximizing quantity and outsiders are assumed to play their best-response quantity, which corresponds to prices at the same level. In contrast to this approach, we want to examine exactly whether this assumptions holds and examine firms' respective pricing behavior in cartelized markets.

In fact, the few detected empirical examples of partial cartels show deviations from theoretical predictions. For example, Hüschelrath et al. (2012) considered the cement industry cartel in Germany and found that theory only partially fitted the outsiders' behavior. Outsiders used the price umbrella of the cartel but cartel members had significantly higher prices than non-cartel members (Hüschelrath et al., 2012, p. 17). Roeller & Steen (2006) also find cartel members' prices to be significantly higher than non-cartel members' prices in their investigation of the Norwegian cement cartel. Further, Harrington Jr. (2006) explains that in various other cartelized markets, outsiders were tried to be driven out of the market by cartel insiders who undercut the outsiders systematically. This entails that prices of cartel outsiders are not equal to those of cartel insiders but are significantly higher or lower.

Since cartels are illegal, cartelised markets are difficult to examine in a extensive empirical examination. Bryant & Eckard (1991) estimated the annual detection rate of cartels in the United States of America by federal authorities to lie between 13% and 17%. Combe et al. (2008) reckoned the annual cartel detection probability in the European Union to range between 12.9% and 13.3%. The pricing behavior of outsiders can only be examined in these detected cartels which unintentionally creates a selection bias. Therefore, we set out to analyze cartel outsiders' behavior in an incomplete cartel by conducting a laboratory experiment. In this way, we can examine the behavior of outsiders in great detail, knowing the exact period of cartel activity and whether indeed cartel agreements were responsible for certain price vectors. We are also able to control for such important parameters as marginal costs or communication which are generally not observable in the field.

We conducted our experiment on the basis of a repeated capacity-constrained price game as described by Bos & Harrington Jr. (2010). To observe partial cartels, a subset of firms in each market was allowed to communicate, since communication is considered as essential feature of effective cartels. Every firm could set its prices freely. To our best knowledge, we are the first to explicitly examine pricing behavior of firms in partial cartels experimentally.

We find that prices for the entire market are distorted when partial cartels form and prices are higher than without a cartel in the market. However, outsiders' prices do not equal cartels' prices in general. Cartel members need to set their price continuously at the maximum level so that outsiders are able to set their price at the same level. If insiders vary their prices, outsiders cannot follow but set significantly lower prices than cartel members on average. We find in our data both cartels that set continuously the maximum price, allowing outsiders to free-ride under

its umbrella, and cartels that vary their prices often in order to undercut outsiders.

The paper is structured as follows. We first explain the model our experiment is based upon. Hereafter, we calculate the corresponding equilibrium. The ensuing chapter describes the experimental design and procedures. After phrasing our hypotheses, we describe our results in great detail and discuss them with regard to economic theory. The last chapter offers a conclusion to our contribution.

2 The Model

We use a model of an infinitely repeated capacity-constrained price game on the basis of the model by Bos & Harrington Jr. (2010). The model is characterized by a market with heterogeneous firms that differ in capacities installed but produce a homogeneous good. Firms produce at marginal costs, $c \geq 0$, and make their price decisions simultaneously. A firm's capacity is denoted by k_i such that $\sum k_i$ denotes the industry capacity and $\sum_{j \neq i} k_j$ is the capacity of a firm's competitors. All market participants have complete and perfect information.

The authors assume that market demand $D(p)$ is price-elastic, i.e. demand is a decreasing function of price. We differ in our model in this particular respect. We consider a market with inelastic demand $D(p) = M$ up to a reservation price of \bar{p} and $D(p) = 0$ if $\bar{p} > 0$ for the benefit of simplicity. We expect participants of the experiment to better understand the market mechanisms in this setup and require less calculation effort. Demand at competitive price level is therefore equal to demand at collusive price level, $D(p) > 0$. This does not change the equilibrium price.

Individual demand of firm i ($D_i(p_i, p_{-i})$) depends on firm i 's price p_i and the vector of prices of the other firms p_{-i} . Let $\Omega(p) \equiv \{j: p_j = p\}$ be all firms that set a price of p and $p_{-i}^{min} \equiv \min\{p_1, \dots, p_{i-1}, p_{i+1}, \dots, p_n\}$ the minimal price of the remaining firms. Demand is then characterized by two additional features.

Firstly,

$$\lim_{\eta \rightarrow 0+} D_i(p_{-i}^{min} + \eta, p_{-i}) = \max \left\{ D(p_{-i}^{min}) - \sum_{j \in \Omega(p_{-i}^{min})} k_j, 0 \right\}. \quad (1)$$

If a firm does not charge the lowest price, it only serves residual demand. In other words, consumers buy from the firm with the lowest price first and buy from the firm with the next higher price only when supply of the firm with the lowest price is exhausted.

Secondly,

$$\text{if } 0 < \sum_{i \in \Omega(p)} D_i(p_i, p_{-i}) < \sum_{i \in \Omega(p)} k_i \text{ then } 0 < D_i(p_i, p_{-i}) < k_i, \forall i \in \Omega(p). \quad (2)$$

This means, if two or more firms charge the same price and therefore capacity exceeds demand at this price, all firms face positive demand but none of these firms can sell all its capacity. We further restrict the plethora of equilibria due to the many ways cartel demand can be allocated among its members by another substantial assumption - Demand is allocated proportional to each firm's capacity if more than one firm charges the same price and supply exceeds demand. This assumption can be justified by the notion of fairness as described by Rawls (1971) and empirical findings by Roeller & Steen (2006) or Vasconcelos (2005), who examined cartel demand distribution in several disclosed cartels. One could further argue that the possibility of selling a unit depends on the capacities installed by firms.

Capacities of firms are allocated in a way that no firm has sufficient capacity to supply the entire demand and any subset of $n - 1$ firms can serve the entire market.

$$k_i < D(p) \text{ and } \sum_{j \neq i} k_j \geq D(p), \forall i \quad (3)$$

Consequently, total-capacity of all firms strictly exceeds total demand, $\sum k_i > D(p)$. Summarizing, capacities in our model are allocated such that $\sum_{j \neq i} k_j \geq D(p) > k_i$. This implies that not even the smallest firm sells a positive amount if it is the only firm that charges the highest price and on the other hand, even the largest firm sells at capacity if it solely charges the lowest price.

