To appear in: **INTERNATIONAL ECONOMIC REVIEW**

Communication and Market Sharing: An Experiment on the Exchange of Soft and Hard Information

Andreas Freitag, Catherine Roux, and Christian Thöni[1]
University of Basel; University of Basel; University of Lausanne

Abstract

We study the role of communication in collusive market sharing. In a series of Cournot oligopoly experiments with multiple markets, we vary the information that firms can exchange: hard information—verifiable information about past conduct—and soft information—unbinding information about future conduct. We find that the effect of communication on the firms' ability to collude depends on the type of information available: while market prices increase only slightly with hard information the price raise due to soft information is substantial. Our results point to the types and contents of communication that should be of particular concern to antitrust authorities.

JEL Classification: C91, L13, L41
Keywords: Collusion, Market Sharing, Cournot Oligopoly, Information, Communication, Experiments

[1]We thank Masaki Aoyagi, three anonymous referees, Miguel Brendl, Aaron Edlin, Miguel Fonseca, John Mayo, João Montez, Georg Nöldeke, Hans-Theo Normann, Luís Santos-Pinto, and Alois Stutzer, as well as audiences at various seminars and conferences for valuable comments and discussions. The usual disclaimer applies. This research project is part of the Swiss Competence Center for Energy Research SCCER CREST of the Swiss Innovation Agency Innosuisse. Financial support from the SNSF (grant no. 100018_182185) is gratefully acknowledged. Please address correspondence to: Catherine Roux, Faculty of Business and Economics, University of Basel, Peter Merian-Weg 6, 4002 Basel, Switzerland. E-mail: catherine.roux@unibas.ch

1 Introduction

What role does communication play in collusive market sharing? We study this question in a laboratory experiment. Our findings suggest that the effect of communication on market sharing depends on the type of communication involved: while non-binding one-time communication on future planned conduct can establish market sharing almost perfectly, the exchange of disaggregated information on recent past behavior—which allows the identification and selective punishment of deviators—increases market prices only slightly. Antitrust rules condition enforcement on information that is observable and verifiable in court. Therefore, evidence on whether firms communicated serves as a smoking gun in antitrust procedures against collusion. To understand which type of communication carries the highest collusive potential is thus central for the design of effective antitrust rules.

Market sharing is a collusive practice prohibited by the European Community competition rules.[2] A market sharing agreement typically determines exclusive territories along geographical borders, the so-called home markets. The colluding firms refrain from entering each other's home market with the result that each market remains insulated from the others. Market sharing agreements jeopardize the unity of a common market and, thus, the European Commission (EC) takes a particularly tough stance on these arrangements.[3]

Evidence on interfirm communication and explicit agreements is crucial for the antitrust enforcement against collusive practices because it makes anticompetitive contacts between firms visible and verifiable in court and thereby facilitates legal prosecution. Despite this fact, colluding firms commonly engage in incriminating communication, and they do so even in the face of large monetary fines (see, e.g., Genesove and Mullin, 2001; Harrington, 2006; Levenstein and Suslow, 2008; Hyytinen et al., 2019). Hence, commu-

[2]We follow the terminology of Belleflamme and Bloch (2004, 2008): by 'market sharing', we designate the reciprocal collusive agreement in which each firm is assigned monopoly rights over a market to distinguish it from 'production quotas' where the firms jointly restrict output within a market. Other names for these arrangements are to be found in the literature, e.g., spheres of influence and multimarket contact (Bernheim and Whinston, 1990), collusion at the extensive and intensive margin (Byford and Gans, 2014), collusion with and without trade (Lommerud and Sørgard, 2001; Colonescu and Schmitt, 2003; Bond and Syropoulos, 2008), exclusive territories and sales quotas (Harrington, 2006).

[3]In a landmark case, the two major producers of soda ash, Solvay and ICI, were sanctioned with the largest antitrust fine imposed by the EC at that time (1990) for having operated a market sharing agreement. The EC found the firms guilty of having confined their soda ash activities to their traditional home markets, with Solvay supplying continental Western Europe and ICI serving the United Kingdom, during at least 17 years (EC IP/90/1057 and OJ L 152, 1991).

nication must be a valuable tool for establishing collusive agreements. Although interfirm communication has recently attracted substantial attention from economic researchers, we still know little about what type of communication facilitates collusion.[4]

According to European case law, communication between firms is more likely to be considered harmful if (i) the information exchanged is firm-specific rather than aggregated, (ii) is concealed from customers and potential entrants, and (iii) concerns either recent conduct or future plans in relation to pricing and supply (Kühn, 2001). Information on recent behavior and decisions is considered as "hard" because it is in principle available and verifiable for the parties. In contrast, communication about planned future market conduct conveys information that is "soft" in the sense that it is unbinding and about intentions, which are not verifiable at the time the firms take their decisions (Kühn, 2001, p. 170). Communication of soft information is known as cheap talk in economic theory. Cheap talk can enhance collusion when it helps firms resolve the strategic uncertainty that typically occurs in games with multiple equilibria (Farrell, 1987).[5] While the impact of cheap talk in pure coordination games (like the battle of the sexes) is well established in the literature, its effect in oligopoly games is subject to debate among economic theorists (Farrell and Rabin, 1996; Whinston, 2008).

Regarding the exchange of hard information, Stigler (1964) argued that it can facilitate collusion very effectively. The heart of Stigler's argument is that to detect and punish deviations from a collusive agreement, firms must be able to monitor their co-conspirators' actions. This ability to monitor makes punishment a credible threat that disciplines the cartel members.[6] Stigler's work has inspired antitrust policy on information exchange between firms. Accordingly, the EC distinguishes between the exchange of aggregate industry and that of individual firm data:[7] while it does not object the

[4]A recent focus is on the precise content of communication that supports collusion. For example, Harrington et al. (2016) compare the collusive effects of price announcements with those of unrestricted communication. Fonseca et al. (2018) and Fischer and Normann (2019) use text mining to understand what kind of language is most useful to supporting collusion.

[5]See, e.g., Cason (1995) for a discussion of cheap talk in collusion in relation to the antitrust investigation around the tariff publishing system in the U.S. airline industry where airlines were alleged to use non-binding price signals to raise fares.

[6]Green and Porter (1984) show that imperfect observability of rivals' past actions makes collusion more difficult in the sense that temporary price wars are needed to sustain collusion. Abreu et al. (1986) extend Green and Porter (1984)'s model to include optimal punishment strategies. Kandori (1992) shows that the set of equilibria increases towards more collusive outcomes when observability improves. Aoyagi and Fréchette (2009), and Aoyagi et al. (2019) provide corresponding experimental evidence.

[7]See Kühn and Vives (1995) for a detailed analysis of the EC's competition policy

exchange of information on sales and production as long as the data does not allow to identify individual firms, the EC has taken the stance in various antitrust decisions that the publication of individualized data would make markets artificially transparent and, thereby, less competitive.[8]

In the present paper, we examine the effect of both types of information—hard and soft—on collusion in an environment with multiple markets. A priori, it is unclear whether, and if so, to what extent communication helps collusion in such an environment. On the one hand, the presence of multiple markets exacerbates the problem of equilibrium selection in games with repeated interactions: firms can collude by either sharing markets along the "home market principle" (Harrington, 2006, p. 24) or jointly restricting supply (establishing quotas) within each of the markets. Soft information may be essential for reducing strategic uncertainty in this context. On the other hand, the existence of home markets offers firms a straightforward way of coordination in the form of market sharing. If market sharing serves as a strong focal point firms may be able to collude without communication (Motta, 2009).

The effect of hard information is also difficult to assess without further study. Intuitively, the exchange of hard information on individualized firm data may be effective in the sense of Stigler (1964). It enables firms to identify and selectively punish a deviating firm in its home market. Targeted punishment has been shown to effectively stabilize collusion in single-market oligopolies (Roux and Thöni, 2015). In a multimarket context, punishment by hitting the cheater in its home market may be particularly attractive as it preserves the collusive relationship with the abiding firms and therefore prevents a general price war and the ensuing breakdown of the entire collusive network (Proctor, 2014).[9] In the absence of information that identifies the deviator, selective punishment is not feasible.[10] But exactly because punish-

regarding information exchange.

[8]See, e.g., the decisions on *UK Agricultural Tractors Exchange* (OJ L 20, 1993), *Fatty Acids* (OJ L 3, 1987). Market transparency is also an important element in the assessment of coordinated effects in merger reviews: the likelihood of tacit collusion in the aftermath of a merger is seen as directly related to the firms' ability to monitor the other firms in the market (EU Guidelines on the Assessment of Horizontal Mergers, 2004, paragraphs 49–51).

[9]In the theory of single-market collusion in repeated games, deviations from a collusive agreement are punished with a reversion to static Nash conditions which hits not only defectors, but all members of the collusive agreement (Friedman, 1971; Green and Porter, 1984; Abreu, 1988).

[10]In Verboven (1998)'s oligopoly model with localized competition, the firms' inability to impose selective punishments is at the heart of their 'communication problem' which makes the use of information exchange mechanisms for collusive purposes worthwhile.

ment can be targeted specifically at the aggressor, collusion may become less stable. Targeted punishment decreases not only the cost of retaliation but also the cost of a deviation (Byford and Gans, 2014).

We report evidence on a series of Cournot oligopoly experiments with multiple markets and repeated interaction. We have a two-by-two factorial design, varying the availability of hard and soft information. In the treatments with hard information, after each period, the players get disaggregated feedback on their rivals' individual supply in that period. Without hard information, in contrast, this feedback is sufficiently aggregated such that the identification of individual behavior is impossible. In the treatments with soft information, the players can engage in one-time free-form communication via a chat in the middle of the game.

Our main motivation to use a laboratory experiment is that it is difficult to get insights into our research question with field data: first, an experimental investigation avoids the sample-selection problems that empirical cartel studies usually face (Posner, 1970). Second, even if we were to observe all existing cartels, we could hardly ever learn about which type of information contributed to what degree to their stability. Finally, running an experiment allows us to effectively control the availability and timing of the information as well as to observe the communication content and its effects.

We can summarize our main results as follows. First, we find that soft information establishes collusion almost perfectly. The chat protocols reveal that the subjects primarily talk about agreements and promises on future conduct which, in theory, are regarded as cheap talk and thus, in principle, without any effect on market outcomes. In our experiment, it turns out that it is exactly this information that carries a strong potential for collusion, especially if it helps firms to agree on a future course of action. This finding is in line with the argument that the exchange of soft information can help to resolve strategic uncertainty. Second, we find that the exchange of hard information tends to help collusion in our experiment. Compared to the impact of soft information, however, this effect seems to be rather small. Third, we find that the key driver behind the strong effect of soft information on collusive success is the explicit consent to a future course of action stated by all group members during the chat.

The remainder of this paper is organized as follows. Section 2 overviews related literature. Section 3 describes the experimental design. Section 4 explains our hypotheses. Section 5 discusses our results. Section 6 briefly concludes.

