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Goppelsroeder, Marie

University of Amsterdam (ACLE)

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Marie Goppelsroeder

ACLE

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Abstract

In this paper we present an experiment in which we test the effects of sequential entry on the stability of collusion in oligopoly markets. Theoretical as well as experimental research suggests that a larger number of firms in an industry makes collusion harder to sustain. In this study, we explore to what extent collusion can be upheld with exogenous entry when groups start off small and when it is common knowledge that the entrant is informed about the history of her group prior to entry. We find that collusion is indeed easier to sustain in the latter case than in groups starting large. We conjecture that an implicit coordination problem is resolved more easily in a smaller group and that coordination, once it has been established, can be transferred to the enlarged group by means of a common code of conduct. Moreover, the results suggest that entrants emulate the behavior of their group upon entry.

JEL Classification: C 72; C92; L13; L40
Keywords: Collusion; Entry; Experiments

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1 Introduction

Oligopoly theory typically predicts that cooperation becomes more difficult to sustain as the number of firms involved in collusion is higher.[1] Intuitively, with a growing number of firms incentives to defect and costs of coordination, communication, and monitoring rise, making it more difficult to maintain a stable cartel. How the number of players in a market alters the behavior of firms has been studied extensively since the pioneering work of Cournot (1838) and Bertrand (1883). Typically, the number of firms is assumed to be exogenously given in these studies.

Moreover, theoretical as well as empirical research on entry has shown that firms joining a cartelized market may disrupt collusive agreements. Porter (1985) and Vasconcelos (2004) extend the Green and Porter (1984) model of price wars under demand fluctuations for entry. Their theoretical predictions show that entry leads to more competitive pricing. Using the data set of the railway cartel JEC that operated in the late 19th century, they both find that cartel stability is inversely related to the number of firms. In addtion, numerous purely empirical cross-section studies as well as case studies have shown how entry can disrupt collusion.[2]

In our study, we test the effect of sequential entry on firm behavior in an oligopolistic market, using an experimental setup. Our objective is to address to what extent markets are able to sustain collusion in the face of entry. In particular, our experiment is designed to examine the effect of entry on groups that start off small and that interact in that same configuration for some time prior to entry. We hypothesize that this gives them the possibility to create a culture of cooperation in the small group which they are able to transfer to the enlarged group, once entry has taken place.

The experimental setup we use is the following: firstly, two players play the Bertrand-duopoly game with fixed matching. An additional player then enters the market within a predetermined time interval. Prior to entry, this player observes the choices of her group. The fact that the entrant observes

[1]See for instance Bain (1956), Tirole, ch.6 (1988)

[2]See Levenstein (1995) on the salt cartel. In addition, Levenstein and Suslow (2004) find that in thirty percent of their cross-section sample studied entry caused cartel breakdown. Note also however that there are case studies indicating that entry can be accommodated. See for instance Levenstein and Suslow (2004, p.38) who show that in industries such as bromine, diamonds, mercury, ocean shipping, oil, potash and sugar the cartel included the entrant.

her group is common knowledge. We compare this setup to a second treatment in which players are matched in groups of three from the very start of the session. In order to test our conjecture, we compare the post-entry rounds of the entrant treatment with the baseline treatment. Higher levels of collusion in the post-entry rounds of the entrant treatment than in the baseline treatment would be consistent with the conjecture that collusion can be nurtured provided that groups start off sufficiently small.

There are a number of experimental studies related to our work. Experimental literature on number effects has established an inverse relationship between market prices and the number of firms in a market. Since Fouraker and Siegel's (1963) seminal book, many experiments have focused on studying Cournot type markets. Huck, Normann and Oechssler (2004) review the existing literature and present a new experiment. They find that the cutoff point between collusion and competition lies somewhere between two and four firms. Whereas collusion regularly occurs in duopolies it becomes increasingly rare with triopolies and quadrupolies.

Moreover, many experimental studies looking into price-setting models have shown that a larger number of firms typically leads to more competitive outcomes. Using a homogeneous Bertrand game, Dufwenberg and Gneezy (2000) confirm a similar trend as Huck, Normann and Oechssler (2004) for Cournot games. Using random matching and constant marginal costs in markets with three and four firms, they find that prices rapidly converged to the Nash levels. In the duopoly markets however, prices remained considerably above competitive levels for most rounds.

Abbink and Brandts (2005) explore the extent to which experimental price setting duopolies are able to achieve collusive outcomes in growing versus shrinking markets. They show that in contrast to theoretical findings, duopolists tend to collude more in shrinking markets. The authors conjecture that participants have an incentive to coordinate early as profits melt away quickly in the future.

The main difference between our study and the experimental literature on number effects is that the latter compares groups of fixed sizes. It is not clear however, what such a number effect is caused by. When studying the consequences of a larger number of firms in a concentrated market, two main effects can be discerned. On the one hand, there is a change in incentives to defect due to a higher number of firms in the market. This effect we denote as the structural effect. Typically, incentives to cheat are higher with more firms involved as individual deviation becomes more profitable relative to the cartel profit. On the other hand, when there are more firms in a market it is harder to coordinate choices. This effect we label the coordination effect.

Empirical literature on cartels has shown that overcoming coordination problems is paramount for cartel stability. Levenstein and Suslow (2004) show that in over twenty-five percent of the cartel cases studied, cartel breakdown occurred because of bargaining problems. Moreover, an early experimental study discerning both mechanisms has been conducted by Dolbear et al. (1968) who find that, by controlling for the monetary incentives, it is mainly the coordination effect causing the number effect.[3] Using sequential entry, our paper proposes an alternative approach to isolate the coordination effect. By comparing the post-entry rounds of the treatment with entry with the post-entry rounds of the treatment with a fixed group size, differences between the treatments can mainly be attributed to this effect. An alternative interpretation of our work is therefore that sequential entry helps to shed light on the question whether a coordination effect exists.

There are only very few experimental studies specifically looking into entry. Sonnemans, Schram and Offerman (1999) explore the extent of cooperation in a public goods game where subjects are assigned in groups of four and where the composition of these groups changes throughout the experiment. In pre-determined rounds at most one subject leaves a group and will be replaced by another subject. The authors show that subjects contribute more in the first round in their new group than in the last round in their old group and that subjects condition their contributions on expected cooperation by their fellow group members. An important difference with our work is that even though the group composition changes, the size of the group is fixed in their experiment.

A public goods experiment that does allow for growing groups through endogenous entry is Guerek, Irlenbusch and Rockenbach (2006). The study shows that larger groups not only reach high levels of contribution but *a fortiori* that the larger the group, the higher the contributions.[4] In much of the same vein as our conjecture, the study highlights that groups can develop a culture of cooperation by slowly growing into a larger group. As entry in our study is predetermined and not chosen by the subjects themselves, we

[3]Moreover, case studies have pointed out the coordination problem of cartels. See for instance Levenstein (1996) for a study in the bromine cartel, Gupta (1997) for the tea industry.

[4]Even though incentives are such that cooperation in smaller groups is easier than in larger ones.

expect that cooperation will be harder to enforce and sustain than in Guerek, Irlenbusch and Rockenbach (2006).

The closest study to ours is Weber (2006), who looks into group cooperation within the framework of a minimum effort coordination game. In a number of different treatments, participants start off in small group sizes which are eventually enlarged following a predefined growth path up until the group reaches a size of 12 participants. The subjects that enter the treatment groups differ with respect to the information they have: in a history treatment, entrants observe the choices of the group they are entering into. In a no-history treatment, entrants do not know anything about the behavior in their group. Weber (2006) compares these treatments with a fixed size control group that starts playing from the beginning with 12 participants. The results show that only in the history treatments, efficient coordination was possible. Weber's results provide support for our conjecture, as he shows that both information conditions of the entrant and starting in small groups are crucial factors to reach efficient coordination.

One important dimension where our paper differs with respect to the work of Weber is that we study entry in an oligopoly setting in which the Pareto-efficient outcome does not coincide with the Nash equilibrium. Coordination on that outcome might therefore be harder to achieve. In the minimum effort coordination game, there is strategic uncertainty as to which of the seven symmetric Nash equilibria will be chosen by the other player(s) but there is no monetary incentive to defect from these equilibria.

To our knowledge, this is the first experimental paper that specifically examines the effects of sequential entry on collusion in an oligopoly game. We find support for the conjecture that collusion can be sustained provided that groups start small and that starting small may help to overcome coordination problems inherent in the larger groups.

The remainder of this paper is organized as follows. In Section 2, we discuss the experimental design. Section 3 presents aggregate results, Section 4 individual results. Section 5 concludes with some policy implications and directions for further research.

2 Experimental Design

2.1 Game

Subjects play a Bertrand game with a homogenous good, inelastic demand and no costs. In each round, a buyer will purchase the good at a constant quantity of one unit up to a given maximum price. This type of demand schedule is also known as box demand.