3 Equilibrium Analysis

3.1 Static Nash Equilibrium

The single shot static Nash equilibrium in our model is the same as in a classic one-shot Bertrand game. Taking into account the decision making of the other firms, the best-response of each firm is to charge the lowest possible price, that is, $p = c$. Deviating to a smaller price, $p < c$, implies losses as costs to produce one unit would be higher than earnings from selling one unit. A price higher than costs, $p > c$, destroys demand and yields no profit at all. Profits of each firm amount to $\Pi_i = (p - c) \frac{k_i}{\sum k_i} * D_i(p_i, p_{-i}) = (c - c) \frac{k_i}{\sum k_i} * D_i(p_i, p_{-i}) = 0$ in this case.

3.2 Stable Partial Cartels

Since we analyze an infinite repeated game, collusion is possible if firms are sufficiently patient (δ). More precisely, there exists a subset of firms in our model that can form a profitable and sustainable partial cartel, typically consisting of the largest firms in the market, as shown by Bos & Harrington Jr. (2010). The cartel fulfills the stability conditions defined by d'Aspremont

et al. (1983) and yields higher profits than the competitive equilibrium. Specifically, internal stability is given, since we assume firms to set prices according to the well known trigger strategy (Friedman, 1971), i.e. deviating from the cartel agreement would revert all firms to static Nash pricing at marginal cost for the remainder of the game, yielding profits of zero. This is the harshest punishment as this is the lowest continuation equilibrium payoff. Therefore, it is not profitable for any firm that is as least as big as the smallest firm in the cartel to leave the cartel and deviate from the cartel agreement. External stability is given due to the allocation rule. It is not profitable for any firm smaller than the smallest firm in the cartel to join the cartel.

Since it is not profit-maximizing for every firm to join the cartel and set the same price, cartel members anticipate that some firms will price below the cartel price. Therefore, they cannot sell at capacity when setting high collusive prices but will only serve residual demand. However, due to the insufficient capacities of the outsiders to satisfy the entire demand, they still face positive demand. Therefore, the actual behavior of outsiders is supposed to be not relevant for cartel members in the model.

3.3 Insiders' Prices

In equilibrium, the cartel permanently sets the collusive-value-maximizing price - that is the monopoly price for residual demand. Let Γ denote the set of cartel members. The cartel price is

$$p^\Gamma = p(K_\Gamma) = \operatorname{argmax} \left(\frac{1}{1-\delta} \right) (p - c) \left(\frac{D(p) - (\sum k_i - K_\Gamma)}{K_\Gamma} \right). \quad (4)$$

With elastic demand the actual height of the price depends on the capacities under control of the cartel. In our model with inelastic demand, the monopoly price for residual demand simply is the reservation price,

$$p^\Gamma = \bar{p}. \quad (5)$$

A price higher than the reservation price, $p^\Gamma > \bar{p}$, would result in a demand of zero, as no consumer is willing to pay more than the reservation price \bar{p} . A lower price would merely lower profits but would not attract any more customers.

Due to the distribution rule of demand in cartels, each cartel member's individual profit in each period is

$$\Pi_i^\Gamma = (\bar{p} - c) \left[D(\bar{p}) - \left(\sum_{j=1}^n k_j - \sum_{j \in \Gamma} k_j \right) \right] \left(\frac{k_i}{K_\Gamma} \right), \quad (6)$$

which is higher than competitive profits for any positive demand.

3.4 Outsiders' Prices

The best-response of outsiders is to undercut the cartel price by a minimal amount ϵ , setting a price of

$$p^O = p^\Gamma - \epsilon \quad (7)$$

and sell at capacity to maximize their individual profit. Setting a lower price, $p^O < p^\Gamma - \epsilon$, generates less profit as the same output will be sold at a lower price. A higher price would reduce demand. Specifically, a price on the cartel level, $p^O = p^\Gamma$ forces the firm to reduce sales according to the proportional demand allocation rule. The marginal increase in price cannot compensate these losses in quantity. A price above the cartel price, $p^O > p^\Gamma$, results in no demand since cartel members can satisfy the entire demand at this price. Hence, no profit can be generated with this pricing strategy. The inflated price of the cartel can be used as an umbrella by cartel outsiders, who can free-ride by selling at a higher price without reducing their production. The consequential profits of each outsider in every period then amount to

$$\Pi_i^O = ((p^\Gamma - \epsilon) - c)k_i. \quad (8)$$

4 Experimental Design and Procedures

We used an asymmetric Bertrand-Edgeworth market with $n = 4$ firms, supplying a homogeneous good. Subjects simultaneously and independently chose a price, p . They could select integers between 0 and 100 for prices. We assumed the firms' production costs up to capacity were zero for the sake of simplicity ($c = 0$). Demand consisted of $M = 300$ computer-simulated consumers who demanded one unit of the good at minimal expense, as long as the price was not greater than $\bar{p} = 100$. We chose an inelastic box-demand setup to keep the experiment as simple as possible.

Capacities were $k_1 = k_2 = 200$ (big firms) and $k_3 = k_4 = 50$ (small firms) and were constant during the course of the experiment. The asymmetric capacity allocation met the conditions for stable partial cartels with heterogeneous firms as described by Bos & Harrington Jr. (2010). Symmetries of large and small firms were chosen to support collusion between firms, since symmetry can be shown to facilitate tacit collusion as shown in Fonseca & Normann (2008). The proportion of firms was chosen to be close to the findings of an empirical analysis by Harrington Jr. (2006) who found an average cartel size of around 75% market size for cartelised markets. Therefore we expect the cartel size of our example to be at the lower end of the observed sizes.

We do not want to analyze the formation process but to examine cartel insiders' and cartel outsiders' behavior (i.e. their respective price setting strategies) in an experimental market

when a partial cartel has formed. To actually observe partial cartels, we used communication as an auxiliary tool, since the strong effect of communication is well known. Crawford & Sobel (1982), Isaac & Walker (1988) and Farrell & Rabin (1996) illustrate that coordination may be facilitated by communication. Experiments by Cooper et al. (1989, 1992) and Charness & Dufwenberg (2006) underline these findings. Fonseca & Normann (2012) analyzed the impact of communication on collusion and confirmed its facilitating effect. For this purpose, chat messages seemed appropriate to render it attractive for subjects to form a cartel and were expected to increase cooperation, since free-form language is supposed to be most effective (Brosig et al., 2003). It was also assumed that in this way subjects felt more secure about their decisions since participants could send messages to reassure each other and reduce uncertainty with regards to their decisions (Crawford, 1998).

Therefore, all else equal, we allowed for communication only between large firms of each group in the treatment group session. Subjects could communicate in every period before they had to make their price decision for one minute in the first 3 periods of each supergame and for 30 seconds in the remaining periods of each supergame. This seemed sufficiently long for the communication phase since previous experiments showed that most talk ended before the one-minute period was over (see for example Fonseca & Normann, 2012). Small firms just had to wait until the game continued. Subjects remained anonymous during the chat and were given neutral names like firm 1 or firm 2 which did not change during the session. Subjects were free to send as many messages as they liked and to talk about what they wanted but had to respect two restrictions: Subjects were not allowed to identify themselves or post offensive messages. All subjects were aware that only the large firms could communicate with each other in each group and that only these firms could see the conversation. Subjects could not communicate with each other in the control group sessions and did not know about the possibility of communication in the treatment group sessions.