2 Related Literature

Our paper is closely related to the literature on market transparency that studies whether more information about opponents' recent actions yields less competitive market outcomes. Overall, this literature is inconclusive. While there is some empirical support for Stigler's argument, oligopoly experiments provide mixed results.[11] Davis and Holt (1998) study the impact of discount possibilities on explicit collusion in posted-offer markets. When discounts can be somewhat inferred from ex-post sales information that is given to the market participants, prices and profits are higher than if this information is absent and discounts are secret. Huck et al. (2000) are first to test the impact of the level of information aggregation on the competitiveness of oligopoly markets in a laboratory experiment. They run two treatments: in one, subjects are given information on their opponents' individual actions—prices or quantities—and profits. In the other, subjects receive only aggregate information—average quantities or prices. The authors find that the availability of individualized information makes markets *more* competitive. They explain this finding with the argument advanced by Vega-Redondo (1997): the publication of individual data increases the competitiveness of markets if it allows firms to imitate their most successful rivals which tend to be those that produce the largest quantity. The findings of Huck et al. (1999), Offerman et al. (2002), and Altavilla et al. (2006) are in line with this argument. Gomez-Martinez et al. (2016) find further support for the imitation hypothesis depending on whether the market environment is competitive or not. Huck et al. (2000) as well as Gomez-Martinez et al. (2016) consider a single-market environment where the demand realization is perfectly observed. In such a framework without any uncertainty, firms can make inferences about their rivals' recent actions based on their past realized profits even if information is aggregated. An unexpectedly low price or high output by a deviating firm would be inferred by all other firms in the market because they would all suffer from a profit reduction. Additional information on each rival's individual actions make a difference insofar as it enables firms to impose selective punishments on the deviators. In a single-market framework, however, such selective punishment is not feasible, unless firms find ways to target punishment towards other firms by means other than prices or quantities (Roux and Thöni, 2015). In our setting with multiple markets, this is different: only individualized information makes the identification and selective punishment

[11] See Albæk et al. (1997) for direct evidence, Levenstein and Suslow (2006) for indirect evidence on joint sales agencies and trade associations, and Potters (2009) for a comprehensive review of the experimental literature on the effect of transparency on the competitiveness of markets.

of deviators possible.[12]

Our analysis echoes the findings of the experimental literature on communication in oligopoly games. These studies show that communication helps collusion, including Daughety and Forsythe (1987); Waichman et al. (2014); Normann et al. (2005); Gomez-Martinez et al. (2016) for Cournot and Andersson and Wengström (2007); Fonseca and Normann (2012, 2014); Cooper and Kühn (2014); Harrington et al. (2016) for Bertrand games. The main difference between our work and this experimental literature is twofold: first, we consider multiple markets. We build on the design by Roux et al. (2016) who use a two-firm two-market setup to study the home bias in international trade. The multimarket setting allows us to study how firms coordinate behavior across markets (rather than within a single market) and to investigate when and to what degree communication helps them to achieve this coordination. In addition to colluding on the intensive margin, a multimarket environment offers the possibility to enter or exit markets, which opens up a broader range of collusive strategies.[13]

Second, while our subjects interact repeatedly, they communicate only once, halfway through the game. We can thus investigate whether soft information has a lasting effect. To our knowledge, there are virtually no oligopoly experiments with one-time communication.[14] Usually, the communication possibility recurs every period (as e.g., in Fonseca and Normann, 2012) or at regular intervals (e.g., every five periods in Gomez-Martinez et al., 2016).

Finally, our paper is related to the literature on market sharing. Although the globalization of markets and the deregulation of industries which used to be regulated on a territorial basis have continuously increased the scope of market sharing over recent years, only few studies examine this collusive practice. These studies theoretically analyze the conditions under which market sharing agreements are stable (e.g., spheres of influence in Bernheim and Whinston (1990), stable and efficient networks in Belleflamme and Bloch (2004)) and, in particular, more stable than quota agreements (e.g., market

[12] In a recent empirical study, Bhaskarabhatla et al. (2016) document on the importance of targeted punishment in the cartel of retail pharmaceutical traders in India.

[13] A related strand of research investigates entry and exit in an experiment where firms have the choice between a number of markets (Gächter et al., 2006), or where firms can contest an existing monopoly market by entering (Edlin et al., 2019).

[14] Notable exceptions are Cooper and Kühn (2014) and Fischer and Normann (2019). They consider one-time communication prior to the start of each of several supergames (respectively proxies for supergames) with stranger rematching between the games. The long-run effect of communication on price setting behavior has been studied by Fonseca and Normann (2012) using a within-subject design. The authors find that even after communication is disabled the cooperation rate remains high. Before communication stops, subjects can talk every period though.

sharing rather than production quotas in Belleflamme and Bloch (2008), and mutual avoidance rather than multimarket contact in Byford and Gans (2014)). Our experimental setup can be seen as capturing a special case of Byford and Gans (2014) with symmetric firms, no trade cost, and no separate entry stage. We rely partly on this study to derive our hypotheses in Section 4. Apart from carefully documented case evidence (e.g., Harrington, 2006), we are not aware of any systematic empirical or experimental study on the topic.

3 Experimental Design and Procedures

We analyze Cournot oligopoly markets with constant marginal costs of production and no fixed costs. There are three symmetric firms that can produce in three equal-sized markets. In the stage game, the firms simultaneously and independently choose quantities for the production of a homogeneous good. Their action sets are numbers between 0 and 74 with 0.1 as the smallest increment. In each market, the price is determined by the same linear market demand $p = \max\{74 - \sum_{i=1}^{3} q_i, 0\}$. The marginal cost of production is equal to 2, and there are no fees attached to market entry.

In the static Nash equilibrium of this game, each firm offers $q_i^N = 18$ in each market, such that the total quantity per firm is equal to $Q^N = 54$. The joint-profit maximizing solution requires monopoly quantities $Q^C = 36$ in all markets. The allocation of the three firms' quantities to markets is indetermined, but our results strongly suggest two focal solutions: (i) market sharing, in which each firm serves only one market with Q^C, and (ii) production quota, in which each firm offers a third of Q^C in each market.

Our main treatments feature the same number of markets and firms. In two additional experiments we expand the findings. First, we investigate whether our results are driven by the symmetry of firms and markets and study a setting with three firms and four markets (with identical parameters as in the main treatments). Second, we test whether the multimarket context of our design is particularly favorable to collusive outcomes. To do this we ran treatments where three firms face a single market. The single market is payoff equivalent to the three markets of our main treatments: firms face a demand of $p = \max\{74 - \frac{1}{3}\sum_{i=1}^{3} q_i, 0\}$, and in the symmetric Nash equilibrium each firm offers $q_i = Q^N$ and earns the same profit as in the treatments with three markets. The symmetric collusive outcome is achieved when all firms offer Q^C, and payoffs are again identical to the collusive outcome with three markets. In contrast to the situation with multiple markets, the single-

Table 1: Experimental treatments and observations

		Soft information	
		not available	available
Hard information	not available	*NoInfo* (90; 30; −)	*SoftInfo* (57; 27; 30)
	available	*HardInfo* (96; 30; −)	*FullInfo* (57; 30; 30)

Notes: Numbers in parentheses show the observations in the treatments with (3 markets; 4 markets; 1 market). In all experiments, group size is three such that the numbers divided by three corresponds to the number of independent observations. Sessions were typically run with 24 to 30 subjects, except for the experiments with three markets, where two sessions in *NoInfo* and one in *HardInfo* were run with 12 to 15 subjects.

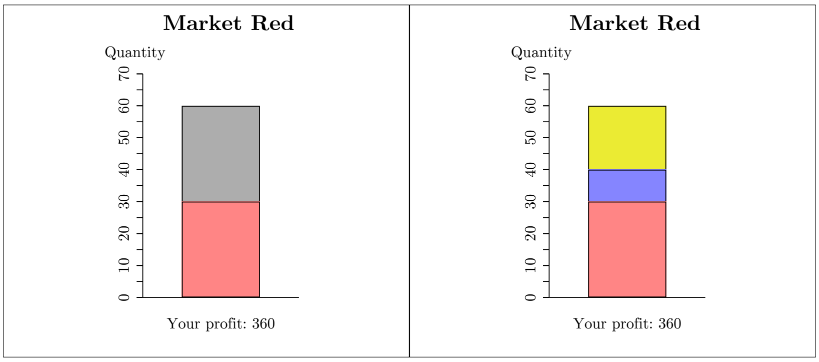
market design has the property that the fully collusive solution is unique.[15] For all treatments and markets it holds that the collusive price is $p^C = 38$ and the static Nash-equilibrium price is $p^N = 20$.

We apply a between-subjects design, i.e., each subject participates only in one treatment. A treatment consists of 20 periods of the stage game. We opted for a finite horizon game (instead of using a random continuation rule) because it is simpler to implement and we do not have to deal with different durations of the supergame in the analysis. On the other hand, the levels of collusion observed in our design may be lower due to the anticipation of end-game effects.[16] At the end of each period, subjects are informed about their rivals' output and their own profits in all markets. In the beginning of the experiment, subjects are randomly allocated to groups of three, and the group composition remains constant across the 20 periods (partner matching). In

[15] More precisely, while all strategy combinations with a total quantity of $3Q^C$ are joint-profit maximizing in the single-market game, there is only one solution which offers equal profits to all firms.

[16] Theoretical models of collusion require infinite repetition which can be simulated in the experiment by a random continuation rule (Dal Bó, 2005; Dal Bó and Fréchette, 2018). It is often observed in experiments that if the time horizon is long enough, subjects behave as if the time horizon was infinite (Selten and Stoecker, 1986; Normann and Wallace, 2012). Dal Bó (2005), on the other hand, finds that the "shadow of the future" (p. 1591) affects subjects' behavior and leads to higher levels of cooperation throughout the game. The recent literature on the effectiveness of information/communication for collusion uses both finite repetition (Gomez-Martinez et al., 2016; Huck et al., 2000) and infinite repetition (Fonseca and Normann, 2012; Harrington et al., 2016).

Figure 1: Screenshot quantity feedback.



Notes: Excerpt from the screen displayed at the end of each period informing the red firm about the outcome in the red market. Left panel: hard information is not available (lower part is red, upper part is gray); right panel: hard information is available (lower part is red, upper parts are blue and yellow).

all treatments, each firm is identified by a different color (yellow, red, and blue). In the main treatments, each market is also assigned one of these three colors. The colors are exogenously determined and stay the same during the 20 periods and are observed by the three players. In the treatments with four markets, we add an additional market with the color purple. In the treatment with one market, there is only a single market with the color purple.

Our main treatment variables are the availability of hard and soft information. Table 1 summarizes the design and the number of observations. Hard information refers to the observability of individual market shares. The treatments differ with respect to the information firms receive at the end of each period. Figure 1 shows a part of the feedback screen in which a firm is informed about the quantities in one of the three markets (for the full screen see the instructions in Appendix A.4). The bars indicate the total quantity offered. The left panel shows the case where hard information is not available, as only the firm's own quantity is highlighted in the firm's color, while the remaining part is gray. When hard information is available the bar is divided into three parts, whereby each color reflects the respective firm's quantity (right panel). Consider a situation where other firms invade a firm's market. In the treatment without hard information, it is impossible to tell which other firm is present in the market, whereas hard information permits to identify the invader(s).

The second treatment variation is implemented as a free-form communication among the three firms. In the treatments with soft information, subjects are allowed to communicate with the other firms in their group. Communication is a one-time event. In between periods ten and eleven, a chat window opens for three minutes, and, during this time, subjects are free to post as many messages as they like. The exception being that subjects are not allowed to identify themselves or to post offensive messages. Subjects are also aware that they talk to their group but that no one outside the group can see the messages they post. We chose free-form communication as it is the least invasive regarding experimenter demand effects and proved very effective to establish collusion in previous experiments (e.g., Fonseca and Normann, 2012; Cooper and Kühn, 2014; Gomez-Martinez et al., 2016; Harrington et al., 2016). Subjects are informed in the written instructions about the existence, the timing, and the exact circumstances of the chat possibility.

The numbers in parentheses in Table 1 indicate the number of subjects for a given treatment and for the experiments with three, four and one markets. The main treatments with three markets and the treatments with four markets were run in all four information conditions. The treatments with one market we ran with soft information only, as the main purpose was to investigate the degree of collusive behavior relative to the treatments with multimarket contact in the conditions which actually permit collusion.