In each round each seller posts an integer price bid from the strategy space $[1, .., 100]$. In the treatments, subjects are either playing in duopolies or in triopolies. The seller posting the lowest price will sell the good and gets profits equal to the price she posted. The other seller will make zero profits. Should the players post an identical price in a given round, profits will be shared equally. Given the price of the other seller(s) it is always profitable to slightly undercut the minimum price.

The Bertrand-Nash equilibrium in the triopoly is to set a price equal to the lower bound of the price interval given at $p = 1$. The corresponding profits at this equilibrium for each player are 1/3. The collusive equilibrium is at the upper bound at $p = 100$ with corresponding profits of 33 1/3 for each player.

In the duopoly game, a Bertrand-Nash equilibrium is given by players setting a price of $p = 1$ which implies that each players receives profits of 1/2. Note however that due to the discretization of the strategy space, a second Nash equilibrium exists at p=2 where each of the players get a profit of 1. By undercutting the Nash equilibrium at $p = 2$, a player would also gain a profit of 1.

2.2 Sources of a Number Effect

As discussed in the introduction, there may be several reasons why collusion is more difficult to enforce in larger markets. Firstly, the incentives to defect from the collusive agreement increase with a higher number of players in the Bertrand game which we refer to as the *structural effect*. Secondly, with more players, there is more strategic uncertainty about the choices of the other players which makes it harder to coordinate on a common price bid. This we refer to as the *coordination effect*. In our experiment we aim to explore this coordination effect using the following two treatments.

- **Entrant Treatment**: Subjects start playing the Bertrand duopoly game. At a given point, a third player enters and the group plays the Bertrand triopoly game.

- **Baseline Treatment**: Subject play the Bertrand triopoly game during the entire experiment.

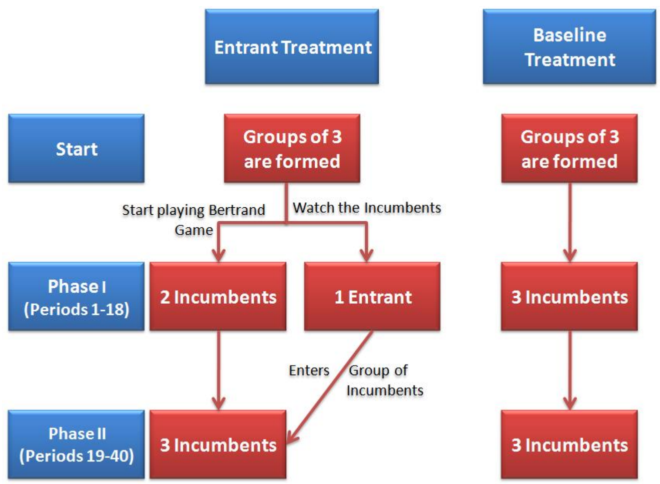

Figure 1: Design of the Experiment.

Figure 1 presents the main features of the experiment. In both treatments players are informed that they play for 40 rounds. In the Entrant Treatment, players are randomly matched in groups of three. Two players are randomly selected and start playing the Bertrand game explained above from the beginning of the experiment while the third group member observes their choices via a computer screen. The fact that the entrant observes their groups prior to joining them is common knowledge. It is also common knowledge that entry takes place between round 15 and 25. We impose entry in all sessions in round 19. After entry occurs, players play the same game in groups of three until the end of the experiment. In the Baseline Treatment, subjects play the same Bertrand game in groups of three throughout the entire experiment. In the following, we will refer to the pre-entry rounds (rounds $1-18$) as the first subsession and the post-entry rounds (rounds $19-40$) as the second subsession in both treatments.

In both treatments the informational feedback subjects receive consists of their own prices and profits as well as the individual prices posted by the other firm(s).[5] Prior to entry, entrants are given the task of predicting the choices in their group. In each round, entrants observe the prices chosen by each group member and guess the minimum price for the following round. We chose for this setup as we wanted to incentivize entrants to pay attention to choices in their group and to learn about the group behavior.

If entrants' guess is within 20 percent of the actual winning bid, they receive profits equal to the average profits of their group members for that round. In case the estimate falls outside that bound, entrants receive zero profits. For fairness considerations, we decided to tie the entrant's profit before entry to the average group profits.

When there a more players in a group, there is more uncertainty about the choices of others, which makes it harder to coordinate. The fact that the groups start in a smaller configuration reduces the initial level of strategic uncertainty, thereby facilitating coordination. Moreover, we conjecture that once cooperation is established, it is possible to transfer it to the enlarged group especially if the entrant is informed about the group's prior choices. This implicitly rests on the assumption that subjects are able to build a set of self-enforcing rules with fewer group members that they are able to transfer to the larger group. This conjecture is also consistent with the findings in Weber (2006).

Theoretically, incumbents should set a price of one or two in equilibrium prior to entry. After entry has taken place, both incumbents and entrants should set a price of one. The collusive benchmark predicts that incumbents set a price of 100 both before and after entry and that entrants also price at 100.

In line with the above discussion, we expect that subjects that start off as duopolists and whose groups are extended to triopolies are closer to the collusive benchmark in the triopoly game than subjects that initially start playing in a triopoly constellation. In order to test this, we compare the triopoly in subsession two in the Entrant Treatment with the subsession one of the Baseline Treatment. One might argue that this approach has some limitations as subjects in the Entrant Treatment in subsession two already

[5]We chose not to reveal the profits of the fellow group members to subjects as some studies have shown that these induce imitation and lead to competitive outcomes. See for instance Offerman et al. (2002) and Huck et al. (1999) for a discussion on this. Note however that they can easily be inferred from the price bid of the other group members.

have some experience in playing the Bertrand-Nash game whereas players in the Baseline Treatment in subsession one do not. We therefore impose an additional, more stringent test by comparing both treatments in subsession two.

3 Aggregate Results

3.1 Subject Pool

The experiment is computerized and the program is written using the ZTree software package from Fischbacher (2007). A transcript of the instructions can be found in the Appendix. The experiment was conducted at the CREED laboratory of the University of Amsterdam in June and September 2008. There were 138 undergraduate students from different disciplines participating in the experiment, with 26 groups in the entrant treatment and 20 groups in the baseline treatment.

For both treatments, subjects were assigned randomly and anonymously in groups of three at the beginning of the experiment. Communication between subjects was not allowed. Moreover, we used a neutral frame to make the game as simple and clear as possible for the participants.[6]Before the start of the experiment, subjects read the instructions on the screen and answered three test questions. They were also handed out a paper copy of the instructions at the beginning of the experiment.

Subjects received a five Euro show-up fee and where paid based on performance for the 40 rounds. The experimental currency was given in points. For each 100 points subjects earned they received Euro 1.50 . The average payment for subjects was 22 Euros for one hour.

3.2 Average Market Prices

Table 1 shows the average winning bid per group for the Entrant Treatment and Baseline Treatment for the two subsessions. In the first subsession, it is not surprising that average winning bids are higher in the Entrant treatment than in the Baseline treatment as we are comparing duopolies with triopolies. Comparing the overall averages of the second subsession, it is clear that in

[6]Note that studies provide mixed results concerning the question whether neutral or economic frames induce more cooperative outcomes. See also Huck et al. (2004).

Average Winning Bids				
	Rounds 1-18		Rounds 19-40	
GroupNr	Entrant	Baseline	Entrant	Baseline
1	100	80.56	93.00	97.68
2	95.10	44.72	90.41	6.77
3	67.44	98.61	88.14	99.95
4	76.11	48.78	61.23	25.23
5	97.11	47.78	86.23	25.50
6	69.94	26.22	18.64	23.10
7	90.55	71.94	99.36	41.04
8	97.17	19.22	99.50	2.95
9	100.00	37.06	91.86	55.82
10	67.00	96.22	26.23	97.68
11	65.83	47.67	77.45	25.41
12	92.39	54.17	51.04	44.05
13	17.33	8.61	5.27	6.45
14	67.17	25.17	28.64	16.27
15	32.56	26.56	22.82	18.00
16	98.10	60.83	77.36	55.05
17	100.00	69.056	76.32	27.95
18	100.00	77.11	99.95	92.36
19	75.44	80.833	29.23	83.00
20	95.61	45.44	94.77	89.45
21	66.28		32.18	
22	96.11		47.86	
23	95.56		66.64	
24	94.50		98.04	
25	93.10		95.45	
26	75.94		57.45	
Overall Average	81.78	53.78	65.95	50.13
Bertrand Benchmark	1	1	1	1
Collusive Benchmark	100	100	100	100

Table 1: Average Winning Bid per Group in the Entrant Treatment and the Benchmark Treatment.

the Entrant Treatment the bid is higher than in the Baseline Treatment (66 compared to 50). In line with previous literature on number effects, the averages are higher in duopolies than triopolies (comparing column three and column four) but it is striking that they remain higher even after entry occurred. In the following sections, we analyze this difference in more detail, by dissagregating the data over time and over groups.