All subjects received written instructions which informed subjects about all the features of the experiment and the markets prior to the start of the experiment. A translated version for both groups can be found in the appendix (A.2). Once all subjects had read the instructions, they could privately ask questions. At the beginning of the experiment, all subjects were randomly assigned to one large firm or small firm and represented this firm for the entire experiment. In each period, before entering their payoff relevant price, subjects could use a profit calculator provided on the screen to test the potential impact of various own and other firm's decisions. The profit calculator reduced differences between subject's cognitive abilities. In the following stage of each period subjects had to enter their price at a computer terminal. Once all subjects did this, the period ended and a screen displayed the prices chosen by each firm in the market, the quantities sold by each firm and the profit of each individual firm in that particular period. Further, the screen displayed the accumulated profits of the respective firm (but not of the other firms) up to that point. Thereafter, the next period started.

We used a between subjects design for the experiment. Participants were either in a control

group or in a treatment group. Both treatments of the experiment respectively consisted of three supergames that had multiple periods each to control for learning effects. Before each supergame subjects were randomly matched with three other firms so that there were two large firms and two small firms in each market. Throughout a supergame all subjects were matched with the same three other subjects in every period. Before each supergame all subjects were randomly assigned to a new group.

The length of a supergame was determined by a random termination rule with a continuation probability of $8/9$. All subjects were informed about the continuation probability. The actual numbers of periods per supergame were determined ex ante by a virtual die to ensure the same length of supergames over all markets, sessions and treatments. The first supergame had 9 periods, the second had 14 periods and the third had 6 periods, summing up to 29 periods in total.

We had 144 participants in total. This is 72 participants per treatment divided into 3 sessions with 24 participants each. Hence, we were able to observe 18 markets per supergame per treatment or 54 markets per treatment respectively. Subjects received a payment consisting of a show-up fee of 5 Euro plus the sum of profits they earned during the experiment. The show-up fee was provided to moderate the expected asymmetric payoffs for subjects due to the differences in capacity of large and small firms. We used an “Experimental Currency Unit” (ECU) for payments, with 15,000 ECU being worth 1 Euro.

The experiments were run in the Düsseldorf Institute for Competition Economics (DICE) Laboratory for Experimental Economics at the Heinrich-Heine-University Düsseldorf in July 2016. The experiment was programmed and conducted with the experiment software z-Tree (Fischbacher, 2007). Sessions lasted for approximately 60 minutes without communication and 80 minutes with communication. Subjects earned between 6 Euro and 26,50 Euro, with the average payment being 13.88 Euro. The online recruiting system ORSEE (Greiner, 2004) was used for recruitment, ensuring that subjects had not participated in similar experiments before. Subjects were students and non-students from a variety of backgrounds.

5 Hypotheses

In the experiment, big firms were not forced to establish cartels but could freely choose if they wanted to collude or not. Several experiments showed that communication has a pro collusive effect (as we have described before), although communication should have no impact on firms behavior according to the extant literature. Fonseca & Normann (2012) showed that all firms in a market collude when all firms are able to communicate with each other. In our experimental setup, only 2 of 4 firms could communicate with each other in each market. Nevertheless, we expect these two firms to collude when communication was allowed, as the mechanics are identical and there is no obvious reason why communication should lose its

impact when it is restricted to a subset of market participants, especially since there were no costs of communication and firms do not have to fear to be detected forming a cartel.

Hypothesis 1: *When communication is allowed, cartels will form*

Once we observe cartels, we expect big firms, that is the potential cartel members, to increase prices above the competitive levels as we have shown in our equilibrium analysis.

Hypothesis 2: *When cartels form, prices of cartel members will be higher than in competition*

The aforementioned economic theory predicts that a partial cartel, raising its price, is sufficient to increase prices for the whole market. In our experiment with the underlying model, we assume non-colluding firms, that is small firms, to recognize the price increase, to infer that a cartel has been formed and expect them to increase their prices, too.

Hypothesis 3: *When cartels form, prices of cartel outsiders will be higher than in competition*

More precisely, according to the model by Bos & Harrington Jr. (2010), cartels are expected to charge the monopoly price for residual demand in every period. In our experimental setting, this is the reservation price of consumers, $p^F = \bar{p} = 100 \text{ ECU}$. Outsiders, pricing optimally by free-riding under the cartel's umbrella, should set a price at $p^O = 100 - \epsilon$ in every period. Since we only allow integer values in our experiment, the smallest possible reduction of the price is by 1 ECU, why outsiders' prices are expected to be at $p^O = 100 - 1 = 99 \text{ ECU}$.

Hypothesis 4: *All firms will constantly choose their respective maximum price*

The main focus of our experiment is the relation of cartel outsiders' prices to cartel insiders' prices. Outsiders' optimal prices in our model should be on the same level but slightly lower than the cartel's price to maximize their profit under the stated assumptions and derived equilibrium. We want to test the common theory and look if prices of outsiders are on the same level as prices of insiders, even if the maximum prices are not reached. We therefore expect small firms to set a price in direct proximity to the cartel price, that is $p^O = p^F - \epsilon$, irrespective of the price level in each market if big firms collude.

Hypothesis 5: *Outsiders' prices will be on the same level as cartels' prices*

6 Results

In this section, we summarize our results and verify the hypothesis on the basis of our data obtained from the experiment. Our intention is to analyze the pricing behavior of firms in partially cartelised markets. To be able to observe partial cartels, we used communication only as an auxiliary tool, since its collusion facilitating effect is well known. This also means, we do not analyze exactly the differences between our control group without communication and our treatment group with communication but instead focus on the differences between periods

in which markets exhibit partial cartels and periods in which markets are characterized by competition. Hence, the definition of a cartel (and competition) is crucial for our analysis.

6.1 Competition & Cartel Frequency

One very essential characteristic of (hardcore) cartels is communication. Due to its strong effect, communication between firms is also legally an important factor to distinguish between tacit collusion and cartels. For example, in EU Competition law the burden of proof is reversed once communication between firms is proven. In this case, the involved firms have to prove that their communication had no effect on the market result whatsoever or will be charged for infringements of article 101 TFEU (Dole v Commission, 2015). We use an even tighter definition of a cartel and assume a cartel to be established only if communication was used and chosen prices of communicating firms were equal in subsequent periods. In contrast, firms are in competition if communication is not available and firms do not choose equal prices higher than 1 in two consecutive periods. The latter would be interpreted as tacit collusion but the definition allows for equal prices due to coincident.