Our previous experience with oligopoly experiments in a multimarket environment (Roux et al., 2016) has shown that the complexity of the environment is quite demanding on the subjects. For the study at hand, we therefore chose to start the experiment with a phase of closed markets. During the first five periods each firm is restricted to offer only in its home market, identified by having the same color as the firm.[17] Aside from allowing subjects to optimize their behavior in a non-strategic environment, this design also resembles the early days of the European Union before liberalization and the open common market. In periods six to ten, all markets are open to all firms. In these periods, subjects have, depending on the treatment, access to hard information or not. The treatments with and without soft information are identical in this phase (barring possible anticipation effects caused by the upcoming chat). In between periods ten and eleven, a screen appears which informs players about their own average profits achieved over the periods one to five and six to ten respectively. After 45 seconds, this screen disappears and play continues.[18] In the treatments with soft information, subjects then

[17]In the treatments with four markets, subjects know about the existence of a fourth market from the start, but during the first five periods no firm can serve the fourth market. In the treatments with one market, there are three monopoly markets in periods one to five (identical to the main treatment), after which all firms switch to the single market with the flatter demand function.

[18]The first two sessions of each of the two treatments without soft information were run without this information screen. We reran the experiment including the information screen to ensure equivalence between the treatments with and without soft information.

enter the chat stage before moving on to period eleven. The chat window is open for 180 seconds. In the chat, subjects are identified by their color. Our main focus in the analysis will be on the second half of the experiment, i.e., periods 11 to 20. This is the phase where we can observe the impact of both soft information—agreements in the chat—and hard information—feedback about individual market shares. The length of the closed market phases as well as all game parameters and the chat (if applicable) are common knowledge before the experiment starts.

The sessions of the main experiments with three markets were run in the WiSo experimental research laboratory of the University of Hamburg between April and August 2017 and were programmed in z-Tree (Fischbacher, 2007); recruitment by hroot (Bock et al., 2014). The additional sessions with four and one market were run at the same location between March and May 2019. Subjects were randomly allocated to computer terminals in the laboratory so that they could not infer with whom they would interact. Throughout the experiment, direct communication was not allowed. We provided written instructions which informed the subjects of all the features of the markets (Appendix A.4). We used an economic framing where we explained the strategic situation in terms of firms, prices, and quantities (as in, e.g., Huck et al., 2004). Prior to the start of the treatment, subjects had to answer control questions. When answering the control questions and when choosing their actions during the game, subjects had access to a payoff calculator allowing them to calculate the payoff of hypothetical combinations of their actions and the actions chosen by their competitors.

For the profits during the experiment, we used an experimental currency unit called talers. The payments to the subjects consisted of a 5 euros show-up fee plus the sum of the profits over the course of the experiment. Losses, if they occurred, were deducted from the show-up fee. The sessions lasted for about 75 minutes, and the average earnings were about 16 euros (standard deviation: 3, range from 8 to 26). We conducted twelve sessions with a total of 300 participants. The subjects were undergraduate students from the University of Hamburg.

4 Hypotheses

We begin with the impact of soft information on the firms' ability to collude. Based on the experimental literature on communication in single-market oligopoly games, which shows that free-form communication facilitates col-

The data suggests that the information screen did not affect the quantity choices of the firms. For the analysis, we will pool the data.

lusion (e.g., Fonseca and Normann, 2012; Waichman et al., 2014; Fischer and Normann, 2019), we expect that soft information leads to more collusive outcomes.

Hypothesis 1. *Prices are higher when soft information is available.*

Whether the effect of soft information should be stronger or weaker compared to single-market oligopoly games seems less clear. Unlike previous studies, we consider an environment that offers firms a straightforward way of coordination in the form of market sharing. Market sharing may serve as a strong focal point (Motta, 2009), such that firms may be able to collude even without communication. Soft information may then become less effective compared to single-market environments.[19] At the same time, the complexity of the environment increases with the number of markets. Soft information may then be particularly helpful in reducing strategic uncertainty.

Next, we consider the impact of hard information on collusion. In the spirit of Stigler (1964), hard information helps firms to monitor adherence to the agreement and may thus facilitate collusion. At the same time, hard information enables firms to use selective punishments and, according to the theoretical model of Byford and Gans (2014), if hard information has an effect at all, it destabilizes market sharing: in their baseline environment with perfect information, firms can achieve the most robust collusive equilibrium by using the strongest enforcement possible, that is, a permanent reversion to the static Nash equilibrium in all markets in response to any deviation from market sharing (grim trigger). Hence, firms do not target their punishment, even if they could, and hard information becomes irrelevant. In an environment with uncertainty, where firms happen to violate collusive terms by mistake, temporary punishment is less costly than punishment involving permanent reversion to competition. In this case, a firm may find it optimal to target its punishment exclusively towards the firm that violated the agreement. Suppose that the firms agree on market sharing, and firm 2 deviates and enters firm 1's market. Instead of reverting to the static Nash quantities in all markets, firm 1 can lower the costs of punishment by entering only firm 2's market and spare firm 3. However, while targeting the punishment towards firm 2 that violated the agreement lowers the cost of punishment for firm 1, it also lowers the costs of deviation for firm 2 in the first place. The punishment threat increases but its strength decreases. With our parameters, for example, a perfectly colluding firm earns a profit of 1296, and the static

[19] The theory of focal points dates back to Schelling (1960) and, with its discussion in Scherer (1967), motivated a great number of empirical and experimental investigations in industrial economics (e.g., Isaac and Plott, 1981; Smith and Williams, 1981; Knittel and Stango, 2003; Lewis, 2015; Byrne and De Roos, 2019).

Nash profits are 972 (grim trigger punishment in all markets). When punishment is targeted towards firm 2, both firm 1 and firm 2 earn the duopoly profits in both markets summing up to 1152. It turns out that, if anything, a cartel utilizing targeted enforcement is less stable than a cartel that cannot use these strategies (Byford and Gans, 2014, Proposition 5, p. 81). As the above theoretical accounts do not allow us to come up with a unidirectional hypothesis on the effect of hard information, we formulate an exploratory research question (ERQ):

ERQ 1. *How does hard information affect market prices?*

We now turn to our additional treatments where we let the three firms compete on four markets. This setting offers no symmetric market sharing outcome and firms will—even if they agree to stay away from their respective home markets—meet on the fourth market. We conjecture that this interaction on the fourth market will make it less likely that the firms reach and maintain collusion:

Hypothesis 2. *Prices are lower in the treatments with four markets than in the treatments with three markets.*

For the treatments with a single market, we have no clear prediction for the overall degree of collusion. On the one hand, the fact that the game lacks the obvious focal solution (market sharing) may make coordination more difficult. On the other hand, the simpler environment reduces strategic uncertainty for firms looking to coordinate, because only one symmetric collusive scheme (quota) is available in the stage game. We do not have an ex-ante reason as to which of the two effects dominates and thus formulate a second exploratory research question:

ERQ 2. *How does the multimarket environment affect prices relative to a single-market environment?*

Finally, the multitude of fully collusive equilibria in our multimarket setting begs the question of what kind of collusive scheme the firms coordinate on. While market sharing may serve as a focal point, a quota scheme reduces firms' deviation incentives. In particular, a quota agreement where each firm offers one third of the monopoly quantity in each market increases the stability of collusion over that of a market sharing agreement.[20] It is not clear

[20]Doing the calculations with our parameters, we find that the critical discount factor above which a quota agreement is sustained by grim trigger strategies is lower (4/7) than the one for market sharing (2/3). This result is a special case of the finding in Byford and Gans (2014) that in the case of Cournot competition, 'intensive margin collusion' is more stable than 'extensive margin collusion' (page 80).

which type of collusive scheme firms will primarily coordinate on (the more obvious or the more stable), but we expect that, once collusion is achieved, lower deviation incentives make quota more stable than market sharing:

Hypothesis 3. *Conditional on having reached a collusive agreement, quota is more stable than market sharing.*

5 Results

We report our results as follows. In Section 5.1, we present the results of the main treatments with three firms and three markets. In Sections 5.2 and 5.3, we compare these findings to those from the treatments with three firms and four markets as well as three firms and a single market. In Section 5.4, we take a closer look at the collusive strategies, in Section 5.5, we analyze the contents of the chat messages in the treatments with soft information, and in Section 5.6, we investigate the stability of collusive agreements.

5.1 Three Firms and Three Markets

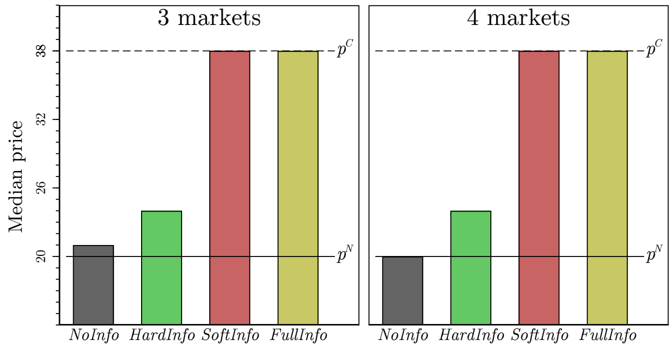
For the experiments with three markets, we conducted twelve sessions with a total of 300 subjects. Average prices in the main phase of the experiment (periods 11–20) are close to the static Nash equilibrium ($p^N = 20$) when soft information is not available (*NoInfo*: 21.8; *HardInfo*: 23.7). In both treatments with soft information, prices are substantially higher (*SoftInfo*: 33.8; *FullInfo*: 34.1). The bilateral treatment differences when comparing the absence or presence of soft information are highly significant (*NoInfo* vs. *SoftInfo*: $p < .001$; *HardInfo* vs. *FullInfo*: $p < .001$).[21] Bars in the left panel of Figure 2 show the treatment effects in terms of median prices. As a reference, we add a solid horizontal line for the static Nash equilibrium price ($p^N = 20$) and a dashed line for the collusive price ($p^C = 38$). Median prices with soft information are exactly at the collusive level, while median prices in the treatments *NoInfo* and *HardInfo* are close to the static Nash equilibrium level. We can confirm our first hypothesis:

Result H1. *Prices are highly collusive when soft information is available and close to the static Nash equilibrium when it is not.*

The effect of hard information is less obvious. When soft information is available, the results are basically indistinguishable (*SoftInfo* vs. *FullInfo*:

[21] We report two sided p-values throughout the text. All non-parametric statistics are two sample Wilcoxon rank-sum tests based on independent group averages.

Figure 2: Median prices in periods 11–20.



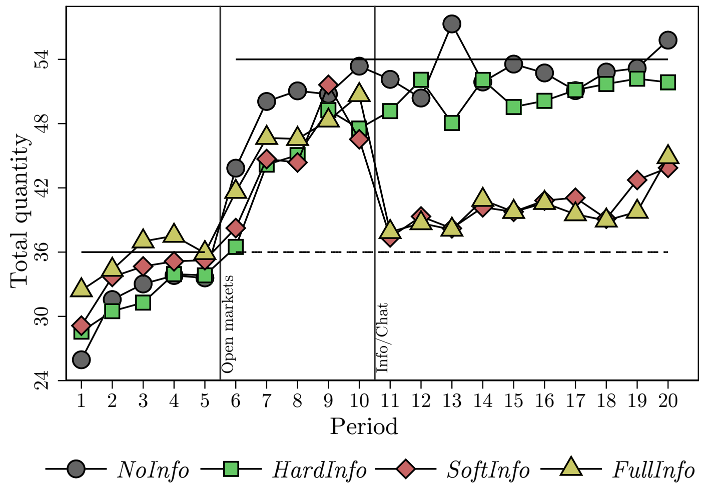
Notes: Median price in market 1–3 (left panel) and market 1–4 (right panel) across treatment, periods 11–20 only. Horizontal lines indicate the static Nash equilibrium price of 20, and the collusive price of 38.

$p = .918$). Without soft information, the prices are somewhat higher for *HardInfo* than *NoInfo*, indicating that hard information might support attempts to collude. However, the difference does not reach significance (*NoInfo* vs. *HardInfo*: $p = .210$). We postpone our conclusions with regard to the effect of hard information to include the data of the treatments with four markets.