3.3 Impact of Entry on Pricing Decisions in Concentrated Markets

In this section, we explore the pricing behavior across our two treatments. When examining the evolution of collusion, one can focus on two different indicators. On the one hand, one can analyze how the *level* of collusion evolves in each treatment by looking at average price bids, average market prices or medians. We present the results of this part of the analysis in this section. On the other hand, one can look at measures of *variance* of collusion such as the fraction of coordinating groups. These latter results will be presented in the Section 3.4.

Figure 2 shows the price bids in a given round averaged over all groups in a given treatment. Figure 3 is constructed the same way for average market price. We start by comparing the prices levels in period one, as subjects at this moment do not have any experience and have not yet learned anything neither about their group nor about the game. It is clear from both of these figures that the Bertrand-Nash equilibrium is not achieved in the first period in any treatment. Average price bids are at 71 and 60 in the Entrant and Baseline Treatment, respectively. Looking at convergence of average prices as well as average market prices in later rounds, we can see that prices tend to increase in the first subsession in both treatments. In the second subsession this trend seems to be reversed for both treatments, an effect which seems stronger when looking at market prices. Moreover, prices do not converge to the Bertrand-Nash equilibrium, a result which is consistent with the findings of Dufwenberg and Gneezy (2000).[7] Looking at market price in Figure 3, they oscillate at collusive levels of over 80 for most periods in the Entrant treatment and then drop after entry revolving at a level around 70. In the baseline treatment, prices are typically between 50 and 60 if we disregard the beginning and the end periods.

Let us now compare the treatments in more detail. If collusion is easier to maintain in groups that start off small, as we conjecture, we should observe a higher degree of collusion post-entry in the groups of Entrant Treatment than in the Baseline Treatment. Also if there exists a coordination effect, we

[7]Note however, that in their setup subjects played the Bertrand game with random matching.

should see higher prices in the Entrant Treatment in subsession two. Indeed the results point into this direction.

Looking at the whole 40 rounds, it is clear that average prices are higher in the entrant treatment than in the baseline treatment. This is not surprising for the first subsession, as we are comparing duopoly markets in the Entrant Treatment with triopoly markets in the Baseline Treatment.[8] What is striking however is that this considerable difference in price bids remains after entry has taken place, providing support for our conjecture.

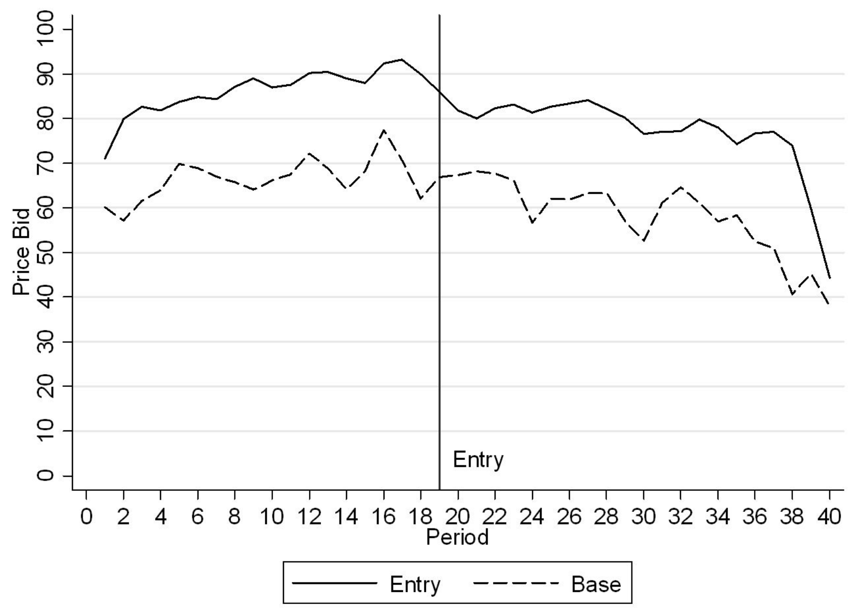

Figure 2: Average Price Bids in Entrant Treatment and Baseline Treatment.

To test for the differences statistically, we compare both series using the non-parametric Mann-Whitney U test based on ranks which tests whether the observation in the treatments stem from the same distribution. We apply the test, comparing the second subsession of the Entrant Treatment with the first subsession of the Baseline Treatment. We also apply the test comparing

[8]Note that for the first subsession, we are comparing duopolies with triopolies which implies that we compare an average of 52 price bids with an average of 60 price bids. In the second subsession, we compare an average of 78 bids with on of 60 bids.

the second subsession in both treatments to test for the coordination effect.[9] As we compare equal sized groups, differences in treatments cannot be due to structural differences and can therefore be attributed to the coordination effect. As stated above, there is a considerable difference in treatments in this subsession, pointing out to the importance of coordination problems as a source of the number effect. Running both tests, yields a highly significant treatment effect at the one percent level.

To get a more complete picture of the bidding behavior, it is insightful to look at the evolution of the market prices per group in both treatments depicted in Figure 3. Differences in market prices across treatments would give even stronger support for our hypothesis as they present the minima of the bids in each group.

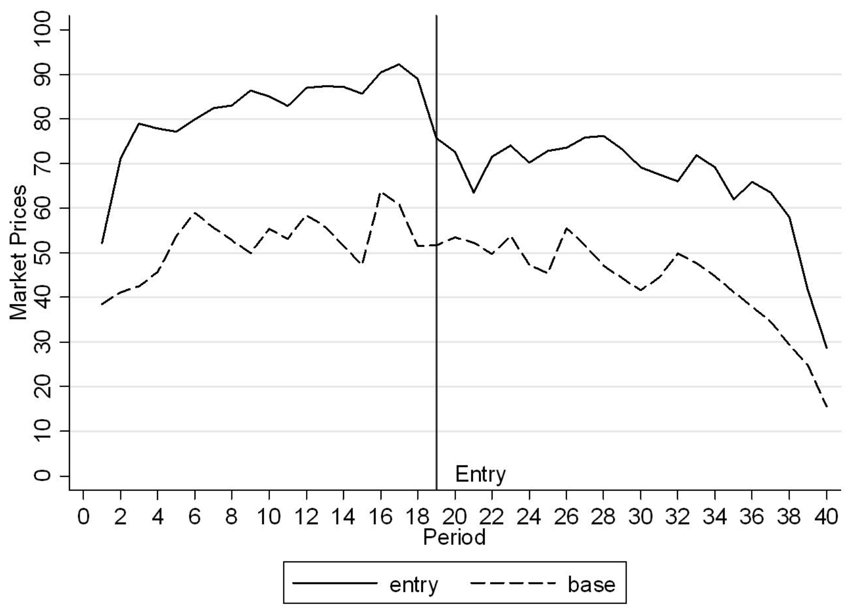

Figure 3: Average Winning Bid in Entrant Treatment and Baseline Treatment.

The pattern displayed in Figure 3 shows that market prices remain consid-

[9]Alternatively, one could also argue that this comparison is used to yield a more stringent procedure in testing for differences in treatments as the subjects in the second subsession in the Entrant Treatment have more experience compared to the subjects in the first subession in the Baseline Treatment.

erably higher in the Entrant Treatment in subsession two. This first impression is confirmed statistically at the one percent level using a Mann-Whitney U test. A significant treatment effect can also be found when comparing the second subsession of the Entrant Treatment. These results provide further support for our conjecture of a coordination effect being present.

Note however that prices drop considerably in comparison to the pre-entry levels. This drop in market prices is mainly caused by groups were collusion could not be established pre-entry. In these markets, both entrants and incumbents undercut strongly the pre-existing market prices thereby bringing down the overall pricing level. In the groups that collude pre-entry the average winning price drops by nine percent from 100 to 91. In the groups unable to establish collusion however average winning price drop by 27 percent from a market price of 75 to 55. We discuss the dynamics of individual group behavior, in particular the pattern of undercutting in more detail in section 4. The sharp drop in market prices is in line with the findings in Porter (1985) and Vasconcelos (2004) discussed in the introduction that show that actual entry leads to more competitive pricing.

Furthermore, there is a negative trend in prices after entry occurs.[10] Note that even though the decrease in market prices after entry is substantial, prices still remain considerably higher than predicted by the Nash equilibria. This observation is consistent with empirical studies which find only a moderate effect of entry on price cost-margins in industries without specific focus on collusive markets.[11]

Figure 4 depicts the median price bids per round per treatment over the 40 rounds. The median has the advantage of being more robust to outliers in the data. Over 50 percent of the bidders in the entrant treatment bid at the perfectly collusive level if we disregard the beginning and the end periods. In the baseline group on the other hand, median price bids remain much lower and vary strongly, oscillating between price bids of 40 up to 85. Again, these differences are highly statistically significant.[12] The above findings can be summarized following observation.

Observation 1 *Market Prices in the Entrant Treatment remain signifi-*

[10]This effect is significant at the 10 percent level.