Due to our approach, some periods in our treatment group are periods without established cartels, whereas there are no periods in our control group with active cartels by definition due to the lack of communication. On the other hand, some periods of our control group, where firms could not communicate but colluded tacitly, are not considered as periods with competition. This also results in some periods not belonging to any of the two categories. The following paragraph describes the distribution of periods with competition and partial cartels.

6.1.1 Tacit Collusion

Participants could theoretically agree on prices tacitly by setting high prices without undercutting each other in our control group. In this regard, the maximum price of 100 ECU is assumed to be a focal point since it is payoff dominant and thus a natural candidate for collusion. However, this price was only chosen by firms 73 times (3,5% of possibilities) in total when firms could not communicate with each other. Moreover, two or more firms chose this price for more than one round simultaneously only in 2 of 54 markets or 14 of 522 periods, thereby exhibiting tacit collusion. Two or more firms never chose any other price for more than one round simultaneously. Apparently, the vast majority of big firms could not coordinate on any common price or a trigger strategy equilibrium without communication. All periods of our control group without tacit collusion will be the benchmark for further analysis.

6.1.2 Frequency of established Cartels

When communication was allowed, cartels were established in 90.74% of the markets (49/54) or in 80.27% (419/522) of possible periods, respectively. Thereby we observe an learning effect

over supergames with increasing rates of collusion (supergame 1: 112/162 - 72.22%, supergame 2: 208/252 - 82.54%, supergame 3: 94/108 - 87.04% of possible periods).

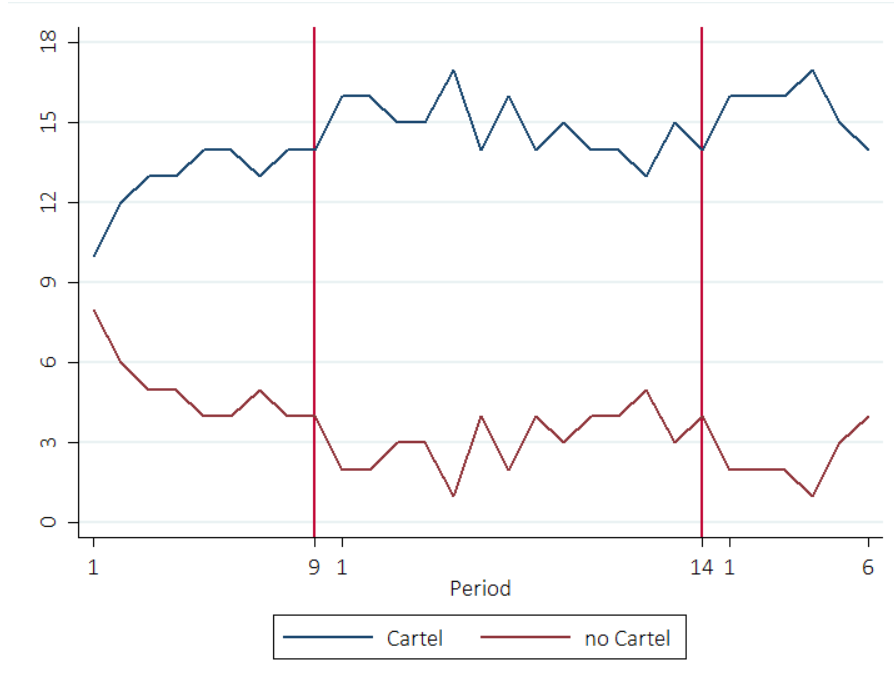


Figure 1: Cartelized Markets per Period

A deeper analysis of the periods without active cartels shows that some participants refused to use the chat and consequently did not set high prices. Therefore, no cartel was formed. Hinlopen (2002) shows that a cartel detection mechanism can deter participants to form a cartel. In this regard, it seems irrational not to use the chat function, since no cartel detection was in force. Whether altruistic motives were in charge in this case cannot be said, since no chat protocol exists for these groups. Therefore, we cannot find a satisfying answer to the question why some participants did not use the chat and did not collude.

Our results therefore show the power of communication once again and underline why the EU considers communication as important factor for collusion. Considering the data, our first qualitative result is in line with the literature mentioned in the Design & Procedures section and confirms hypothesis 1.

Result 1: *When communication is allowed, cartels form*

These periods with active cartels will be the basis of our analysis of the price setting behavior in partial cartels.

6.2 Price Setting Behavior

We will next study the price setting behavior of participants in our benchmark group (in competition) and in cartelized markets. The comparison of the two will give us further insights about partial cartels.

6.2.1 BIGS and SMALLS

For a simpler analysis, we calculated the mean prices charged by firms with large capacity and the mean prices charged by firms with low capacity in each market for every period. This is reasonable since we are interested in the behavior of the two categories, potential cartel members and cartel outsiders. Furthermore, we have to take into account that prices are not fully independent within the categories in our treatment group since we consider a cartel as established if both big firms choose equal prices. Therefore the average price is simply the price chosen by the cartel. Henceforth, we will call these proxies “BIGS” for the average price of firm 1 and firm 2 and “SMALLS” for the average price of firm 3 and firm 4.

6.3 Benchmark: Pricing Behavior in Competition

We next evaluate our benchmark, that is the prices chosen by participants in our control group when no tacit collusion occurred. Participants chose from the full range of available prices (0 – 100) in their attempt to maximize profits. They ended up at an average selling price of 32.07 ECU. The average chosen price was 36.46 ECU (24.399 sd). Although we can observe fierce price competition, selling prices are not at the very end of the price scale but at a higher level.

In this context, BIGS have an average selling price of 32.33 ECU and SMALLS have an average selling price of 31.83 ECU when firms compete with each other. A two-sided t-test, stating average prices of small firms equal average prices of large firms in competition cannot be rejected ($p = 0.6712$).