Figure 3 shows treatment averages of the total quantity per firm over the course of the 20 periods. Horizontal lines indicate the theoretical benchmarks which are the monopoly quantity when firms operate in protected markets (period 1–5) and the static Nash equilibrium for the remainder of the experiment where all markets are open to all firms (Q^N). The dashed line indicates the symmetric collusive outcome (Q^C). In the closed market phase, total quantities converge to the monopoly quantity. Once the markets open, quantities quickly increase and converge towards the static Nash quantity, i.e., we replicate what is well known from the literature, namely, that Cournot oligopoly markets with more than two firms produce results close to the static Nash equilibrium (e.g., Huck et al., 2004; Roux and Thöni, 2015). After period ten, subjects receive information about their average profits in the two phases played so far and enter, dependent on the treatment, the chat phase.

Figure 3 shows that the treatment effects documented in Figure 2 are stable over time. In period eleven, both *SoftInfo* and *FullInfo* show average total quantities close to the collusive level, and the quantities remain low until the last two periods. On the other hand, the two treatments without soft information result in quantities close to the static Nash equilibrium. The test for bilateral treatment comparisons in total quantities results in very similar

Figure 3: Three markets, quantities over time.



Notes: Average total quantity offered in all three markets, over the 20 periods and by treatment. In period 1–5 markets are closed and firms can offer only in the market of their color. In periods 6–20 markets are open; after period 10 subjects receive information about their average profits in the previous two phases, and, in case of *SoftInfo* and *FullInfo*, communicate within the group. Solid lines indicate static Nash equilibrium quantities, the dashed line indicates collusive quantities.

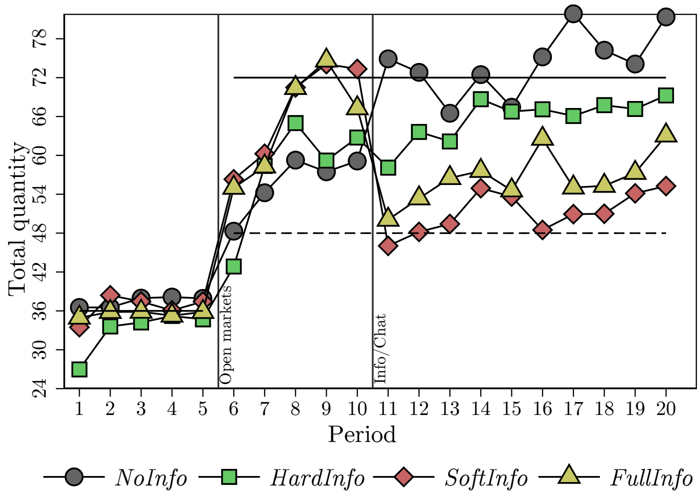
p-values than the tests for differences in pricing reported above.

To conclude, in accordance with the literature on single-market Cournot games, we find outcomes close to the static Nash equilibrium when communication is not possible. The presence of a strong focal point in terms of home markets seems not sufficient to enable firms to collude in the absence of soft information. With soft information, a majority of the firms reach a collusive agreement, and most agreements are stable over time, barring end-game effects.

5.2 Three Firms and Four Markets

Do the treatment effects discussed so far hinge on the strong symmetry between firms and markets? To check this, we turn to the experiments where three firms share four markets. We conducted four sessions with a total of 117 subjects. Figure 4 shows the results of the treatments with four markets. Relative to the theoretical benchmarks, we observe similar results in total quantity when we introduce asymmetry between the number of firms and the number of markets. Like before, the firms are monopolists in periods one to five, after which all firms have access to four markets. We adjust the

Figure 4: Four markets, quantities over time.



Notes: Average total quantity offered in all four markets, over the 20 periods and by treatment. In period 1–5 markets are closed and firms can offer only in the market of their color. In periods 6–20 markets are open; after period 10 subjects receive information about their average profits in the previous two phases, and, in case of *SoftInfo* and *FullInfo*, communicate within the group. Solid lines indicate static Nash equilibrium quantities, the dashed line indicate collusive quantities.

theoretical benchmarks to the situation with four markets, i.e., the collusive total quantity is 48 and the static Nash equilibrium is at 72. Again, we find that the opening of the markets produces a strong increase in quantities with convergence towards the static Nash equilibrium.

Both treatments with soft information show quantities closer to the collusive outcome in periods 11–20 than their counterparts without soft information. Both bilateral differences are significant (*NoInfo* vs. *SoftInfo*: $p < .001$; *HardInfo* vs. *FullInfo*: $p = .049$). With respect to the second treatment variation, we find again that hard information seems to facilitate collusion when soft information is not available, this time reaching significance (*NoInfo* vs. *HardInfo*: $p = .029$). Conversely, when soft information is available then this result seems reversed, albeit far from significant (*SoftInfo* vs. *FullInfo*: $p = .562$).

The right panel in Figure 2 shows the median prices. Recall that the game is calibrated such that price predictions are identical for all treatments. Median prices in the treatments with four markets are very similar to those from the treatments with three markets. None of the tests comparing average prices between the treatments with three and four markets is anywhere near significance ($p > .7$). To conclude, we do not find evidence to support our second hypothesis that the existence of a fourth market would hamper collusive success of the three firms:

Result H2. *Across all information conditions, prices are very similar in the treatments with three and four markets.*

While we expected (but did not find) differences in the levels of collusion between the treatments with three and four markets, our hypotheses regarding the effects of soft and hard information are independent of this variation. We can therefore investigate the treatment effects in the combined sample. Hypothesis 1 is clearly supported in the joint sample, as all bilateral comparisons between the respective treatments are significant for both three and four markets. Concerning the effect of hard information, we find weakly significant evidence for higher prices under hard information when soft information is not available (*NoInfo* vs. *HardInfo*: $p = .059$). In the treatment with soft information we observe the opposite, i.e., hard information leads to lower average prices. However, the difference is far from significance (*SoftInfo* vs. *FullInfo*: $p = .722$). To provide further evidence on the treatment effects in the combined sample we ran random effects regressions explaining the quantity offered on all available markets by the treatment dummies, while controlling for period effects. The regression results confirm lower quantities in *HardInfo* relative to *NoInfo* (weakly significant, $p = .062$, see Model (1) of Table A.1 in the appendix), and no significant differences between *SoftInfo* and *FullInfo* ($p = .511$).[22]

To conclude, in an environment that is conducive to collusion (soft information), hard information does not seem to matter or does even lower collusion. On the other hand, the weakly significant difference between *NoInfo* and *HardInfo* provides suggestive evidence for a positive effect of hard information on collusion. While this latter finding is not in line with the theoretical predictions in Byford and Gans (2014), it supports the intuition of Stigler (1964):

Result ERQ1. *In the treatments with outcomes close to the static Nash equilibrium (NoInfo and HardInfo), hard information tends to increase prices. With soft information, we find no systematic effect of hard information.*

[22]We also ran a model with treatment-specific time effects. None of the coefficients reaches significance (Model (2) in Table A.1).

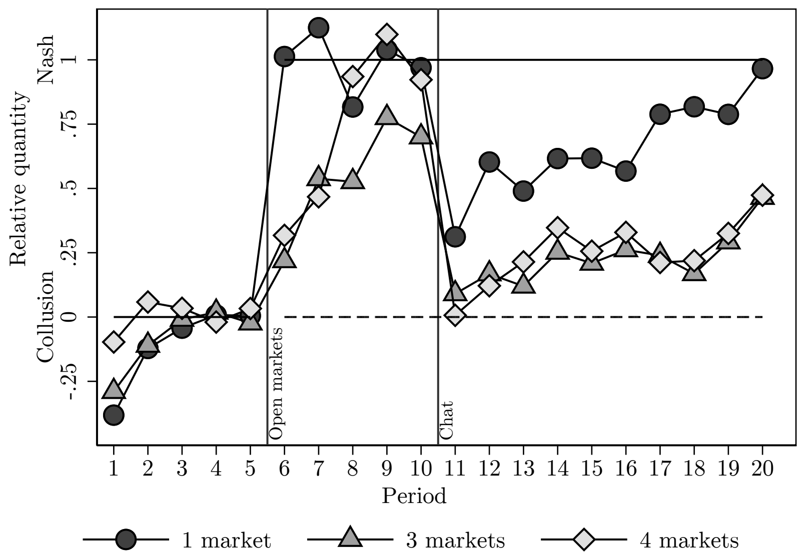
5.3 Three Firms and One Market

Increasing the number of markets over the number of firms does not seem to substantially affect the success of collusion. In the treatments with soft information, we observe highly collusive outcomes both with three and four markets. In a next step, we test whether the multimarket environment in combination with soft information gives rise to particularly collusive outcomes. For this, we compare the results of the treatments with three and four markets to a treatment with a single market. Recall that parameters ensure that the single-market treatment is payoff equivalent to the treatments with three markets. An extensive literature on single-market oligopolies suggests that, in the absence of soft information, results are close to the static Nash equilibrium (e.g., Huck et al., 2004). To study whether our multimarket setup fosters collusion, we therefore restrict our attention to the two treatments with soft information.

Like in the treatments with three and four markets, we do not find significant price differences in periods 11–20 between *SoftInfo* and *FullInfo* for one market (*SoftInfo* vs. *FullInfo*: $p = .353$). Quantities tend to be higher in *FullInfo* than in *SoftInfo*, again suggesting that, when soft information is available, hard information does decrease collusive success. Yet, the differences still do not reach statistical significance, neither in the new sample nor in the combined sample.[23] In the following we therefore pool the observations of the two treatments and focus on the effects of the different number of markets. To make the quantities in the treatment with four markets directly comparable to the quantities in the other two treatments, we rescale the total firm output such that zero means the collusive quantity and one refers to the static Nash equilibrium quantity. Figure 5 shows the relative quantities over time. The results of the treatments with three and four markets are almost identical with respect to collusion in periods 11–20. In contrast, the outcome of the treatment with a single market is substantially less collusive. While the chat has a strong effect in period 11, the average quantities are clearly more competitive throughout periods 11–20 and approach the Nash equilibrium quantities towards the end of the game. This is also reflected in the prices, where both treatment comparisons reach significance (1 market vs. 3 markets: $p = .001$; 1 market vs. 4 markets: $p = .010$). Random effects estimates confirm these results. Quantities are significantly higher in the treatments with 1 market compared to the treatments with multiple markets. If we allow for treatment specific time effects, quantities increase over

[23]The random effects model for quantities yields $p = .340$, see Model (3) in Table A.1. In none of the estimates of the combined sample we find significant differences between *SoftInfo* and *FullInfo*, $p > .24$ (Models (4) to (6) in Table A.1).

Figure 5: Quantities in experiments with 1, 3, and 4 markets.



Notes: Relative quantities over the 20 periods and for the experiments with one, three, and four markets. Data from *SoftInfo* and *FullInfo* pooled for each number of markets. Relative quantities is defined as $Q_i^r = \frac{Q_i - Q^C}{Q^N - Q^C}$, with Q_i being firm i's total quantity on all available markets.