[11]See for instance Geroski (1991) and Geroski (1995).

[12]At the 1 percent level using a Mann-Whitney U test both when comparing the second subsession in treatments as well as when comparing the first subsession of the Baseline Treatment with the second subsession of the Entrant Treatment.

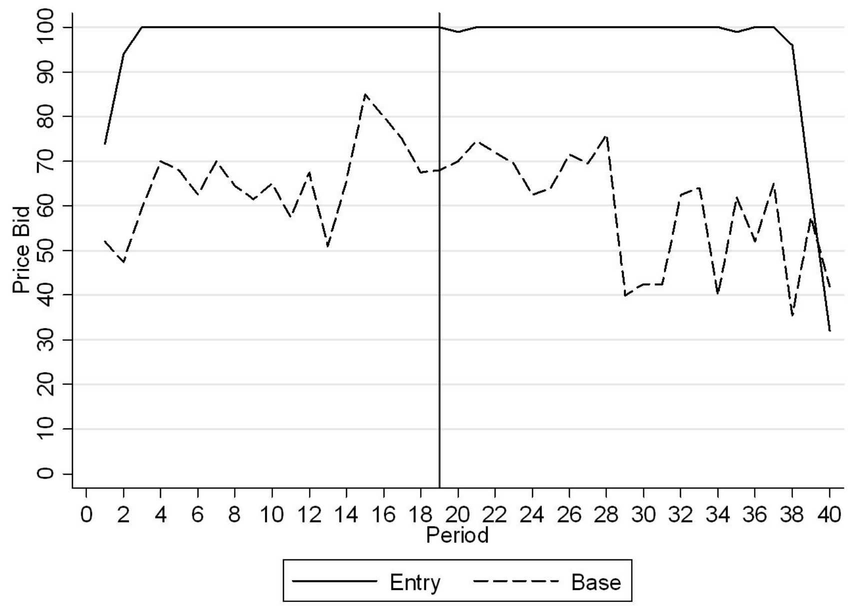

Figure 4: Median Prices in Entrant Treatment and Baseline Treatment.

cantly higher than in the Baseline Treatment. This supports our conjecture that it is easier to collude in groups that started off small. Moreover, we find evidence for a coordination effect.

3.4 Impact of Entry on Cooperation

In this section, we concentrate on measures of variance of collusion. In particular, we explore the degree of cooperation among groups. One way to do this is to look at the frequency of common price bids across treatments. A higher fraction of coordination in the second subsession of the Entrant Treatment than in the Baseline Treatment would provide evidence in favor of our conjecture. Figure 5 shows the frequency of coordination on a common price larger than two per group in each treatment for each round. The entrant treatment displays a much higher degree of coordination. This difference is highly significant.[13] In line with our conjecture and the findings of Weber

[13]Mann Whitney U test at 1 percent level comparing both the second subsession in treatments as well as the first subsession of the Baseline Treatment with the second subsession of the Entrant Treatment.

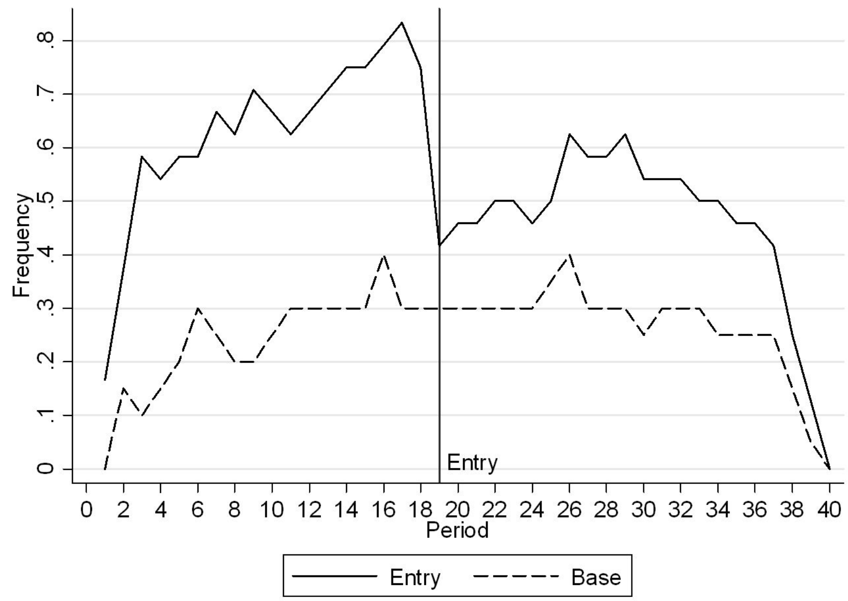

Figure 5: Coordination on a Common Price in Entrant Treatment and Baseline Treatment.

(2006), the results suggest an inherent coordination problem can be overcome provided that groups start off small.

The frequency of coordinating groups steadily increases in the pre-entry periods peaking at at over 80 percent just before entry which could be due to learning and experience. At the entry period, it drops considerably to about 40 percent of coordinating groups. As mentioned earlier, this is mainly due to entrants who initiated undercutting in the period they join their group. The pattern after entry is similar to that before entry to the extent that the fraction of coordinating groups increases over time even though the high level of pre-entry coordination is not reached again. After period 36 a clear end-effect emerges. In the Baseline Treatment, the percentage of coordinating groups is much lower, revolving around 30 percent in most of the periods. The strongest form of collusion emerges when a group manages to coordinate at the Pareto-efficient price bid of 100. At this market price, firms share the entire surplus of the market, either receiving half of the profit (before entry) or a third of the profits (after entry). Figure 6 shows the frequency of coordination at the perfectly collusive level for both treatments. The evolution of

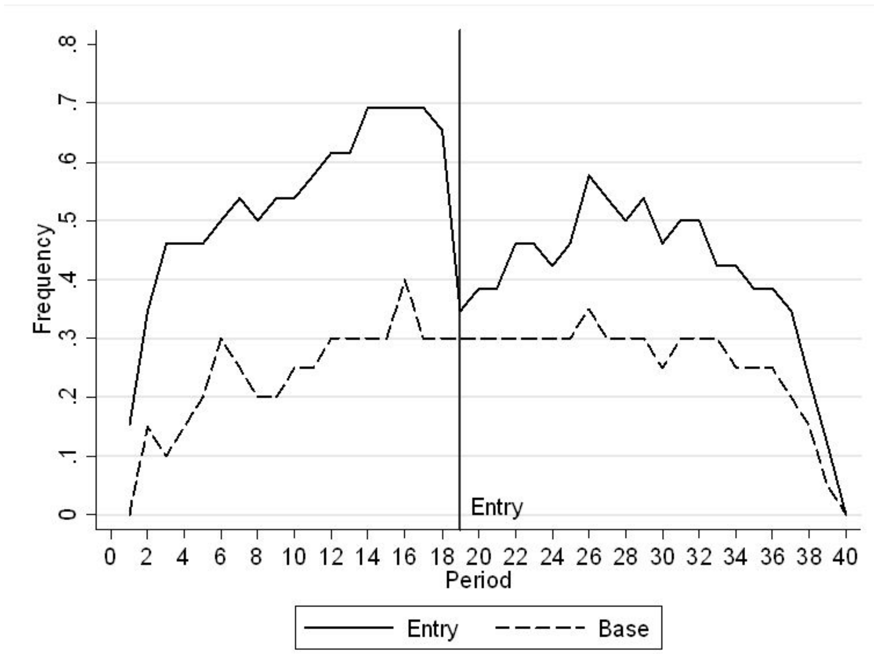

Figure 6: Coordination on the Perfectly Collusive Outcome in Entrant Treatment and Baseline Treatment.

perfectly collusive groups is similar to that in Figure 5 with signicantly more collusion in the Entrant Treatment both when comparing subession two of the Entrant Treatment with subsession one of the Baseline Treatment, but also when comparing the second subession of both treatments.[14] The higher degree of coordination in the Entrant Treatment in the second subsession compared to the Baseline Treatment also provides evidence for the existence of a coordination effect as a major cause for the number effect. Note that the market in our experiment can also be interpreted as a shrinking market as incumbents know that there will be future entry. In line with Abbink and Brandts (2005), we find that subjects facing shrinking profits have an incentive to coordinate early knowing that profits post-entry will be substantially reduced.

Observation 2 *Groups in the Entrant Treatment coordinate significantly more than groups in the Baseline Treatment. This also holds for Pareto effi-*

[14]Mann Whitney U test at 1 percent level.

cient coordination. This provides further evidence of the coordination effect in tacit collusion.

4 Individual Results

4.1 Behavior of Entrants

The dominant insight from the literature surveyed in the introduction is that entrants in cartelized markets may destabilize collusion. In our setup, the entering party knows the market history and this is common knowledge. We conjecture that this helps groups to sustain collusion. To test this conjecture and to get a deeper insight into the determinants of the entrants' behavior, this section explores in how far entrants respond to the performance of their group prior to entry.