However, we observed heterogeneous price levels between groups. The average selling price was between 9.54 ECU and 83 ECU across groups. More precisely, BIGS average selling price was between 10.37 ECU and 75 ECU across groups, whereas SMALLS average selling price was between 8.11 ECU and 89 ECU across groups. A Kruskal-Wallis test stating prices are equal across groups (same population) can be rejected at the 1% level ($p = 0.0001$). The markets with high averages are the two markets where tacit collusion occurred in earlier periods. Prices of SMALLS and BIGS did not differ significantly in most competitive markets. A Wilcoxon signed-rank test stating prices of BIGS and SMALLS are equal cannot be rejected in 40 of 54 markets.

	avg. Price All (sd)	avg. Price BIGS (sd)	avg. Price SMALLS (sd)
competition	32.07 (21.438)	32.33 (20.525)	31.83 (22.315)

Table 1: Prices Overview

6.3.1 Comparison with theoretical Benchmark for Competition

As discussed in the equilibrium analysis, prices should be expected at the very bottom of the spectrum without collusion. Since a price of 0 is a weakly dominated strategy (compare Kreps, 1990, p. 446), a price of 1 would also reflect perfect competition and the lowest acceptable price. Indeed, a price of 1 was chosen only in 1.91% (34 times) of all cases in competition and a price of 0 was chosen in 0.06% of the cases, that is 1 time in total without cartel activity. Combined, this accounts for 1.97% of prices chosen by participants in markets with competition. Competitive prices were not at the very end of the price scale but at a higher level. This is in line with theory (compare Kreps, 1990, p. 446) and prior experiments on Bertrand-Edgeworth markets. Considering the distribution of prices, we find that firms did compete with each other if no cartel was established, although prices were above the minimum price. Most firms did not agree tacitly on any price but did not accept the minimum price either. This is consistent with prior research by Fonseca & Normann (2013).

6.4 Pricing Behavior in cartelized Markets

6.4.1 Price level of Cartel Members

In the next paragraphs, we look at the selling prices of participants representing BIGS in periods when they decided to form a cartel and compare them with the selling prices in competition (see also table 2). Overall, cartel members had an average selling price of 96.21 ECU (10.604 sd) when they coordinated on prices. Again, we observe significant group differences. The average selling price of cartels was between 73.5 ECU² and 100 ECU. A Kruskal-Wallis test stating prices are equal across groups (same population) can be rejected at the 1% level ($p = 0.0001$).

Over all groups, a one-sided t-test shows that prices of BIGS were higher when a cartel had been formed than prices of BIGS without a cartel ($p = 0.0001$). A Mann-Whitney U test shows that prices of cartel members were statistically significantly different ($p=0.0001$). This should be no surprise and supports common theory on cartel pricing. Although groups exhibited heterogeneity in their price levels, our results are in line with common theory and confirm our hypothesis 2.

Result 2: *When partial cartels form, prices of cartel members increase (higher than in competition)*

²in one market big firms chose the same price only once and therefore had an average price of 45 ECU

6.4.2 Price level of Cartel Outsiders

We now look at the pricing behavior of cartel outsiders when a cartel is active. Selling prices of outsiders were at 88.01 ECU on average when a cartel was active (see also table 2). This entails that prices of SMALLS were significantly higher in a cartelised market than in a competitive market over all groups (one-sided t-test, $p = 0.0001$). Group differences remain. SMALLS average selling price was between 66 ECU and 99 ECU across groups. A Kruskal-Wallis test stating prices are equal across groups (same population) can be rejected at the 1% level ($p = 0.0001$). The results reflect the cartel situation. When cartel members established a high price level, cartel outsiders could statistically significantly raise their price, too. In market with lower price levels, outsiders' price levels are lower, too.

Result 3a: *When partial cartels form, prices of cartel outsiders are higher than in competition*

Considering our results so far, it seems obvious that once a cartel forms, prices of cartelists rise and outsiders follow. The higher prices of the cartel are indeed used as an umbrella in our experiment.

6.4.3 Market Prices with Cartels

Result 2 and result 3a also reveal a more general effect: We can confirm the common notion that when a cartel forms, the price level of the market in general rises, as we discussed in the related literature. The obtained data show that prices of SMALLS as well as BIGS rose when a cartel was formed in the majority of cases. Further support is given by average selling prices over all groups, which were at 92.32 ECU. A one-sided t-test shows that average selling prices of all firms combined were higher when a cartel was active than in markets with competing firms ($p = 0.0001$). Again, we have group differences. The group averages are in the range from 68.75 to 99.5 ECU. A Kruskal-Wallis test stating prices are equal across groups (same population) can be rejected at the 1% level ($p = 0.0001$). The former tests lead to result 3b.

Result 3b: *A partial cartel is sufficient to raise prices above the competitive level for the entire market*

The different price levels already indicate how much outsiders depend on the cartelists' behavior. The following table (table 2) summarizes these results.

	avg. Price All (sd)	avg. Price BIGS (sd)	avg. Price SMALLS (sd)
competition	32.07 (21.438)	32.33 (20.525)	31.83 (22.315)
cartel	92.32 (14.429)	96.21 (10.604)	88.01 (16.710)

Table 2: average Price Level Competition/Cartel

6.4.4 Comparison with theoretical Benchmark for Cartels

We now look at the cartelised markets in more detail and compare our results with the theoretical prediction of our model and the common beliefs in the mentioned literature on partial cartels. First, we explore whether participants chose their respective maximum prices or whether they chose different prices for some reason. To assess the pricing behavior of insiders and outsiders, we first consider descriptive statistics of the results.

Over all markets, the maximum price of 100 ECU was chosen 334 (of 419 possible times) times by cartel members, which accounts for 79.71% of possible opportunities. It is only reasonable for outsiders to charge the maximum price (minus a minimal amount) in cases when the cartel charges a price of 100 ECU. In fact, a price of 99 ECU was chosen 175 times (of the 334 possible times) on average by cartel outsiders when the cartel priced at 100 ECU, which accounts for 52.39% of possible opportunities. Therefore, a t-test stating the average selling price of insiders equals their respective maximum price, i.e. 100 ECU can be rejected at the 1% level ($p=0.0001$) as well as a t-test stating the average selling price of outsiders equals their respective maximum price, i.e. 99 ECU ($p=0.0001$). Apparently, cartel members did not always charge the highest price but deviated from the maximum price many times.

However, a deeper analysis of the price distribution reveals very heterogeneous behavior of cartel members between markets in this regard. The established cartels can roughly be categorized into two types.

In 21 of the 49 cartelized markets cartel members constantly choose the maximum price. The average price of cartels in these markets does not significantly differ from 100 ECU (mean of 100 ECU). Cartels of this type (1) account for the majority of incidences where the maximum price was chosen. Nevertheless, outsiders in these markets charged the second highest price on average only in 16 cases, that is 76%, in a statistically significant manner. A t-test can not be rejected in only 16 groups ($p > 0.05$).

Colluding firms of the other type (2) switched between many prices. The average price of cartels does not equal the maximum price (t-test, $p < 0.0001$) in the other 28 markets. Cartel members in these markets also chose the maximum price for many periods but account for all chosen prices which are below the theoretical predictions, why also outsiders' average prices do not equal 99 ECU. A t-test can be rejected at the 1% level ($p = 0.0001$) overall and for 24 of the 28 markets with this scenario at the 5% level. Therefore, we cannot support the predictions by the model in general and have to reject hypothesis 4.