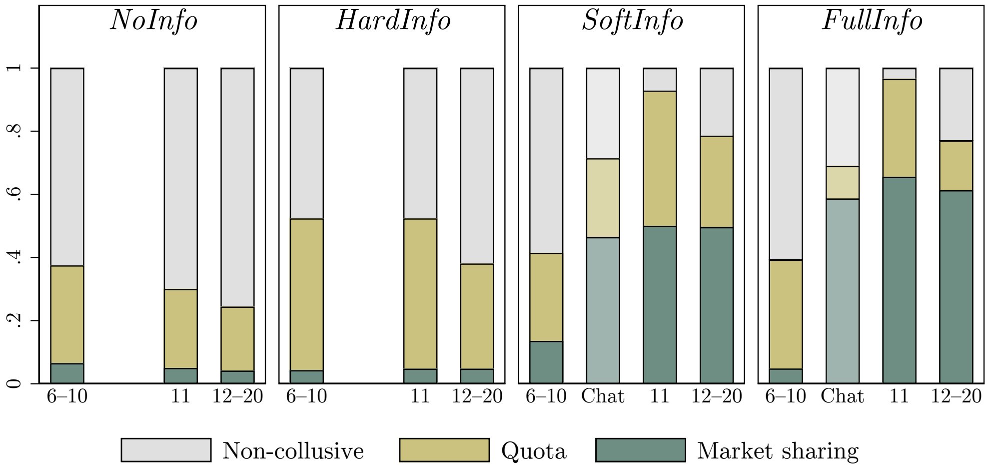
time significantly faster in the single market treatments (see Models (4) to (6) in Table A.1). This indicates that it is more difficult to maintain collusion in the single market environment. To conclude, we have a clear-cut answer to our Exploratory Research Question 2:

Result ERQ2. *In the presence of soft information, the multimarket setting results in prices that are substantially higher compared to prices in the single-market setting.*

5.4 The Nature of Collusive Agreements

In the light of the highly collusive outcomes observed in our experiments with soft information, we now investigate the types of collusive agreements. We focus our analysis on two types: (i) market sharing, and (ii) production quota. We define market sharing as a one-to-one matching between firms and markets in which firms offer positive quantities. As production quota qualifies any situation which gives rise to prices above the static Nash equilibrium in all three markets ($p^m > 20$ for $m = 1, 2, 3$), but is not market sharing. For the treatments with four markets, we apply the same definition and ignore the outcome on the fourth market for the moment.

Figure 6: Collusive agreements in the three home markets.



Notes: Bars show the fraction of groups with a market sharing agreement (one-to-one matching between firms and markets), or another collusive agreement resulting in prices above the static Nash equilibrium level in all three home markets (Quota). We distinguish between the periods 6–10 (prior to the chat or information), period 11, and periods 12–20. The lighter bar shows the fraction of groups that agreed on market sharing or quota in the chat. We pool data from treatments with three and four markets.

Figure 6 shows the frequency of market sharing and quota agreements in the four treatments. We pool the data from the experiments with three and four markets, as the results are very similar.[24] The left bars in each panel of Figure 6 show the frequency of market sharing and quota agreements in periods 6–10, while the two right bars do so for periods 11 and 12–20 respectively. For the two treatments with soft information, the remaining intermediate bars show the outcome of the chats. We coded each group chat as to whether the group members agreed on market sharing or some other form of collusion (see Section 5.5 for more details). In periods 6–10, about 40 percent of the outcomes are collusive in all four treatments. The collusive agreements predominantly take the form of quotas, while market sharing is very rare.

For the two treatments *NoInfo* and *HardInfo*, not much changes in period 11. In particular, there is no indication whatsoever that the information stage without the chat would help firms to coordinate on market sharing. In the two treatments with soft information, we observe that market sharing dominates quota in the chat, especially in *FullInfo*. This carries over to actual behavior: there is a clear correspondence between the fraction of groups that

[24]We ran Fisher exact tests for differences in the frequencies of the three categories between three and four markets, for each information condition separately as well as the whole sample. None of the tests indicated significant differences.

Table 2: Chat protocol

1	Firm A: *if everyone supplies 12 everywhere, we will do best, right?*
2	Firm B: *36 is the profit maximizing quantity*
3	Firm B: *yes*
4	Firm B: *or everyone in his own market 36*
5	Firm B: *right?*
6	Firm A: *yo, I think too, I do not care if everyone in his own [market] or 12 everywhere*
7	Firm C: *yo*
8	Firm B: *let us do 36 in the own [market]*
9	Firm B: *is easier*
10	Firm B: *ok?*
11	Firm C: *okay*
12	Firm A: *everything clear*
13	Firm B: *great!*

Note: Example of a chat protocol from the experiment with three firms and three markets and treatment *FullInfo*.

agree on market sharing in the chat and choose their quantities accordingly in period 11, and beyond. Comparing the four panels of Figure 6 reveals that the higher rate of collusion in *SoftInfo* and *FullInfo* is mainly due to the fact that communicating in the chat enables many groups to coordinate on market sharing. In all four panels of Figure 6, the fraction of market sharing situations is remarkably similar in period 11 and the remaining periods 12–20, while this is less the case for quota. This is a first indication that—contrary to our Hypothesis 3—quota might be less stable over time than market sharing.

If we combine market sharing and quota we observe that 30 (52) percent of the groups in *NoInfo* (*HardInfo*) reach a collusive outcome in period 11. In the two treatments with soft information, the corresponding percentages are 93 percent in *SoftInfo* and 97 percent in *FullInfo*. We can compare these number to the results of the single-market treatments, where we observe percentages of collusive play of 90 percent in *SoftInfo* and 80 percent in *FullInfo* in period 11 (not shown in Figure 6).[25]

[25] The increase of collusive agreements when comparing the two treatments with soft information to the two treatments without soft information is highly significant ($p < .001$, Fisher exact test). The increase of collusive agreements from the single-market to the multimarket treatments does not reach significance ($p = .177$). In accordance to our results on ERQ1 we find that *HardInfo* generates more collusive agreements than *NoInfo* ($p = .047$), while the two treatments with soft information are indistinguishable ($p = .611$).

5.5 Chat Analysis

In this section we use information from the chat transcripts from *SoftInfo* and *FullInfo* to complement the quantitative analysis (following Fischer and Normann, 2019; Kimbrough et al., 2008). In a typical chat history, one of the subjects initially proposes a collusive strategy and the other two agree to form a collusive agreement. The strategies that are predominantly proposed are market sharing and quota, and most often the group follows the initially proposed strategy without discussing alternatives. Only about a quarter of the groups discuss both strategies, and the majority of these groups eventually agree on market sharing.

Table 2 shows an example of a chat protocol (translated from German) that illustrates how groups resolve strategic uncertainty. In line 1, Firm A suggests to agree on quota, while, in line 4, Firm B suggests to share markets. Questions are used to elicit reactions from the other firms (lines 5 and 10). In line 9, Firm B argues that market sharing is easier to implement than quota, and the group members ultimately agree on market sharing.

In a next step, we analyze the messages and the outcome of the chat systematically. Following Fischer and Normann (2019), we recruited two research assistants who independently coded all messages. The coders received a set of predefined categories and were incentivized to code the messages accurately using the method proposed by Houser and Xiao (2011). Each message was coded with respect to these categories, whereby a message could be assigned to multiple categories. The coders were not informed about our hypotheses.

Table 3 shows the main categories and the share of groups that exchanged at least one message of the respective category (upper part) and the chat outcomes on the group level (lower part). We report results separately for the different numbers of markets. As we find no evidence that the chat content is sensitive to the availability of hard information we pool the data along this dimension ($p > .1$, χ^2-tests). The rightmost column reports Cohen's κ, a measure for inter-coder agreement, which varies from zero (rate of agreement expected by chance) to one (perfect agreement). For most of the categories, we observe an inter-coder agreement of 0.6 or above, which is considered a substantial agreement in the literature. The low score for the category threat indicates that coders agree poorly on which messages represent a threat.[26]

The category market sharing proposal (quota proposal) captures mes-

[26] The set of predefined categories draws from Cooper and Kühn (2014) and Dijkstra et al. (2018). See Appendix A.2 for summary information and inter-coder agreement for the complete list of categories, and Appendix A.3 for the instructions provided to the coders.

Table 3: Classification of chat messages and outcomes

	1 market	3 markets	4 markets	κ
Market sharing proposal: Home market	–	0.76	0.89	0.74
Quota proposal: Home market	–	0.46	0.39	0.78
Market sharing proposal: Single/4th market	0.17	–	0.13	0.67
Quota proposal: Single/4th market	0.82	–	0.97	0.66
Appeal to mutual benefits	0.95	0.93	0.95	0.64
Explicit quantitative statement	0.85	0.79	0.84	0.79
Threat	0.25	0.09	0.11	0.17
Disagreement	0.33	0.16	0.24	0.52
Question	0.95	0.91	0.89	0.90
Market sharing agreement: Home markets	–	0.53	0.53	0.75
Quota agreement: Home markets	–	0.18	0.16	0.95
Market sharing agreement: Single/4th market	0.10	–	0.05	0.87
Quota agreement: Single/4th market	0.50	–	0.63	0.67

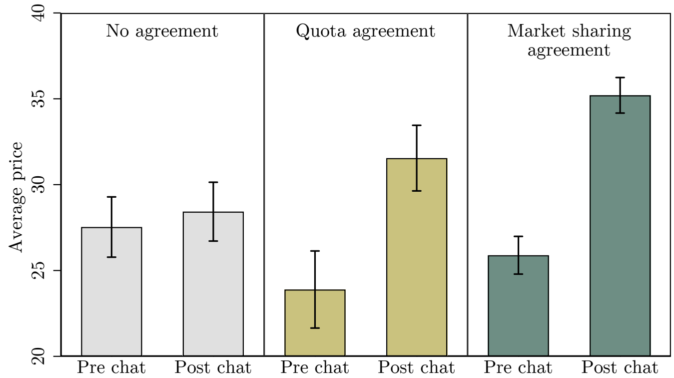
Notes: The upper part reports the percentage of groups where the category was coded at least once (average of the two coders), for one, three, and four markets separately. A message can be categorized into multiple categories. The lower part reports the percentage of groups that reach the corresponding agreement. We define a group as having reached an agreement if each member of the group states the interest in the specific collusive strategy at least once. We only consider groups where the coding of both coders categorizes them as having reached an agreement. The rightmost column shows Cohen's κ to measure inter-coder agreement (Cohen, 1960), ranging from 0 (agreement expected by chance) to 1 (perfect agreement). κ larger than 0.8 can be considered an "almost perfect", above 0.6 "substantial", and between 0.4 and 0.6 "moderate" agreement (Landis and Koch, 1977).

sages that signal the willingness to participate in a market sharing (quota) agreement in either the three home markets or the single/fourth market. In order to qualify as market sharing, markets must be shared either across markets (multimarket) or over time by taking turns (single market), such that the quantity supplied by one firm does not affect the profit of any other firm. The percentages confirm our observations from Figure 6 that market sharing dominates quota in the home markets, while the opposite is true for the fourth or the single market.

Chats also frequently contain messages appealing to mutual benefits. Here, subjects underline the advantages of playing according to proposed strategies which might increase the credibility of messages. Subjects also frequently state quantities and pose questions to align strategies and ensure that group members agree with proposed strategies. Threats or disagreements on the other hand are rare in our data. We consider these patterns in line with the interpretation that the chat is mainly used to resolve strategic uncertainty about collusive strategies.

Once all three subjects in a group have signaled their willingness to participate in market sharing (quota), we consider the agreement to be formed.

Figure 7: Collusive effect of agreements.



Notes: Bars show average prices across all available markets in period 6 to 10 (Pre chat) and period 11 to 20 (Post chat). The left panel shows the groups that did not reach an agreement during the chat, the middle (right) panel shows the groups that agreed on quota (market sharing). Data of both treatments with soft information and one, three, and four markets are pooled. Spikes indicate standard errors, clustered on group.

We require both coders to mark the group as having reached an agreement. The lower part of Table 3 reports frequencies of agreements in the home markets and in the single/fourth market. In the former, market sharing is clearly the predominant collusive strategy. In the single/fourth market, where market sharing is only possible over time by taking turns, quota is the dominant collusive scheme. Further evidence for the relative attractiveness of market sharing comes from groups that discuss both strategies. There is not a single group that agrees on quota after market sharing had been proposed as a first proposal. However, in the groups where quota is proposed initially, 23 percent of the groups that eventually collude agree on market sharing. We conclude that in a multimarket context, firms coordinate rather on the more focal than on the—according to our theoretical argument—more stable collusive scheme.

Explicit agreements in the chat are the key driver behind the strong impact of soft information on prices documented above. Figure 7 shows the average price in the periods before and after the chat. We pool the data from all treatments with soft information. The left panel shows that for the groups which could not agree on a collusive strategy (32 percent of the groups), prices only slightly increase. In contrast, for the groups that coordinate on quota (middle panel, 26 percent) and even more so for those that agree on market sharing (right panel, 42 percent) price increases are substantial and highly significant ($p = .019$ and $p < .001$, respectively).