We first examine to what extent entrants imitate the behavior of the incumbents. In order to do this, we compare per group the corresponding minimum bid of the incumbents averaged over the last three rounds before entry (periods $16-18$) and price bid of the entrant in the corresponding group in the first period after entry (period 19). Figure 7 shows the results. Each of the points represents one of the 26 markets in the entrant treatment. If the entrant follows the pre-entry price bids of her group members, most of the data points would lie on the 45 degree line. Figure 7 indicates that there is indeed some degree of imitation taking place. In the upper right corner, there are thirteen groups that cluster at a price bid of 100. Moreover, three additional groups have price bids of either 100 or 99. In these markets, the entrant matches the collusive price bid of her group. Overall, in more than 60 percent of the groups, the entrant imitates the collusive pricing post-entry.

To analyze what determines entrants' behavior after entry in more detail, we categorize the markets pre- and post-entry. We define a market as collusive in subsession one or in subsession two (periods $1-18$ and periods $19-40$, respectively) if during at least 9 consecutive periods before (after) entry groups were able to coordinate on a collusive price of 99 or 100. Note that this time interval exactly correspond to 50 percent of the periods in the first subsession. Otherwise the market is defined as non-collusive. Using this rather strict definition, over 60 percent of the markets in the entry treatment still classify as collusive prior to entry.[15]

[15]Although this definition is strict as one could also define a market at lower market

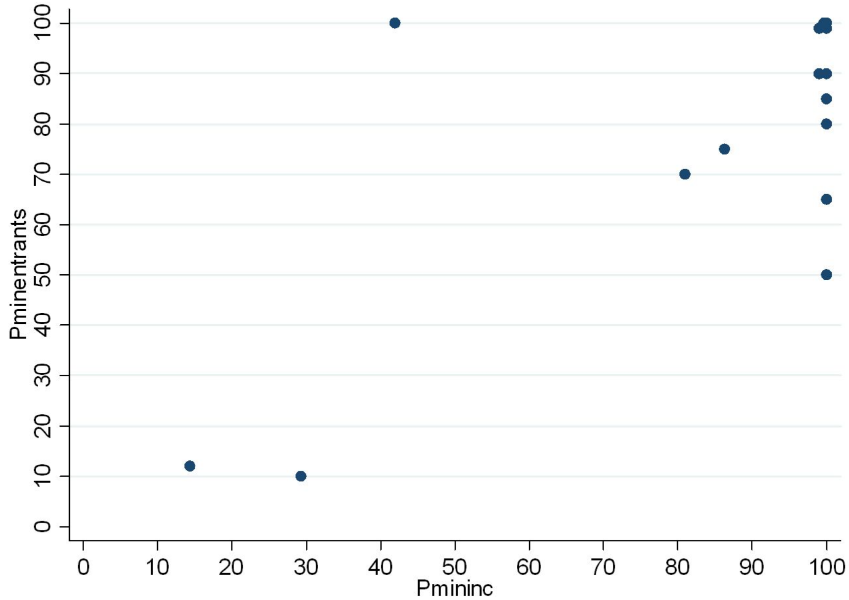

Figure 7: Correlation between Price Bid of Entrant in t=19 and Average Price Bids of Incumbents in t=16-18.

We characterize several possible reactions of entrants in the first period after entry occurs (period 19) which we condition on the type of market they join. The reference point of the reaction of the entrant is the minimum of the price bids of the other players (which is the market price). We distinguish four possible reactions of entrants: firstly, they can match the minimum price bid of the previous period. Secondly, they can undercut that bid by setting a price bid of between $1 - 10$ price increments below the minimum. Thirdly, entrants can compete by pricing more than 10 price increments below the minimum price set in the previous period. Lastly, entrants can signal their willingness to collude by setting a price in period 19 which is higher than the minimum price. Using this classification, we can generate Table2. In this table, the reaction of the entrant is relative to the market price of period 18. The characterization of the markets is based on entire subsession one.

In the collusive markets, a clear majority of the entrants follow the behavior of their group. Almost 70 percent of them match the market price

prices as collusive, we chose this classification to be conservative. A less restrictive classification only strengthens our findings but does not qualitatively alter the results.

	Pre-Entry Market Behavior		
Reaction of Entrant	Collusive	Non-collusive	All
Match	11 (69 percent)	2 (20 percent)	13 (50 percent)
Undercut	3 (19 percent)	2 (20 percent)	5 (19 percent)
Compete	2 (12 percent)	3 (30 percent)	5 (19 percent)
Signal	-	3 (30 percent)	3 (12 percent)
	16 (100 percent)	10 (100 percent)	26 (100 percent)

Table 2: Reaction of Entrant in t=19 to Group Behavior in subsession 1.

and collude as well. A representative market in which an entrant always matched is depicted in Figure 8. The Figure nicely illustrates how both incumbents perfectly collude from the very start and how the entrant emulates this behavior after entry.

In three markets entrants undercut, whereas in two markets there is strong undercutting. Signalling by entrants was not observed in collusive markets. This is due to the fact that almost all (14 out of 16) of the collusive markets priced at the perfectly collusive level in period 18 so that signalling was ruled out by definition.

The reactions of entrants in the non-collusive markets are distributed more evenly. Matching the market price was much less prevalent than in collusive markets (20 percent). This is not surprising, given that the market price typically is less attractive in these markets. Entrants therefore try to steer away from it either by undercutting in order to gain the whole market share or by trying to signal their willingness to coordinate at a higher price. This latter reaction occurred in 3 markets of the markets. Figure 9 exemplifies a market with a signalling agent. Prior to entry, there are episodes both of competition and of collusion. In period 19, one incumbent decreases his price bid and in the following period the other incumbent follows suit. The entrant, on the other hand, consistently bids the fully collusive price thereby eventually restoring collusion.

A majority of 50 percent (5 markets) of the entrants however undercut or undercut strongly (compete) in the first period after entry. Entrants might strongly undercut the minimum price bid in period 18 as they expect the level of cooperation to decrease even though they would generally prefer to collude. If these expectations would be an issue, one should observe undercutting in the first and/or second period after entry followed by periods of signalling. We therefore examine the sequence of reactions of entrants in the four periods following entry.[16]

Table 3 shows that expectations of lower market prices by entrants indeed seem to be a relevant factor in both collusive and non-collusive markets. In the collusive markets in almost 20 percent of the cases the entrant first undercuts in the first and/or second period and subsequently signals by raising the price bid. In non-collusive markets, this phenomenon is much stronger: in 50 percent of the groups (5 markets) entrants first undercut and then signal. An example of such a group is also depicted in Figure 10. The entrant first competes at a price of 75 but then signals his willingness to collude from period 21 onwards by setting the fully collusive price of 100 during the 5 following periods.

An alternative explanation for this behavior could be that in non-collusive markets the price level is much lower to start with. This in turn forces undercutting entrants to signal more once the undercutting phase hits in in order to prevent prices from falling to competitive levels.

Another surprising finding is that in the collusive markets 56 percent of the entrants match the price bid of 99 or 100 in all of the first four post-entry periods even though the incentives to undercut are very strong.

	Pre-Entry Market Behavior		
Reaction of Entrant	Collusive	Non-collusive	All
Always Match	9 (56 percent)	-	9 (35 percent)
Always Undercut	-	1 (10 percent)	1 (4 percent)
Always Signal/Match at 100	1 (6 percent)	2 (20 percent)	3 (11 percent)
Undercut, then Signal/Match	3 (19 percent)	5 (50 percent)	8 (31 percent)
Signal, then Undercut	-	2 (20 percent)	2 (8 Percent)
Other	3 (19 percent)	-	3 (11 percent)
	16 (100 percent)	10 (100 percent)	26 (100 percent)

Table 3: Reaction of Entrant in t=$19-22$ to Group Behavior prior to Entry.

To summarize, the prevalent response of entrants who join collusive markets is to match the collusive price thereby stabilizing and sustaining collusion post-entry. There is much more variation in the behavior of entrants who join non-collusive markets. Moreover, a large majority of these entrants undercut in at least two periods (80 percent) within the four periods following entry.

[16]Table 3 is constructed in the same way as Table 2. In each of the four periods, we look at the reaction of the entrant relative to the minimum bid of her group members in the period before.