Result 4a: *Cartels do not constantly charge their maximum prices in general*

Result 4b: *Outsiders only charge their maximum price if insiders constantly charge their maximum price*

The following figure (figure 2) illustrates the average prices over all markets and firms per period for competition and with cartels. A further figure (figure 3) is found in the appendix

and shows the price patterns of the different types of cartels and the respective reaction by outsiders.

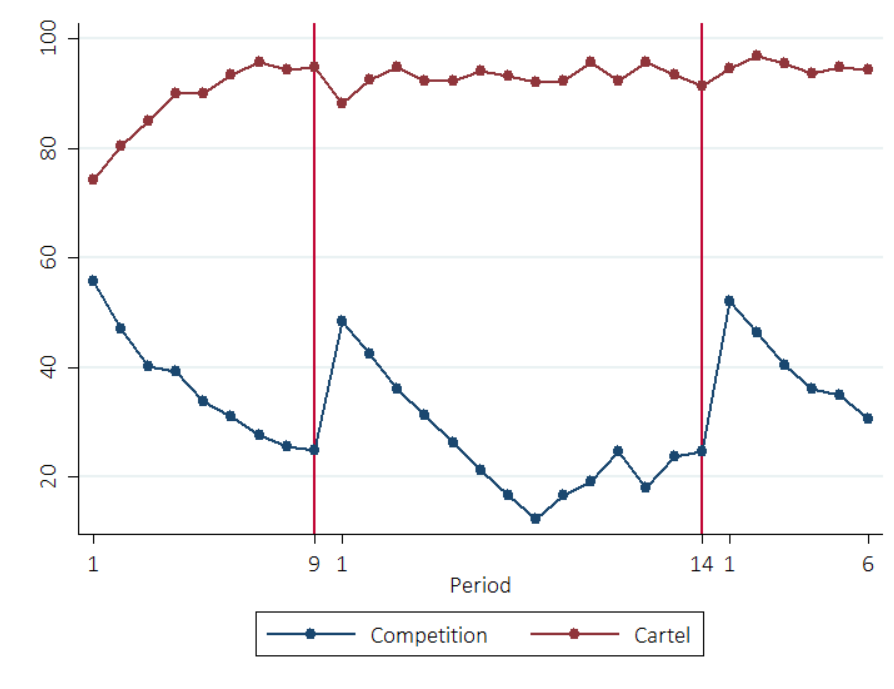


Figure 2: Average Prices per Period

6.4.5 Outsider Prices and Cartel prices

We now look at the main object of our examination - that is, differences between prices of insiders and prices of outsiders. Since price levels differed from theoretical predictions both in the competitive markets and in cartelised markets, we concentrate on this less restrictive assumption of theory. Therefore, we check whether prices of outsiders and insiders were equal on any price level.

In our model, “same level” is defined as an outsider price equal to the cartel price minus a minimal amount, $p^O = p^\Gamma - \epsilon$, which is $p^O = p^\Gamma - 1$ in our experiment. We compare our observed data with theoretical predictions over all groups.

The respective predicted price of each period, $p^O = p^\Gamma - 1$ (or the highest selling price $p^O = p^\Gamma$), was chosen by both outsiders in only 34.84% of the cases overall. In 48.69% of the cases, both outsiders set a price in range of $p^O = p^\Gamma - 10$ to $p^O = p^\Gamma$. In 56.32% of the cases, at least one outsider charged the optimal price, $p^O = p^\Gamma - 1$ or the highest selling price $p^O = p^\Gamma$. In 74.70% of the cases, at least one outsider priced in close proximity to the cartel ($p^O = p^\Gamma - 10$) or set the same price as the cartel, $p^O = p^\Gamma$.

Table 3 summarizes the pricing behavior of outsiders and shows that even when cartels chose the maximum price of 100 ECU, outsiders did not choose their optimal price simultaneously in the majority of cases.

	both outsiders		at least one outsider	
	$p^\Gamma \geq p^O \geq p^\Gamma - 1$	$p^\Gamma \geq p^O \geq p^\Gamma - 10$	$p^\Gamma \geq p^O \geq p^\Gamma - 1$	$p^\Gamma \geq p^O \geq p^\Gamma - 10$
$p^\Gamma = 100$	40.72%	56.29%	65.57%	83.23%
$p^\Gamma \neq 100$	11.76%	18.82%	20.00%	41.18%
overall	34.84%	48.69%	56.32%	74.70%

Table 3: Price of Insiders and Outsiders

A Wilcoxon signed-rank test stating that prices of outsiders are on the optimal level ($p^O = p^\Gamma - 1$) can be rejected at the 1% level ($p = 0.0001$) over all groups and also if both types of cartels are considered separately. On group level, a Wilcoxon signed-rank test stating that outsider prices are on the optimal level has to be rejected in 29 of 49 markets ($p \leq 0.05$). Even when cartels were of type 1, outsiders charged the optimal price in a statistically significant manner in only 12 of these 21 markets. Hence, the hypothesis that outsider prices are on the same level as cartel prices (or just below cartel prices) cannot be verified.

Result 5: *Prices of cartel outsiders and cartel members are not necessarily on the same level*

7 Discussion

Only in 21 of the 49 markets with cartels, participants constantly chose prices on maximum level and outsiders behaved as predicted by our model, showing prices of outsiders and insiders at the same level over the course of the cartel duration. Obviously, the relation of outsiders' prices and cartel insiders' prices seems to be more complicated than the model suggests. There are several aspects which can explain why the pricing behavior deviates from theoretical predictions.

7.1 Joint Deviation

First, theory does not cover the possibility of cartel members to deviate jointly from an agreed price. Nevertheless, as described before, communication is an essential feature of cartels. Since communication is available to firms in every period, firms do not have to choose necessarily the maximum price but can quickly coordinate on any price of the price range without costs. Therefore, we want to think of the cartel members as one merged firm which acts accordingly and consequently dominates the market due to its size.

This feature virtually changes the capacity allocation and relation of demand to capacities to $K^\Gamma = \sum_{i \in \Gamma} k_i > D(p)$ and $K^O = \sum_{i \notin \Gamma} k_i < D(p)$, what implies $k_{i \notin \Gamma} < D(p)$.

This constellation of asymmetric firms in Bertrand-Edgeworth markets is analyzed by Hirata (2009) and De Francesco & Salvadori (2008). The authors explain in great detail the equilibria ensuing from a market with three firms, of which only one firm can supply the entire demand and the remaining firms are minor players.