5.6 Cartel Stability

In Section 4, we pointed out that deviation incentives are larger in market sharing than in quota, and predicted more stability over time for quota agreements. We explore the relative stability of quota and market sharing using regression analyses. Table 4 shows random effects models explaining profits in periods 11–20.[27] To maintain comparability between the four-market and the other treatments, we rescale the profits in the former by three quarters. In Model (1), we run a baseline estimate with market and treatment dummies. Given the effects on total quantities discussed above, the results are not surprising. Compared to the baseline (*NoInfo*), profits increase slightly when adding hard information. This effect is significant at five percent, providing additional support for our Exploratory Research Question 1. In accordance to Hypothesis 1, we find that profits increase substantially with the availability of soft information, while the difference between the coefficients for *SoftInfo* and *FullInfo* is not statistically significant ($p = .43$, post-hoc Wald test). We also confirm our findings that the presence of a fourth market does not importantly impede collusion, while profits in the single-market treatments are substantially lower compared to the multimarket treatments.

In Model (2), we add a variable for time effects (Period) and include dummy variables indicating whether a group reached a market sharing or a quota agreement in the chat. In the treatments with four markets, these dummies refer to agreements regarding the home markets only. We find a significantly positive effect of agreeing on market sharing during the chat on average profits. For quota, we find a coefficient of similar magnitude but it is not significant due to higher variance.

In Model (3), we estimate separate time trends for the groups that agree on quota or market sharing and the groups that do not reach an agreement. Comparing the coefficients on the interaction terms, we find that profits of firms with market sharing agreements decay slower than those of firms with quota agreements ($p = .012$, post-hoc Wald test). Contrary to Hypothesis 3, this suggests that market sharing is more stable than quota. Note that these results might be driven by our treatments with one market where quota agreements are the predominant choice. In Model (4), we restrict the estimates to the treatments with multiple markets. The point estimate for the profit decay in quota remains almost twice as large as for market sharing, but the difference between the coefficients does no longer reach significance ($p = .263$, post-hoc Wald test). Nevertheless, as the theoretical argument put forward in support of Hypothesis 3 does not make any distinction between

[27] As we estimate effects in a panel data, we use a random effects specification to address individual heterogeneity (Fréchette, 2012).

Table 4: Regression for profit in periods 11–20

	Dependent variable: Profit			
	(1)	(2)	(3)	(4)
HardInfo	125.89*	125.90*	125.90*	125.90*
	(50.20)	(50.22)	(50.23)	(50.25)
SoftInfo	371.39**	293.68**	293.68**	277.11**
	(51.23)	(66.41)	(66.42)	(59.02)
FullInfo	333.07**	256.89**	256.89**	270.83**
	(49.18)	(55.17)	(55.18)	(58.58)
1 market	−190.85*	−176.30*	−176.30*	
	(74.98)	(74.20)	(74.21)	
4 markets	−20.78	−19.56	−19.56	−20.15
	(35.27)	(34.16)	(34.17)	(34.25)
Period		−6.99**		
		(2.33)		
MS agrmt.		111.62*	183.94*	189.41**
		(49.55)	(73.69)	(73.22)
Q agrmt.		103.07	369.69**	257.74**
		(73.99)	(89.44)	(80.01)
MS agrmt. × Period			−8.55**	−7.47**
			(2.67)	(2.73)
Q agrmt. × Period			−21.09**	−14.17**
			(4.19)	(5.32)
No agrmt. × Period			−3.88	−2.98
			(3.21)	(3.26)
Constant	837.60**	945.60**	897.51**	883.70**
	(39.18)	(57.01)	(68.16)	(69.13)
χ^2-test	79.5	109.9	164.5	161.9
p	0.000	0.000	0.000	0.000
R^2	0.082	0.089	0.090	0.109
N	4770	4770	4770	4170

Notes: Random effects estimates. Dependent variable is a firm's profit on all markets in a period. Profits of firms in our setting with 4 markets are rescaled by a factor of 3/4. Explanatory variables are treatment dummies (with *NoInfo* and 3 markets as the baseline); dummies indicating groups that reached a collusive agreement (market sharing or quota), or no agreement; period, and interactions. Robust standard errors, clustered on group, in parentheses. $^{+}$ $p < 0.1$, * $p < 0.05$, ** $p < 0.01$.

single and multimarket environments, we can use the joint data set to evaluate the hypothesis. Taken together, the evidence speaks against Hypothesis 3 and points towards superior stability of market sharing agreements.

Result H3. *Conditional on having reached a collusive agreement, quota is not more stable than market sharing.*

Higher complexity of quota agreements may explain this result. For example, Hyytinen et al. (2019) report evidence on Finnish cartels suggesting that quota cartels involve more complex contracts than market sharing agreements. Moreover, the fact that quota seems less stable and is most frequent in the single-market environment may explain our finding on the differences between single and multimarket environments. As quota is predominant in the former, observed differences in stability can explain why it seems more difficult to maintain a collusive agreement in a single-market environment. In fact, we find that agreements established in the chat last on average four periods in the single-market and seven periods in the multimarket setting, and the difference is statistically significant ($p = .040$, Wilcoxon rank-sum test).

6 Conclusion

Antitrust law and practice suggest that communication between firms is crucial for establishing and stabilizing collusion. But what role does communication play for collusion in multimarket environments? And what type of information has to be shared for communication to be particularly helpful? We investigate these questions in a series of Cournot oligopoly experiments with multiple markets and firms. We have a two-by-two factorial design, varying the availability of two different types of information: (1) soft information which is on planned future conduct, unbinding, and not verifiable and (2) hard information which is on recent past behavior and (in principle) verifiable. In our main experiments, there are three firms and three markets. In addition, we study environments where the three firms have access to four markets or only a single market.

We find that market prices are highly collusive when soft information is available and close to the static Nash equilibrium when soft information is unavailable. This suggests that soft information is extremely helpful for collusion and that, as firms in our study have only one opportunity to chat, it has long-lasting effects. Moreover, we find that the presence of multiple markets reinforces the effect of soft information: compared to a scenario where firms can collude in a single market only, our multimarket environment shows substantially higher market prices. The key driver behind the strong effect of soft information on collusive success is the explicit consent of all group members to a certain collusive strategy during the chat. It turns out that the most successful collusive strategy is market sharing (relative to collusion on production quotas in all markets). On the other hand, despite being arguably a strong focal point, our results suggest that market sharing is highly unlikely to arise in the absence of soft information. The agreements strongly affect market prices: prices increase by 32 percent for those that coordinate on quota and by 36 percent for those that coordinate on market sharing. The exchange of hard information increases market prices only slightly, and we observe such a price rise only when soft information is not available.

It is difficult to assess to which extent the strong differences between the effectiveness of hard and soft information are transferable to real markets. First, the two treatment variations (soft and hard information) vary in more than one dimension. Given that the two concepts are substantially different, it seems an impossible task to come up with a design that implements a true ceteris paribus variation of soft and hard information. There are, however, a number of interesting variations of our design, which might be worthwhile to investigate in future research. For example, the disclosure of soft information is voluntary in our experiment while the disclosure of hard information is automatic. If the voluntary disclosure of information itself signals a firm's willingness to collude and if firms wish to reciprocate voluntary disclosure with collusive behavior, the effect of hard information in our design may be understated. Furthermore, the fact that we let firms only communicate once in the treatments with soft information might have an impact on their collusive success. While it is intuitive to think that repeated chat opportunities would help to maintain coordination on collusive play, it could also be that multiple communication opportunities undermine cartel stability because of renegotiation. Finally, from an experimental point of view it might be interesting to investigate to what extent the strong collusive outcome in our multimarket experiments hinges on our framing of the home markets. While we think it is natural and realistic to design the environment in a way which leaves no doubt about the allocation of firms to markets, coordinative success in the laboratory will likely decrease when the environment does not offer clues to allocate the markets.

To conclude, the multimarket environment we consider turns out to be very competitive, and, in line with the evidence from previous oligopoly experiments, it seems difficult to achieve a tacitly collusive outcome in the lab. A single opportunity to communicate soft information, however, changes this conclusion drastically. For the observed upsurge in collusion, reaching an agreement on the type of collusive strategy to be pursued (market sharing or quota) is key. The single chat opportunity exactly serves this purpose. Accordingly, our study points to the type of information that should be of particular concern in antitrust enforcement. Increased market transparency due to the availability of hard information (as collected and distributed by joint sales agencies) may not be very effective for market sharing. What truly seems to matter is the sharing of future plans. Consequently, it is soft information that antitrust authorities should pay special attention to. Moreover, once firms establish a mutual understanding, additional exchange or meetings are superfluous which can make a collusive market-sharing infringement difficult to detect in practice.

References

Abreu, D., "On the Theory of Infinitely Repeated Games with Discounting," *Econometrica* 56 (1988), 383–396.

Abreu, D., D. Pearce and E. Stacchetti, "Optimal cartel equilibria with imperfect monitoring," *Journal of Economic Theory* 39 (1986), 251–269.

Albæk, S., P. Møllgaard and P. B. Overgaard, "Government-assisted oligopoly coordination? A concrete case," *Journal of Industrial Economics* 45 (1997), 429–443.

Altavilla, C., L. Luini and P. Sbriglia, "Social learning in market games," *Journal of Economic Behavior & Organization* 61 (2006), 632–652.

Andersson, O. and E. Wengström, "Do Antitrust Laws Facilitate Collusion? Experimental Evidence on Costly Communication in Duopolies," *Scandinavian Journal of Economics* 109 (2007), 321–339.

Aoyagi, M., V. Bhaskar and G. R. Fréchette, "The impact of monitoring in infinitely repeated games: perfect, public, and private," *American Economic Journal: Microeconomics* 11 (2019), 1–43.

Aoyagi, M. and G. R. Fréchette, "Collusion as public monitoring becomes noisy: experimental evidence," *Journal of Economic Theory* 144 (2009), 1135–1165.

Belleflamme, P. and F. Bloch, "Market Sharing Agreements and Collusive Networks," *International Economic Review* 45 (2004), 387–411.

———, "Sustainable collusion on separate markets," *Economics letters* 99 (2008), 384–386.

Bernheim, B. D. and M. D. Whinston, "Multimarket Contact and Collusive Behavior," *RAND Journal of Economics* 21 (1990), 1–26.

Bhaskarabhatla, A., C. Chatterjee and B. Karreman, "Hit where it hurts: cartel policing using targeted sales and supply embargoes," *Journal of Law and Economics* 59 (2016), 805–846.

Bock, O., I. Baetge and A. Nicklisch, "hroot – Hamburg Registration and Organization Online Tool," *European Economic Review* 71 (2014), 117–120.

Bond, E. W. and C. Syropoulos, "Trade Costs and Multimarket Collusion," *RAND Journal of Economics* 39 (2008), 1080–1104.

Byford, M. C. and J. S. Gans, "Collusion at the Extensive Margin," *International Journal of Industrial Organization* 37 (2014), 75–83.

Byrne, D. P. and N. De Roos, "Learning to coordinate: a study in retail gasoline," *American Economic Review* 109 (2019), 591–619.

Cason, T. N., "Cheap talk price signaling in laboratory markets," *Information Economics and Policy* 7 (1995), 183–204.

Cohen, J., "A coefficient of agreement for nominal scales," *Educational and psychological measurement* 20 (1960), 37–46.

Colonescu, C. and N. Schmitt, "Market Segmentation, Market Integration, and Tacit Collusion," *Review of International Economics* 11 (2003), 175–192.

Cooper, D. J. and K.-U. Kühn, "Communication, Renegotiation and the Scope for Collusion," *American Economic Journal: Microeconomics* 6 (2014), 247–278.

Dal Bó, P., "Cooperation under the shadow of the future: experimental evidence from infinitely repeated games," *American Economic Review* 95 (2005), 1591–1604.