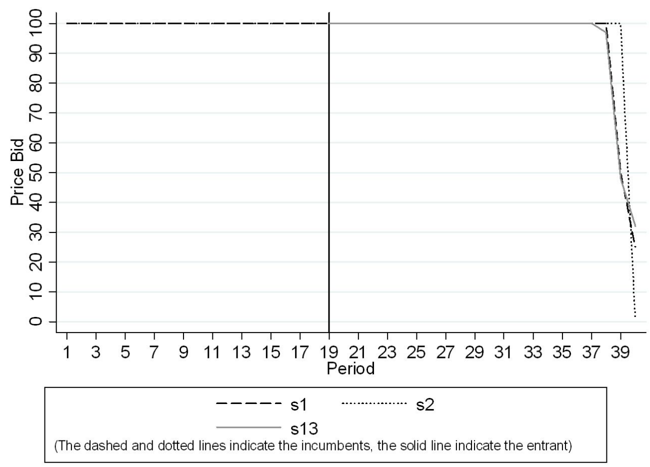

Figure 8: Price Bids in Group 1 of Session 1, Example of "Always Collude" in a collusive Market

On the other hand, signalling is observed in a majority of these markets as well.

Observation 3 *The large majority of entrants that enter a collusive market also colludes, thereby sustaining the pre-existing cartel. In non-collusive markets, the majority of entrants undercut at some point thereby making it harder to establish collusion. Overall, entrants' responses reinforce the behavioral patterns of the markets pre-entry: entrants in cartelized markets mainly collude, whereas entrants in non-cartelized markets mainly engage in pricing behavior which is not conducive to collusion.*

4.1.1 Entrant's Pre-Entry Estimates and their Post-Entry Behavior

Prior to entry, entrants were asked to guess the minimum price bid of their group. If their estimate was within 20 percent of the actual market price, they received the average payoff of their group, otherwise they received nothing. To see whether there is a relation between entrants' profits pre-entry and the overall group behavior post-entry, we first construct a pre-entry versus

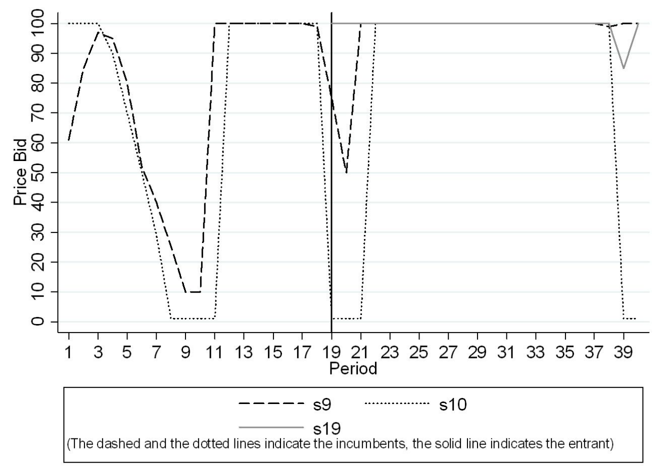

Figure 9: Price Bids in Group 5 of Session 2, Example of "Always Signal" in a non-collusive Market

post-entry measure of profitability per group given by:

$$z_i = \frac{\frac{1}{19}\sum_{t=19}^{37} p_i^t}{\frac{1}{16}\sum_{t=3}^{18} p_i^t} \tag{1}$$

where p_i^t gives the market price in a given period t for a given group i.[17] For a given group, z_i is larger than one if the average market prices are higher post-entry than pre-entry and smaller than one if the reverse holds. We also constructed a measure of (in-)accuracy of the estimate given by

$$a_i = \frac{|estimate_i^t - p_i^t|}{p_i^t} \tag{2}$$

where p_i^t is defined as equation (1) and where $estimate_i^t$ gives the estimate of an entrant of a given group i in period t. Equation (2) measures the percentage deviation of an entrant's estimate from the actual minimum bid in a given period. The variable a_i therefore shows how (in-)accurate an entrant's estimate was on average. Figure 12 plots z_i on the vertical axis and the median of a_i on the horizontal axis. We conjecture that there is a positive

[17]We excluded the first two and the last three periods in order to account for learning and end effects, respectively.

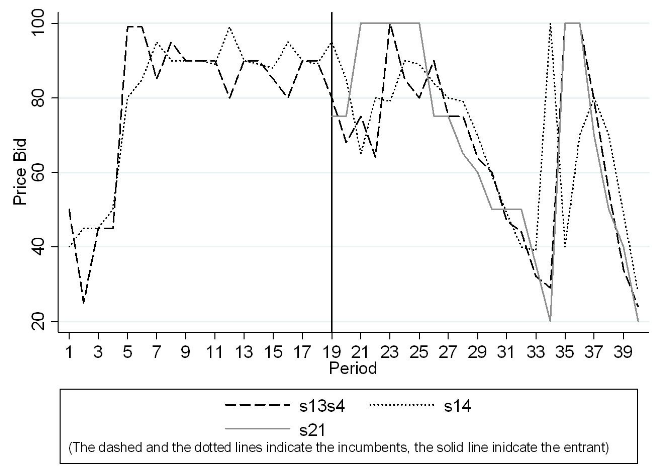

Figure 10: Price Bids in Group 7 of Session 4, Example of "Undercut, then Signal" in a non-collusive Market

relationship between the ability of an entrant to estimate the actual minimum price and relative group profitability post-entry. If entrants' are precise in their estimates, we expect them to have learned the game and therefore improve or at least not deteriorate the group performance a lot as measured by z_i. The graph should therefore depict a negative relationship between the inaccuracy of the estimate a_i and the relative group performance post-entry z_i. Looking at all groups, Figure 12 shows that there is a significant negative correlation between the two variables.[18] The results of this graph should be taken with a grain of salt however. The problem with this type of analysis is that it is especially easy for entrants in collusive groups to make predictions as there is much less variability in market prices than there is for entrants in non-collusive groups. It is also these groups that perform almost as good or as good pre-entry as well as post-entry. This is why a lot of points cluster around a z_i value close to one and an inaccuracy level a_i of close to zero. In non-collusive groups, it is harder for entrants to make correct estimates and to learn. Also, groups that did not collude pre-entry hardly ever established collusion post-entry.

[18]The Spearman's rank correlation coefficient equals -0.47 and is significant at the 5 percent level.

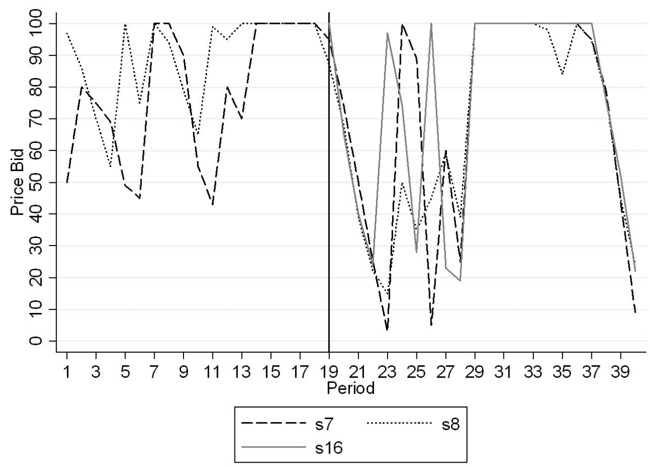

Figure 11: Price Bids in Group 2 of Session 4, Example of "Always Undercut" in a non-collusive Market

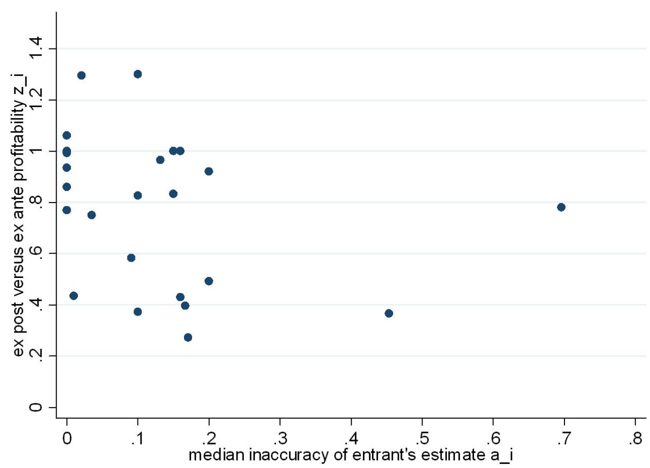

Figure 12: Relative Profitability versus Estimate Accuracy for all Entrant Treatment Groups

4.2 Behavior of Incumbents

This section presents the reaction of incumbents to entry analogous to Section 4.1 above. Table 4 shows that incumbents in both collusive as well as non-collusive markets match the price much more often than entrants. Analogous to the analysis of entrants, the reaction of incumbents in period 19 takes the price bid of the other incumbent in period 18 as a benchmark. Over 90 percent of the incumbents match in collusive markets while only 35 percent match in the non-collusive markets. An illustration of such a market is given in Figure 8. In collusive markets, undercutting and competing by incumbents is hardly observed. In non-collusive markets this occurs more often with 40 percent of incumbents either undercutting or competing. These observations are in line with empirical studies on reactions of incumbents to entry without a specific focus on collusive markets. Robinson (1988) and Yip (1982) find almost no reaction to entry by incumbents in the short-term. Cubbin and Domberger (1988) find only a reaction by incumbents in roughly a third of the cases. Moreover, Levenstein and Suslow (2004) find that in many industries cartels accommodated entrants. Entry was accommodated in cases such as the bromine cartel, the diamonds cartel, the potash cartel and the sugar cartel.