Observing that outsiders use the cartel price as umbrella, cartel members have an incentive to deviate **jointly** from the former cartel price and charge a price just below the outsiders' price, since they serve only the residual demand when pricing higher than outsiders (e.g. at the maximum price, \bar{p}). Firms have to assess whether they want to be a monopolist on residual demand or lower their prices in order to undercut outsiders slightly and cover the entire demand. Cartel members cannot sell at capacity since their combined capacities exceed demand in any case, but can sell a larger amount than residual demand by undercutting and serving the outsiders' former market share. This trade-off pays off until a minimum price of \underline{p} is reached, at which the cartel, when serving the entire demand, would earn the same profit as selling residual demand at the maximum price. The minimum price of the cartel is therefore

$$\underline{p}^\Gamma = \bar{p} * \frac{(D(p) - K^O)}{\min\{K^\Gamma, D(p)\}}. \quad (9)$$

Under these assumptions, the minimum price of a non-cartel firm would be $\underline{p}^O = \bar{p} * \frac{(D(p) - K^\Gamma)}{\min\{K^O, D(p)\}} = 0$ since $D(p) - K^\Gamma < 0$. In other words, since the cartel can serve the entire market, there is no residual demand outsiders could fall back to. Consequently, their reservation price and corresponding profits from residual demand are 0 ECU. However, knowing that the cartel minimum price is $\underline{p}^\Gamma = \bar{p} * \frac{(D(p) - K^O)}{\min\{K^\Gamma, D(p)\}} > 0$, a price below \underline{p}^Γ is a non-credible threat by cartel members. Therefore, the minimum price of the outsider should not be below

$$\underline{p}^O = \underline{p}^\Gamma - \epsilon. \quad (10)$$

Once the cartel notices that outsiders undercut the minimum price, it will charge the maximum price \bar{p}^Γ again and earn the maximum profit from residual demand, as we have shown in our equilibrium analysis for pure strategies. As soon as the outsiders adjust their prices and try to free-ride under the cartel's umbrella by setting $p^O = \bar{p}^\Gamma - \epsilon$, the cartel can undercut the outsiders again with $p^\Gamma = \bar{p} - 2\epsilon$ and the circle starts again.

7.2 Pricing Strategies

In our examination of the pricing behavior of firms in incomplete cartels we identified two cases of pricing strategies or types of cartels.

In the first case, as described by Bos & Harrington Jr. (2010), cartels allowed outsiders to follow its price and played pure strategies by not changing its price. Outsiders played their best-response and followed the cartel price. They could maximize their profit by free-riding under the umbrella. Considering the descriptive statistics of these groups, it appears that the only groups where outsiders are able to follow are the groups where cartels did not deviate from their maximum price. Therefore, we conclude that prices of insiders and outsiders can be equal only if the cartel constantly charge the predicted price. However, even in these groups, outsiders were reluctant to adjust their prices as predicted at the beginning. It took multiple rounds of constant cartel prices until the outsiders approximated the cartel price. Due to the revealed wariness at the beginning, prices of outsiders were statistically significant on cartel level only in 16 of these 21 markets, which could exhibit an behavioral bias.

In the second case, cartels do not allow outsiders to free-ride under their price umbrella but deviated jointly from the former cartel price as soon as outsiders adjusted their price or even before in order to receive the entire demand. Consequently, outsiders could not charge prices on the level of cartel insiders but had to randomize their price to avoid being exploited. Markets with these kind of cartels show impressively that outsiders cannot adjust their prices optimally and prices of outsiders and insiders are not equal if the cartel does not price on a constant level. In this case, prices can only be equal by coincident. Our data show that both strategies describe cartel behavior accurately, possibly depending on individual preferences of cartel members. Equal prices of insiders and outsiders were only observed in the minority of cases.

8 Conclusion

In economic theory it seems undisputed that if partial cartels form, outsider prices and cartel prices are on the same level (compare Blair & Maurer, 1982; Inderst et al., 2014). However, the pricing behavior in incomplete cartels has actually never been under scrutiny. Moreover, all models concerned with this topic assume rational agents and do not consider insights of behavioral industrial organization. Empirical literature on this topic has not come up with reliable findings. We examined explicitly the pricing behavior of cartel outsiders in incomplete cartels. Due to the secret nature of cartels, we used a laboratory experiment for this purpose. More specifically, we conducted a repeated capacity-constrained price game with asymmetric firms on the basis of the model by Bos & Harrington Jr. (2010). Participants could form partial cartels by communication via a chat tool.

The theoretical equilibrium expects cartels to charge the maximum price and outsiders to play their best-response by slightly undercutting this price to gain the highest possible profit in every period. However, due to communication, cartel members can deviate jointly from the focal cartel price and coordinate on any other price in order to undercut outsiders, which is not covered by theory. Therefore, we find that outsiders' prices depend heavily on the attitude of cartel members towards outsiders. We showed that when insiders play aggressive strategies

and try to undercut outsiders, prices are only equal coincidentally. That is, if cartels do not allow outsiders to free-ride and vary their prices frequently, prices of outsiders and insiders are significantly different. Moreover, even if cartels do allow outsiders to free-ride under their umbrella, outsiders revealed a certain wariness at the beginning. Irrespective of the used strategy, we confirm the common notion that market prices are distorted and higher when a cartel exists than without a cartel in the market, although the cartels were incomplete, which underlines the threat cartels pose on consumers.

Our work shows the need for further research on the pricing behavior in incomplete cartels of both insiders and outsiders. The results further indicate the importance of preferences of cartel members for the market outcome in this situation. This however is beyond the scope of this study. Certainly, we note that the pricing behavior of outsiders is not as simple as standard economic theory suggests and the general conclusion that cartel outsiders' prices equal insiders' prices should not be taken as granted.

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Appendix

A.1 Figures

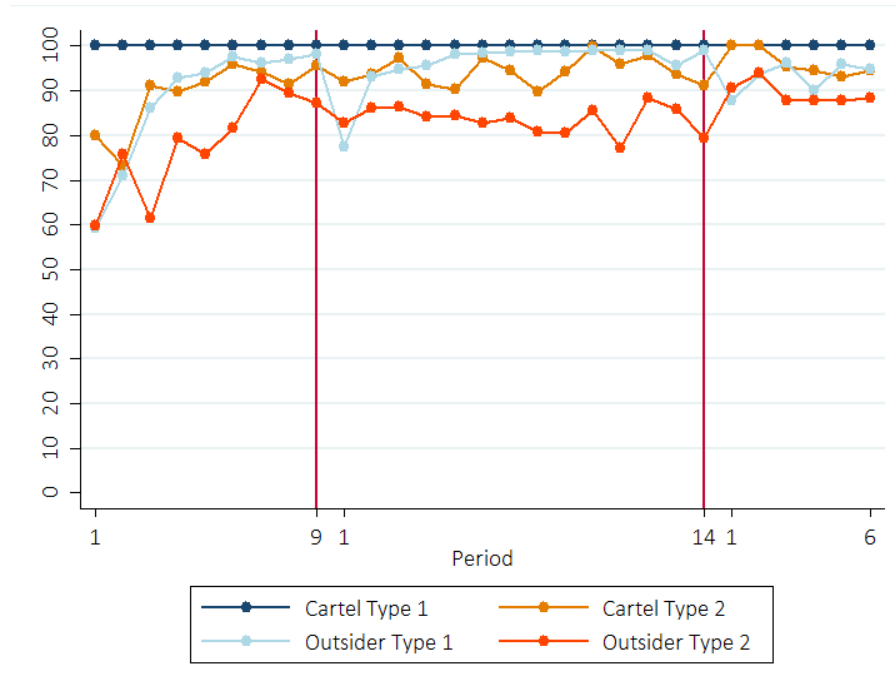


Figure 3: Average Prices per Period, Cartel Types

A.2 Experimental Instructions

Instructions – translated from German - for Control Group and Treatment Group

Hello and welcome to our experiment!