Dal Bó, P. and G. R. Fréchette, "On the determinants of cooperation in infinitely repeated games: a survey," *Journal of Economic Literature* 56 (2018), 60–114.

Daughety, A. F. and R. Forsythe, "The effects of industry-wide price regulation on industrial organization," *Journal of Law, Economics, & Organization* 3 (1987), 397–434.

Davis, D. D. and C. A. Holt, "Conspiracies and secret discounts in laboratory markets," *Economic Journal* 108 (1998), 736–756.

Dijkstra, P. T., M. A. Haan and L. Schoonbeek, "Leniency Programs and the Design of Antitrust: Experimental Evidence with Free-Form Communication," Working paper, 2018.

Edlin, A., C. Roux, A. Schmutzler and C. Thöni, "Hunting unicorns? Experimental evidence on exclusionary pricing policies," *Journal of Law and Economics* 62 (2019), 457–484.

Farrell, J., "Cheap talk, coordination, and entry," *RAND Journal of Economics* 18 (1987), 34–39.

Farrell, J. and M. Rabin, "Cheap talk," *Journal of Economic Perspectives* 10 (1996), 103–118.

Fischbacher, U., "z-Tree - Zurich Toolbox for Readymade Economic Experiments," *Experimental Economics* 10 (2007), 171–178.

Fischer, C. and H.-T. Normann, "Collusion and bargaining in asymmetric Cournot duopoly—An experiment," *European Economic Review* 111 (2019), 360–379.

Fonseca, M. A., Y. Li and H.-T. Normann, "Why factors facilitating collusion may not predict cartel occurrence–experimental evidence," *Southern Economic Journal* 85 (2018), 255–275.

Fonseca, M. A. and H.-T. Normann, "Explicit vs. Tacit Collusion–the Impact of Communication in Oligopoly Experiments," *European Economic Review* 56 (2012), 1759–1772.

———, "Endogenous cartel formation: experimental evidence," *Economics Letters* 125 (2014), 223–225.

Fréchette, G. R., "Session-effects in the laboratory," *Experimental Economics* 15 (2012), 485–498.

Friedman, J. W., "A Non-Cooperative Equilibrium for Supergames," *Review of Economic Studies* 38 (1971), 1–12.

Gächter, S., C. Thöni and J.-R. Tyran, "Cournot competition and hit-and-run entry and exit in a teaching experiment," *Journal of Economic Education* 37 (2006), 418–430.

Genesove, D. and W. P. Mullin, "Rules, communication, and collusion: narrative evidence from the Sugar Institute Case," *American Economic Review* 91 (2001), 379–398.

Gomez-Martinez, F., S. Onderstal and J. Sonnemans, "Firm-Specific Information and Explicit Collusion in Experimental Oligopolies," *European Economic Review* 82 (2016), 132–141.

Green, E. J. and R. H. Porter, "Noncooperative Collusion under Imperfect Price Information," *Econometrica* 52 (1984), 87–100.

Harrington, J. E., "How Do Cartels Operate?," *Foundations and Trends in Microeconomics* 2 (2006), 1–105.

Harrington, J. E., R. H. Gonzalez and P. Kujal, "The relative efficacy of price announcements and express communication for collusion: experimental findings," *Journal of Economic Behavior & Organization* 128 (2016), 251–264.

Houser, D. and E. Xiao, "Classification of natural language messages using a coordination game," *Experimental Economics* 14 (2011), 1–14.

Huck, S., H.-T. Normann and J. Oechssler, "Learning in Cournot oligopoly–an experiment," *Economic Journal* 109 (1999), 80–95.

———, "Does information about competitors' actions increase or decrease competition in experimental oligopoly markets?," *International Journal of Industrial Organization* 18 (2000), 39–57.

———, "Two Are Few and Four Are Many: number Effects in Experimental Oligopolies," *Journal of Economic Behavior & Organization* 53 (2004), 435–446.

Hyytinen, A., F. Steen and O. Toivanen, "An Anatomy of Cartel Contracts," *Economic Journal* 129 (2019), 2155–2191.

Isaac, M. R. and C. R. Plott, "Price controls and the behavior of auction markets: an experimental examination," *American Economic Review* 71 (1981), 448–459.

Kandori, M., "The use of information in repeated games with imperfect monitoring," *Review of Economic Studies* 59 (1992), 581–593.

KIMBROUGH, E. O., V. L. SMITH AND B. J. WILSON, “Historical Property Rights, Sociality, and the Emergence of Impersonal Exchange in Long-Distance Trade,” *American Economic Review* 98 (2008), 1009–1039.

KNITTEL, C. R. AND V. STANGO, “Price ceilings as focal points for tacit collusion: evidence from credit cards,” *American Economic Review* 93 (2003), 1703–1729.

KÜHN, K.-U., “Fighting collusion by regulating communication between firms,” *Economic Policy* 16 (2001), 168–204.

KÜHN, K.-U. AND X. VIVES, *Information exchanges among firms and their impact on competition* (European Communities, 1995).

LANDIS, J. R. AND G. G. KOCH, “The measurement of observer agreement for categorical data,” *Biometrics* 33 (1977), 159–174.

LEVENSTEIN, M. C. AND V. Y. SUSLOW, “What determines cartel success?,” *Journal of Economic Literature* 44 (2006), 43–95.

———, “International Cartels,” *Issues in Competition Law and Policy* 2 (2008), 1107–1126.

LEWIS, M. S., “Odd prices at retail gasoline stations: focal point pricing and tacit collusion,” *Journal of Economics & Management Strategy* 24 (2015), 664–685.

LOMMERUD, K. E. AND L. SØRGARD, “Trade Liberalization and Cartel Stability,” *Review of International Economics* 9 (2001), 343–355.

MOTTA, M., “Cartels in the European Union: economics, law, practice,” in X. Vives, ed., *Competition Policy in the EU: Fifty Years on from the Treaty of Rome* (Oxford University Press, 2009), 95–134.

NORMANN, H.-T., J. RÖSCH AND L. M. SCHULTZ, “Do buyer groups facilitate collusion?,” *Journal of Economic Behavior & Organization* 109 (2005), 72–84.

NORMANN, H.-T. AND B. WALLACE, “The impact of the termination rule on cooperation in a prisoner’s dilemma experiment,” *International Journal of Game Theory* 41 (2012), 707–718.

OFFERMAN, T., J. POTTERS AND J. SONNEMANS, “Imitation and belief learning in an oligopoly experiment,” *Review of Economic Studies* 69 (2002), 973–997.

POSNER, R. A., “A statistical study of antitrust enforcement,” *Journal of Law and Economics* 13 (1970), 365–419.

POTTERS, J., “Transparency about past, present, future conduct. Experimental evidence on the impact of competitiveness,” in J. Hinloopen and H.-T. Normann, eds., *Experiments and Competition Policy* (Cambridge University Press, 2009), 81–104.

PROCTOR, A. J., “Tacit Collusion Indicators in Merger Control under Varied Focal Points,” *Journal of Competition Law and Economics* 10 (2014), 959–987.

ROUX, C., L. SANTOS-PINTO AND C. THÖNI, “Home Bias in Multimarket Cournot Games,” *European Economic Review* 89 (2016), 361–371.

ROUX, C. AND C. THÖNI, “Collusion among many firms: the disciplinary power of targeted punishment,” *Journal of Economic Behavior & Organization* 116 (2015), 83–93.

SCHELLING, T. C., *The strategy of conflict* (Harvard University Press, 1960).

Scherer, F. M., "Focal point pricing and conscious parallelism," *Antitrust Bulletin* 12 (1967), 495–504.

Selten, R. and R. Stoecker, "End behavior in sequences of finite Prisoner's Dilemma supergames A learning theory approach," *Journal of Economic Behavior & Organization* 7 (1986), 47–70.

Smith, V. L. and A. W. Williams, "On nonbinding price controls in a competitive market," *American Economic Review* 71 (1981), 467–474.

Stigler, G., "A Theory of Oligopoly," *Journal of Political Economy* 72 (1964), 44–61.

Vega-Redondo, F., "The evolution of Walrasian behavior," *Econometrica* 65 (1997), 375–384.

Verboven, F., "Localized Competition, Multimarket Operation, and Collusive Behavior," *International Economic Review* 39 (1998), 371–398.

Waichman, I., T. Requate and C. K. Siang, "Communication in Cournot competition: an experimental study," *Journal of Economic Psychology* 42 (2014), 1–16.

Whinston, M. D., *Lectures on Antitrust Economics* (MIT Press, Cambridge, Massachusetts, 2008).

A Appendix

A.1 Additional tables

Table A.1: Regression for total quantity in periods 11–20

	Dependent variable: Total quantity					
	(1) 3/4 markets	(2) 3/4 markets	(3) 1 market	(4) all obs.	(5) all obs.	(6) all obs.
HardInfo	-3.31^{+}	-4.12		-3.31^{+}	-3.31^{+}	-4.18
	(1.78)	(4.82)		(1.78)	(1.78)	(4.77)
SoftInfo	-14.12^{**}	-17.95^{**}		-14.61^{**}	-14.61^{**}	-17.61^{**}
	(1.75)	(4.51)		(1.78)	(1.78)	(4.80)
FullInfo	-13.02^{**}	-16.24^{**}	4.79	-12.55^{**}	-12.55^{**}	-15.81^{**}
	(1.74)	(4.46)	(5.02)	(1.77)	(1.77)	(4.75)
1 market				7.77^{**}	-3.06	-1.40
				(2.65)	(6.96)	(6.99)
4 markets	0.47	0.47		0.46	-4.43	-4.14
	(1.26)	(1.26)		(1.25)	(3.39)	(3.45)
Period	0.40^{**}	0.29	1.01^{**}	0.48^{**}	0.31^{**}	0.22
	(0.09)	(0.22)	(0.35)	(0.09)	(0.09)	(0.21)
HardInfo × Period		0.05				0.06
		(0.26)				(0.26)
SoftInfo × Period		0.25				0.19
		(0.26)				(0.27)
FullInfo × Period		0.21				0.21
		(0.27)				(0.27)
1 market × Period					0.70^{*}	0.59^{+}
					(0.35)	(0.36)
4 markets × Period					0.32	0.30
					(0.21)	(0.21)
Constant	47.38^{**}	49.07^{**}	29.72^{**}	46.20^{**}	48.76^{**}	50.22^{**}
	(2.13)	(4.11)	(8.21)	(2.12)	(2.25)	(3.97)
χ^2-test	163.0	200.2	8.9	174.8	179.7	220.6
p	0.000	0.000	0.012	0.000	0.000	0.000
R^2	0.097	0.097	0.024	0.082	0.083	0.083
N	4170	4170	600	4770	4770	4770

Notes: Random effects estimates. Dependent variable is the sum of the quantites offered on the markets available in a period. Models (1) to (2): data from treatments with three and four markets; Model (3): data from 1 market treatments; Models (4) to (6): all observations. For comparability we multiply the dependent variable in our setting with 4 markets by 3/4. Explanatory variables are treatment dummies (with *NoInfo* and 3 markets as the baseline, except in Model (3), where *SoftInfo* is the baseline), period, and interactions. Robust standard errors, clustered on group, in parentheses. $^{+}$ $p < 0.1$, * $p < 0.05$, ** $p < 0.01$.

A.2 Classification of chat messages

Table A.2 reports the share of groups that exchanged at least one message of the respective category, for each market setting and for the complete list of categories. The rightmost column reports Cohen's κ, a measure for inter-coder agreement. The categories were predefined and draw from Cooper and Kühn (2014) and Dijkstra et al. (2018).