	Pre-Entry Market Behavior		
Reaction of Incumbent	Collusive	Non-collusive	All
Match	29 (91 percent)	7 (35 percent)	36 (69 percent)
Undercut	2 (6 percent)	4 (20 percent)	6 (11 percent)
Compete	1 (3 percent)	4 (20 percent)	5 (10 percent)
Signal	-	5 (25 percent)	5 (10 percent)
	32 (100 percent)	20 (100 percent)	52 (100 percent)

Table 4: Reaction of Incumbent in t=19 to Entry.

The reactions of incumbents in the first four periods after entry are more dispersed. Again, in the collusive markets the majority of incumbents always matches as illustrated in Figure 8. In the non-collusive markets, many of the incumbents undercut or compete a group of which is shown in Figure 9 where both incumbents s9 as wel as incumbents s10 compete. Other incumbents try to signal their willingness to collude. A group where this happens is depicted in Figure 10 where incumbents S14 signals both in period 19 and 20.

Observation 4 *In the first period after entry, the majority of incumbents match the price bid of the other incumbents, especially in markets that were defined as collusive prior to entry. In the longer run, incumbents from collusive markets mainly match whereas incumbents from non-collusive markets mainly either undercut or signal.*

	Pre-Entry Market Behavior		
Reaction of Incumbent	Collusive	Non-collusive	All
Always Match	18 (56 percent)	-	18 (35 percent)
Undercut/compete in at least 3 of 4	-	7 (35 percent)	7 (13 percent)
Signal 3 out of 4	-	5 (25 percent)	5 (10 percent)
Undercut/compete then Signal	4 (13 percent)	-	4 (8 percent)
Match, then signal	3 (9 percent)	-	3 (6 percent)
Other	7 (22 percent)	8 (40 percent)	15 (29 percent)
	32 (100 percent)	20 (100 percent)	52 (100 percent)

Table 5: Reaction of Incumbent in t=19 − 22 to Entry.

4.3 Initiators of Undercutting and Punishment by Group Members

In this section we take a closer look at markets where undercutting or competing takes place in the period after entry. We are particularly interested whether there is a pattern concerning who initiates undercutting and whether this depends on the type of market, that is whether the market is collusive or non-collusive.

In markets defined as collusive in the first subsession, undercutting or competing by either of the three players occurs in six markets of 16 markets. In four of these markets this was initiated by the entrant only. In one market, undercutting was initiated by the incumbents and in another market it was initiated by incumbents and entrant simultaneously.

In non-collusive markets, the picture is more mixed. Undercutting occurred in eight out of ten markets. In two out of ten markets, it is initiated simultaneously by entrants and incumbent(s), an example of which is shown in Figure 10. In three markets, it is the entrant who starts. In the remaining three markets, at least one incumbent starts to undercut. This happens in Group 5 of Session 2 shown in Figure 9 in which both incumbents compete.

As it is the participants in non-collusive groups who pull down the average market prices after entry as shown in Figure 3, it is interesting to analyze whether there is some pattern concerning competing between entrants and incumbents in these groups. In three groups, a total of five incumbents compete. Their average bid reduction compared to the market price in period 18 is 47 percent. Concerning the entrants, we can single out three of them who compete. Their average bid reduction however is only 18 percent. The fall in market prices after entry therefore mainly stems from competing incumbents in non-collusive groups.

As undercutting was often initiated by entrants, one would expect that incumbents in the corresponding markets, especially in the collusive ones, react by retaliating in the form of punishment. We define punishment as setting a price bid of one in the period after undercutting occurs. In collusive markets severe undercutting however only happens in a single market, in which one of the incumbents punishes an undercutting entrant in one period and then reverts to the fully collusive price bid in the following period. Punishing occurs more often in markets defined as non-collusive pre-entry. In two of three of those markets, an entrant initiates undercutting and one of the incumbents punishes in one period and reverts to full collusion in the following period. In the third market, an incumbent initiates undercutting (in period 18) and the other incumbent subsequently punishes for three consecutive periods before reverting to full collusion. This is illustrated in Group 5 of Session 2 shown in Figure 9.

Observation 5 *Undercutting or competing is often initiated by entrants, especially in collusive markets. In non-collusive markets, undercutting or competing by either entrants or incumbents is equally likely but it is mainly the incumbents who compete thereby causing the strong reduction in average market prices in the period after entry. Moreover, punishment occurs more often in non-collusive markets than collusive markets.*

5 Concluding Remarks

This research explores the effects of entry on firms' price decision and firms' incentive to coordinate their pricing strategies in concentrated markets. We show that groups that start off as duopolies and are extended to triopolies collude more compared to baseline groups that interact in groups of three from the very start of the experiment. We attribute this difference in treatments to collusion being easier to establish in smaller groups in which coordination on a common price is less difficult. Entrants who have observed the group's choices emulate their behavior upon entry. By transferring the implicit set of self-enforcing rules from the smaller to the larger group, collusion can be sustained after entry has occurred.

The results also suggest the existence of a coordination effect in collusion. This effect refers to the increased difficulty of coordination as more players need to agree to a common scheme of sharing the profits and is related to a higher level of strategic uncertainty with more players in a market. An alternative interpretation of our findings is therefore that the coordination problem can be alleviated if groups starts off in a small configuration first before they are enlarged.

Moreover, we identify some patterns concerning individual group behavior. The results suggest that entrants seem to imitate the mode of behavior of their group members upon entry: the majority of entrants joining collusive market collude as well thereby sustaining collusion. This gives further evidence for the self-enforcing rules argument discussed above. The majority of entrants in non-collusive markets reinforce competition by undercutting the price bid of incumbents. In addition, undercutting is often initiated by entrants, an effect which is particularly strong in collusive markets. Punishment occurs in these markets, but is rare.

The results of this study contribute to the existing literature on number effects such as Fouraker and Siegel (1963) as we show that the number effect is caused by a coordination problem inherent in larger groups which can be partially resolved by starting as a smaller group.

Moreover, the study adds to the findings of Weber (2006), as we show that the coordination problem can also be resolved in an oligopoly game in which the Pareto-efficient outcome of the stage game does not coincide with the Nash equilibrium. Moreover, in our setting subjects gain by deviating from the Pareto-efficient outcome of the stage game, an effect which is not present in the minimum effort coordination game studied in Weber (2006).

The results may also have some relevance with regards to policy matters. In coordinated effects analysis in merger control, our findings suggest that an analysis that purely focuses on the number of players, their market shares or HHI values may not suffice. It appears that it is important to also consider how a certain markets structure has formed over time. Tacit collusion might be sustainable in larger markets provided that they grow slowly enough. If a firm enters a mature, cartelized industry and knows the market, it could well be that this entrant simply joins the cartel, internalizing the collusive agreement so that tacit collusion can be sustained. Secondly, it suggests that entry as such does not necessarily have to be a destabilizing factor for cartels as is often claimed.

Further research could be done along the following dimensions. Firstly, it is interesting to study larger groups to see whether the coordination problem could still be overcome if groups contain more than three players. There could then be several points of entry. One could set up an experiment starting with two players gradually adding entrants until a group reaches its maximum size towards the end of the session. Another line of research could test the behavior of uninformed entrants, as this could help to explain the importance of entrant's information in bringing about collusion. It would also be interesting to explore the reverse treatment of reducing an existing triopoly to a duopoly to test whether the observed effects are symmetric.[19] This might have some implications for competition policy as the reduction of the number of firms can also be interpreted as a merger. Less coordination in the reduced groups may suggest that there is a lower risk of coordinated effects due to a merger. We will explore some of these dimensions in future studies.

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6 Appendix

6.1 Instructions Baseline

General

Welcome to this experiment on decision-making! Please read these instructions carefully. The experiment lasts 20 rounds. You can earn money in this experiment. The amount of money that you are able to earn depends on the decision you make as well as the decisions taken by the other persons in your group. You will receive an initial payment of 5 Euros. In addition, you can earn points with the decisions you make during the experiment. Your earnings in points each round will be summed up at the end of the experiment. You receive 1.50 Euros per 100 points you earned. At the end of the experiment the amount that you earned will be paid out to you in cash.

Neither you nor any other subject will be asked to reveal her/his identity during or after this experiment. Please keep your decisions private and note that communication with any other subject is not permitted during the experiment. If you have any questions, please raise your hand and an experimenter will come to your booth.

Roles of Subjects and Groups

You are randomly matched with two other persons at the beginning of the experiment. All subjects remain in the same group during the entire experiment. You will not be told which two other subjects you are matched with.

Sequence of Events and Tasks

In each round, each participant in your group is asked to choose a whole number between 1 and 100. The three numbers are compared and the group member who chose the lowest number gets points equal to the number she/he chose. The other group members will receive no points. In case of a tie of two group members, each of them gets half of the points they chose. In case of a tie of three group members, each of them gets a third of the points they chose.