Please read this instruction set very carefully to the end.

In this experiment you will repeatedly make decisions to earn money. How much you earn depends on your decisions and on the decisions of three other randomly assigned participants. Please do not talk to your neighbors and be quiet during the entire experiment. If you have a question, please raise your hand. We will then come to your booth and answer your question personally. All participants receive (and are currently reading) the same instructions. You will remain completely anonymous to us and to the other participants. We do not save any data in connection with your name. At the end of the experiment, you will get your profit paid in cash.

Market

In this experiment you will have to make decisions for one of four firms in a market. All four firms sell the same product and there are no costs of producing this good.

This market is made up of 300 identical consumers, each of whom wants to purchase one unit of the good at the lowest price. The consumers will pay as much as 100 Experimental Currency Units (ECU) for a unit of the good.

Firm 1 and firm 2 are able to produce 200 units of the product and can supply an according number of consumers each. Firm 3 and firm 4 are able to produce 50 units of the product and can supply 50 consumers each.

Your earnings are calculated as the product of your sold units and your selected price.

Distribution of consumers

In each period, all firms have to set their price, at which they want to offer their units. The firm who set the lowest price will sell its capacity at the selected price.

All consumers who haven't bought a unit yet will then buy from the firm with the second lowest price. When there are still consumers left who haven't bought a unit yet, consumers buy from the firm with the next lowest price.

If more than one firm set the same price and if the number of consumers firms can supply is higher than the number of consumers who haven't bought the good, they will split the available consumers proportionally to the firms' capacity. An example is given later.

At the end of each period, all the firms are informed of the chosen prices by all firms in their group, the number of consumers each firm served (= sold units), profits of each firm and their own cumulated profits over all periods. For simulations of your potential profits, we will provide you with a "Profit Calculator", where you can check possible combinations of prices chosen by firms and the associated profits, prior to your price selection.

Communication (*only for treatment group*)

Prior to your price decision, firm 1 and firm 2 will be able to communicate with each other in the market. For that purpose, we will provide participants representing these firms with a chat box, which can be used to send messages to the other person representing firm 1 or firm 2. If you are firm 3 or firm 4 you will not be able to communicate or read messages and just have to wait. Only firm 1 and firm 2 in each market will be able to see the sent messages. In the first 3 periods of each game firms are allowed to communicate for 60 seconds, in each additional period they have 30 seconds for this purpose.

They are allowed to post how many messages they like and talk about what they like. There are only two restrictions on messages: they may not post messages which identify themselves (e.g. age, gender, location etc.) and they may not use offensive language. After the assigned time expires, the chat box will close and all firms will have to choose their price.

Groups

You will be randomly assigned to one of the firms at the beginning of the experiment and remain assigned to this firm for the entire experiment.

The experiment is divided into 3 games, that have multiple periods each. Throughout a game you will be matched with the same three other firms in every period. However, you will be assigned to a new group before each game.

Duration

After every period, the computer will draw a ball of a virtual urn with 9 balls which are numbered from 1 to 9, to determine whether the experiment continues. If a value of 9 is shown, the experiment is over. If any other value is shown, the experiment continues. The ball is then returned to the urn. The odds of playing another periods is therefore $\sim 89\%$ in each period.

At the end of the experiment, which is after 3 games, you will be told of the sum of profits made during the experiment, which will be your payment. You will receive 1 Euro for every 15,000 ECU you earn during the experiment. You will also receive 5 Euro for participating.

Examples

For a better understanding, two illustrative examples follow:

Example 1: Suppose that the firms choose the following prices: Firm 1 sets a price of 85 ECU, firm 2 chooses a price of 100 ECU, firm 3 chooses a price of 75 ECU and firm 4 chooses a price of 95 ECU.

Firm 3 set the lowest price and therefore faces a demand of 300 consumers. It has only capacity to produce 50 units. Therefore it sells all its 50 units at a price of 75 ECU, making a profit of $50 * 75 \text{ ECU} = 3,750 \text{ ECU}$. Firm 1 has the second lowest price and will face a demand only of $300 - 50 = 250$ consumers. Firm 1 has a capacity of 200 and can supply 200 consumers at its price of 85 ECU, therefore making a profit of $200 * 85 \text{ ECU} = 17,000 \text{ ECU}$.

Firm 4 has the lowest remaining price and sells all its 50 units at a price of 95 ECU making a profit of $50 * 95 \text{ ECU} = 4,750 \text{ ECU}$. There is no consumer in the market left who has not bought a unit of the good, therefore firm 2 sell no units at its price and has profits of zero, $0 * 100 \text{ ECU} = 0 \text{ ECU}$.

Example 2:

Suppose that the firms choose the following prices: Firm 1 sets its price at 38 ECU. Firm 2 and firm 3 both set their price at 65 ECU. Firm 4 sets its price at 99 ECU.

Firm 1 sets the lowest price. All 300 consumer want to buy its units. Therefore it can sell all its units and has a profit of $200 * 38 \text{ ECU} = 7,600 \text{ ECU}$.

Given that firm 2 and firm 3 set the same price and also given that their combined capacity ($200+50=250$ units) is larger than the number of consumers ($300-200=100$), they will have to share the available consumer according to their capacities. Firm 2 has a capacity of 200, firm 3 has a capacity of 50. Hence, firm 2 will sell $200/(200+50)*100 = 80$ units at a price of 65 ECU, therefore making a profit of $80 * 65 \text{ ECU} = 5,200 \text{ ECU}$. Firm 3 will sell $50/(200+50)*100 = 20$ units at a price of 65 ECU making a profit of $20 * 65 \text{ ECU} = 1,300 \text{ ECU}$. All consumers are satisfied. Firm 4 sells no unit at its price of 99 ECU and thus makes no profit ($0 * 99 \text{ ECU} = 0 \text{ ECU}$).

Good luck!