Table A.2: Classification of chat messages

	1 market	3 markets	4 markets	κ
Market sharing proposal: Home market	–	0.76	0.89	0.74
Quota proposal: Home market	–	0.46	0.39	0.78
Market sharing proposal: Single/4th market	0.17	–	0.13	0.67
Quota proposal: Single/4th market	0.82	–	0.97	0.66
Other collusive strategy proposal	0.07	0.01	0.05	0.23
Appeal to mutual benefits	0.95	0.93	0.95	0.64
Explicit quantitative statement	0.85	0.79	0.84	0.79
Threat	0.25	0.09	0.11	0.17
Disagreement	0.33	0.16	0.24	0.52
Question	0.95	0.91	0.89	0.90
Encouragement	0.33	0.38	0.55	0.46
Greeting	0.70	0.61	0.74	0.96
Referring to another player directly	0.57	0.37	0.61	0.73
Fun	0.40	0.39	0.47	0.41
Request proposal	0.50	0.37	0.37	0.70
Previous events	0.63	0.38	0.42	0.79
Message cannot be grouped	0.23	0.12	0.03	0.48

Notes: This table reports the frequencies of each category for one, three, and four markets separately. Frequency is the percentage of groups where the category was coded at least once (average of the two coders). A message can be categorized into multiple categories. The rightmost column shows Cohen's κ to measure inter-coder agreement (Cohen, 1960), ranging from 0 (agreement expected by chance) to 1 (perfect agreement). κ larger than 0.8 can be considered an "almost perfect", above 0.6 "substantial", and between 0.4 and 0.6 "moderate" agreement (Landis and Koch, 1977).

A.3 Full list of categories and instructions for coders

This appendix shows the instructions and explanations on the predefined categories provided to the coders.

Instructions on categorization of messages

Your task:

Your task is to evaluate into which categories each message falls. One message can fall into as many categories as you seem appropriate. There are 17 categories outlined below.

Your payoff:

You will earn your regular hourly wage for the time you spend on this task. At the end of the categorization, 50 messages will be chosen at random. For each message, where your evaluation matches the other evaluation perfectly, you will be paid 1 CHF in addition.

The available categories:

Category	Explanation
Signals willingness to participate in market sharing in markets red, yellow and blue	The message signals that the sender is interested in a market sharing agreement in the three markets red, yellow and blue.
Signals willingness to participate in quota agreement in markets red, yellow and blue	The message signals that the sender is interested in a quota agreement, where each player provides a certain quantity in more than one of the three markets red, yellow and blue.
Signals willingness to participate in market sharing in market violet, including the possibility to taking turns	The message signals that the sender is interested in a market sharing agreement, including the possibility to taking turns, in market violet.
Signals willingness to participate in quota agreement in market violet	The message signals that the sender is interested in a quota agreement, where each player provides a certain quantity in market violet, every period.
Signals willingness to participate in another type of collusive strategy	The message signals that the sender is interested in a collusive strategy other than market sharing and quota agreement in any market.
Appeal to mutual benefits	The message refers to mutual benefits (losses) of (not) playing a collusive strategy.
Request for proposal	The message requests other members of the group to propose a common strategy.

Encouragement of strategy	The message has an encouraging element to it that goes beyond just agreeing to a proposed strategy. The message signals rather enthusiasm or particular happiness about the collusive strategy. (This category can only be a valid choice if the sender signals willingness to participate in some form of collusive agreement at the same time).
Greeting	The message contains a greeting toward the other members of the group.
Funny message	The message aims to amuse the other group members.
Threat	The message mentions negative consequences for other players, given a certain behavior.
Disagreement	The message signals disagreement to a proposed collusive strategy.
Previous events	The message refers to events that happened in previous rounds of the experiment.
Direct contact	The message mentions another player directly.
Questions	The message contains a question.
Explicit quantitative statement	The message contains explicit quantity suggestions on how much should be offered in a market. (This category can only be a valid choice if the sender signals willingness to participate in some form of collusive agreement at the same time).
Other	Please specify your thoughts in a brief comment, of why this message cannot be grouped.

A.4 Instructions

[Instructions for the *NoInfo* treatment, translated from German. The parts that are different in the instructions for the *SoftInfo*, *HardInfo*, and *FullInfo* are reported in boxes.]

Instructions

You are taking part in an economic study. You can, depending on your decisions, earn a fair amount of money. It is therefore important that you read these instructions carefully.

These instructions are solely for your private use. You are not allowed to communicate with the other participants during the entire study. If you have any questions, please contact the supervisors.

During the study, we will not speak of euros but of talers. Your earnings will first be calculated in talers. The total amount of talers you earn during the study will be converted to euros at the end of the study. The following conversion rate applies:

$$1000 \text{ talers} = 0.55 \text{ euros}$$

At the end of today's session, you will receive your earnings from the study in cash. You remain anonymous during and also after the study.

The study is divided into 20 separate rounds. The participants are divided into groups. Each group consists of three participants. The composition of the groups remains the same for all 20 rounds. Hence, you are in a group with the same two participants for all 20 rounds.

Each participant is the manager of a firm. There are three identical markets. In rounds 1 to 5 each firm can only serve one of the three markets. In rounds 6 to 20 all firms in a group can serve all three markets. In each round, you decide which of the markets to serve and how many units of the goods to supply. (In rounds 1 to 5 you only decide about the units of the good.) The other firms in your group do exactly the same thing. The following rule applies: the larger the total quantity supplied in a market, the lower is the market price of the good. The unit cost amounts to 2 talers, and thus, the per-unit profit equals the market price minus 2 talers.

We will explain the exact procedure of the study in the next pages.

Information on the Exact Procedure of the Study

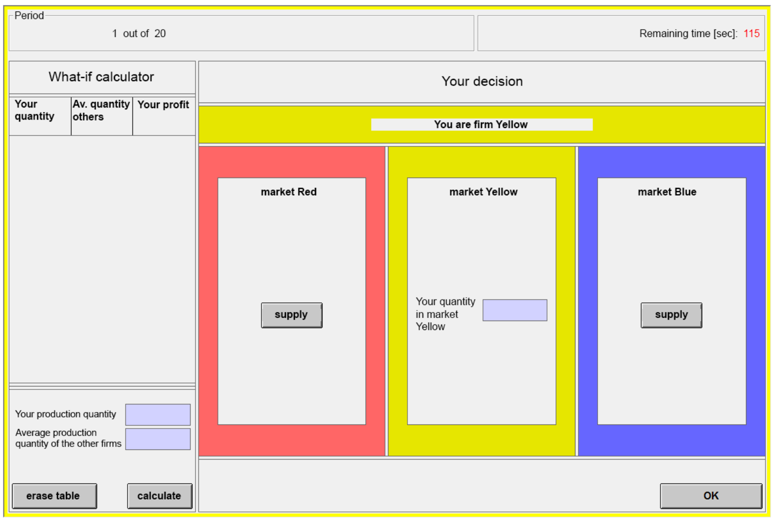
At the beginning of each round, each manager has to decide which of the markets to serve and how many units of the good to supply. In each of the three markets, the firms face the same market demand which is

$$P = 74 - Q.$$

P is the market price and Q is the total quantity supplied. For example, if your firm and the other two firms in your group supply the good in the same market, Q is the sum of the quantity supplied by your firm and the quantity supplied by the other two firms.

In each group, there is a firm Yellow, a firm Red and a firm Blue. The three colors are randomly assigned to the participants. You are informed about the color of your firm on the decision screen. One of the three colors is also randomly assigned to each of the markets. Thus, there is a market Yellow, a market Red and a market Blue. The colors of the firms and the markets stay the same throughout all 20 rounds. In rounds 1 to 5 each firm can only serve the market with the same color. In the following rounds 6 to 20 all firms have access to all markets.

In the first round, you see the following decision screen:



The round number appears in the upper left corner of the screen. In the upper right corner, you can see how many more seconds you have to enter your quantity.

You can use the "What-if-calculator" to determine your profits from different combinations of your quantity and the average quantity of the other two firms in one single market. These calculations are purely hypothetical and do not influence your payments. They only serve an informational purpose.

If you want to supply in one particular market, you need to click on the supply-button first. If you do, an input field appears. There is no supply-button in the market with the same color as your firm, and the input field appears immediately. You set your quantity by entering a number in the input field (maximum one decimal). If you click on the supply-button in round 1 to 5, you will get a message saying that supplying in this market is not possible yet. Once you have entered your quantity, you must click on the OK-button. You can then no longer revise your decision for that round.

After all firms have made their decision, your profit in each market will be determined for this round.

Your profit in one market is determined as follows:

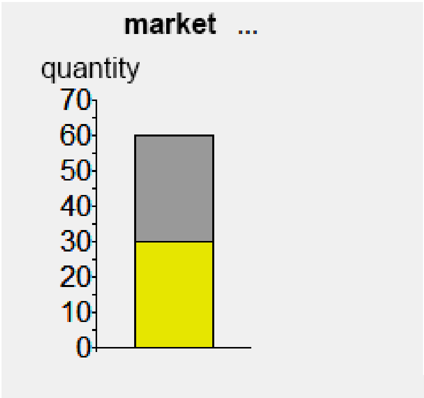
$$\begin{aligned}[74 &- (\text{your quantity} + \text{the quantity of the other firms})] \cdot (\text{your quantity}) \\ &- 2 \cdot (\text{your quantity}).\end{aligned}$$

The profit of the other firms in the market is determined in the same way. The above expression shows that, given your quantity in a market, the larger the quantities of the other firms in this market, the smaller your profit. The same is true for the other firms. The larger the quantity you choose, the smaller the profit of the other firms in this market. The expression in the brackets is the market price. If the total quantity supplied in one market exceeds 74 units, the market price is zero. You can also incur losses.

In all subsequent rounds, the outcome of the previous round is displayed in the upper half of the screen.

In rounds 2 to 20, you see the following decision screen:

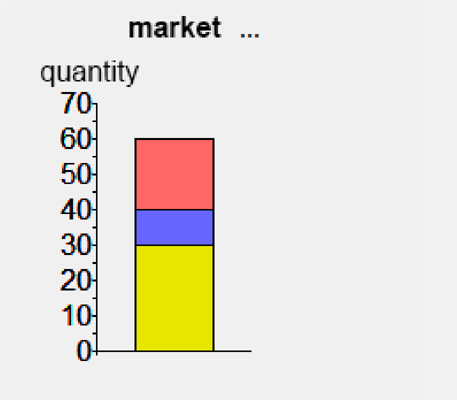
Bars show the outcome of the previous round in each market.



The length of the bar shows the total quantity supplied in the particular market. The parts in different colors inform you about how much of the total quantity your firm (in the color of your firm) and how much the other firms (in gray) supplied in this market. If your firm did not serve the particular market, the color of your firm does not appear in the bar. If none of the other firms served the particular market, the color gray does not appear in the bar. Your profit earned in the particular round and market is written in the line below the bars.

The picture shows an example for one of the markets. Your firm (yellow) has supplied 30 units. The two other firms together have supplied 30 units (gray) and, thus, the total quantity supplied in this market is 60.

HardInfo* and *FullInfo



The length of a bar shows the total quantity supplied in the particular market. The parts in yellow, red and blue inform you about how much of the total quantity each firm supplied in this market. If a firm did not serve the particular market, the color of that firm does not appear in the bar. Your profit earned in the particular round and market is written in the line below the bars.

The picture shows an example for one of the markets. Your firm (yellow) has supplied 30 units, firm blue 10 units, and firm red 20 units. Thus, the total quantity supplied in this market is 60.

In the lower half of the screen, you can enter your quantity for the current round, exactly as you did in the previous rounds.

Between round 10 and 11 you will be informed about your average profits in rounds 1 to 5 and 6 to 10 respectively. For this purpose, an information screen opens during 45 seconds. After 45 seconds this information screen closes and you can enter your quantity for the current round, exactly as you did for the previous rounds.

SoftInfo and _FullInfo_

Between round 10 and 11 you will have a one-time opportunity to communicate with the other firms in your group. For 3 minutes, a chat window allows you to talk to the other firms in your group. No one, except the two other firms in your group can see those messages. The number of messages is unlimited. However, your messages must not reveal your identity (age, address, gender etc.) or offend other members of your group. After 3 minutes, the chat window closes and you can enter your quantity for the current round, exactly as you did in the previous rounds.

Do you have any questions?