For instance if the first group member chooses the number of 45, the second group member chooses the number 93 and the third group member chooses the number 51, the first group member receives 45 points and the second group member and the third group member receive 0 points. If the first and the second group member chooses the number of 22, and the third group member chooses the number 79, the first group member and the second group member receive 11 points and the third group member receive 0 points. If all three group members choose a price of 54, each of them gets 18 points.

Information for Subjects during the Experiment

When they submit their choice, from round 2 onwards, the participants will see the results of the previous round of their group. They will see their own choices, the number of the other participants in her/his group, her/his own points in that round and her/his total accumulated points up to that round.

Participants will also have a history table from round 2 onwards which shows the results of all preceding rounds of their group. It displays her/his own past numbers chosen, the numbers chosen by the other participants in her/his group, her/his past points gained and her/his past accumulated points up to that round.

GOOD LUCK WITH THE EXPERIMENT!

6.2 Instructions for Incumbents in Entrant Treatment

General

Welcome to this experiment on decision-making! The experiment lasts 40 rounds. You can earn money in this experiment. The amount of money that you are able to earn depends on the decision you make as well as the decisions taken by the other persons in your group. You will receive an initial payment of 5 Euros. In addition, you can earn points with the decisions you make during the experiment. Your earnings in points each round will be summed up at the end of the experiment. You receive 1.50 Euro per 100 points you earned. At the end of the experiment the amount that you earned will be paid out to you in cash.

Neither you nor any other subject will be asked to reveal her/his identity during or after this experiment. Please keep your decisions private and note that communication with any other subject is not permitted during the experiment. If you have any questions, please raise your hand and an experimenter will come to your booth.

Roles of Subjects and Groups
You are randomly matched with two other persons at the beginning of the experiment. This group consists of two subjects, called Starters, who participate in the group from the start of the experiment. The other subject, called Entrant, joins the group in a randomly chosen round between round 15 and round 25 and will participate in this group until the end of the experiment. In this experiment you are a Starter. All subjects remain in the same groups in this experiment. You will not be told which two other subjects you are matched with.

Sequence of Events and Tasks

Before Entrant enters

Decisions of Starters

In each round, the two Starters are asked to choose a whole number between 1 and 100. The two numbers chosen are then compared and the Starter who chose the lowest number makes earnings in points equal to the number she/he chose. The other Starter will get no points. If both Starters choose the same number the points are split equally between them.

For instance, if one Starter chooses the number 44 and the other Starter chooses the number 89, the first Starter gets 44 points and the second Starter gets nothing. If both Starters choose the number 16, for instance, both will get 8 points.

The Entrant will observe the round results of her/his group in each round before she/he enters. In each round, she/he will see the numbers chosen by the two Starters.

After Entrant enters

Immediately before the round in which the Entrant enters, both the Starters and the Entrant are informed about the fact that entry takes place by a message on their computer screen. The following round then starts and the group members again have to choose a number in each round except that there are now three active group members, the two Starters and the Entrant, that have to choose a price. As before, in each round, until the end of the experiment, each group member chooses a number. The three numbers are compared and the group member who chose the lowest number gets points equal to the number she/he chose. The other group members will receive no points. In case of a tie of two group members, each of them gets half of the points they chose. In case of a tie of three group members, each of them gets a third of the points they chose.

For instance if the first Starter chooses a price of 45, the second Starter chooses a price of 93 and the Entrant chooses a price of 51, the first Starter receives 45 points and the second Starter and the Entrant receive 0 points. If all three group members choose a price of 36, each of them gets 12 points.

Information for Subjects during the Experiment

Starters

Before Entry

When they submit their choice, from round 2 onwards, the Starters will see the results of the previous round of their group. They will see their own choices, the number of the other Starter, her/his own points in that round and her/his total accumulated points up to that round. Starters will also have a history table from round 2 onwards which shows the results of all preceding rounds of their group. It displays her/his own past numbers chosen, the numbers chosen by the other Starter, her/his past points gained and her/his past accumulated points up to that round.

After Entry

After entry Starters will have the same screens when they make their entry. They will see the results of the last round as well as a history table showing all results so far. Starters also see the choices made of the entrant in their group after entry. This is shown in the last round results and the history table.

Entrants

Before Entrant enters

Before joining their group, Entrants will see the numbers chosen by each

Starters of their group in each round on their computer screens.

After Entrant enters

After the Entrants entered their group, the Entrants will have the same screens as the Starters. They will see their own choices, the choices of the 2 Starters in their group and their own earnings.

GOOD LUCK WITH THE EXPERIMENT!

6.3 Instructions for Entrants in Entrant Treatment

General

Welcome to this experiment on decision-making! The experiment lasts 40 rounds. You can earn money in this experiment. The amount of money that you are able to earn depends on the decision you make as well as the decisions taken by the other persons in your group. You will receive an initial payment of 5 Euros. In addition, you can earn points with the decisions you make during the experiment. Your earnings in points each round will be summed up at the end of the experiment. You receive 1.50 Euro per 100 points you earned. At the end of the experiment the amount that you earned will be paid out to you in cash.

Neither you nor any other subject will be asked to reveal her/his identity during or after this experiment. Please keep your decisions private and note that communication with any other subject is not permitted throughout the course of the experiment. If you have any questions, please raise your hand and an experimenter will come to your booth.

Roles of Subjects and Groups

You are randomly matched with two other subjects in the beginning of the experiment. This group consists of two subjects, called Starters, who participate in the group from the start of the experiment. The other subject, called Entrant, joins the group in a randomly chosen round between round 15 and round 25 and will participate in this group until the end of the experiment. Immediately before the start of the experiment, you receive a message on the screen informing you whether you are a Starter or an Entrant. All subjects remain in the same groups in this experiment. You will not be told which two other subjects you are matched with.

Sequence of Events and Tasks

Before Entrant enters

Decisions of Starters

In each round, the two Starters are asked to choose a whole umber between 1 and 100. The two numbers chosen are then compared and the Starter who chose the lowest number makes earnings in points equal to the number she/he chose. The other Starter will get no points. If both Starters choose the same number the points are split equally between them.

For instance, if one Starter chooses the number 44 and the other Starter chooses the number 89, the first Starter gets 44 points and the second Starter gets nothing. If both Starters choose the number 16, for instance, both will get 8 points.

Decisions of Entrants

The Entrant will observe the round results of her/his in each round before she/he enters. In each round, she/he will see the numbers chosen by the two Starters.

Before joining her/his group, an Entrant has to submit an estimate of the minimum number chosen by her/his group in each round. Her/his earnings in each round depend on the difference between this estimate and the realized minimum number in her group. If the entrants estimate is within 20 percent of the actual minimum number then she/he will receive the average earnings of his group in this round. If not he/she will earn nothing in this round.

For example, if one Starter chooses 78, the other Starter chooses 89, the minimum number is 78. If the estimate equals 34, the Entrant will receive no points in that round. If one Starter chooses 30, the other Starter chooses 69, the minimum equals 30. If the estimate equals 33, the difference is 3 and falls within the 20 percent estimation error and her/his earnings are (30+0)/2=15.

Sequence of Events and Tasks

After Entrant enters

Immediately before the round in which the Entrant enters, both the Starters and the Entrant are informed about the fact that entry takes place by a message on their computer screen. The following round then starts and the group members again have to choose a number in each round except that there are now three active group members, the two Starters and the Entrant, that have to choose a price. As before, in each round, until the end of the experiment, each group member chooses a number. The three numbers are compared and the group member who chose the lowest number gets points equal to the number she/he chose. The other group members will receive no points. In case of a tie of two group members, each of them gets half of the points they chose. In case of a tie of three group members, each of them gets a third of the points they chose.

For instance if the first Starter chooses a price of 45, the second Starter chooses a price of 93 and the Entrant chooses a price of 51, the first Starter receives 45 points and the second Starter and the Entrant receive 0 points. If all three group members choose a price of 36, each of them gets 12 points.

Information for Subjects during the Experiment

Starters

When they submit their choice, from round 2, onwards the Starters will see the results from that round of their group. They will see the number they chose in that round, the number of the other active group member(s), her/his own points in that round and her/his total accumulated points up to that round.

Starters will also have a history table from round 2 onwards which shows the results of the last rounds. It displays her/his own past numbers chosen and the numbers chosen by the other group member(s), her/his past points gained and her/his past accumulated points up to that round. (Note that the numbers displayed in this example are randomly generated by the computer. They provide no guidance as to how you should choose your numbers).

Entrants

Before Entrant enters

Entrants will watch the choices of the Starters in each round their computer screens before they join the group on.

After Entrant enters

After the Entrants entered their group, the Entrants will have the same screens as Starters.

GOOD LUCK WITH THE EXPERIMENT!