Communicating Cartel Intentions*

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Abstract

While the economic harm of cartels is caused by their price-increasing effect, sanctioning by courts rather targets at the underlying process of firms reaching a price-fixing agreement. This paper provides experimental evidence on the question whether such sanctioning meets the economic target, i.e., whether evidence of a collusive meeting of the firms and of the content of their communication reliably predicts subsequent prices. We find that already the mere mutual agreement to meet predicts a strong increase in prices. Conversely, express distancing from communication completely nullifies its otherwise price-increasing effect. Using machine learning, we show that communication only increases prices if it is very explicit about how the cartel plans to behave.

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1 Introduction

From an economic point of view, the bad thing about cartels is that they reduce welfare through high collusive prices. However, there is no legal remedy against high collusive prices as such. It is rather the meeting in a collusive context (see Calvano et al., 2020) and the process of reaching a price fixing agreement that is deemed sanctionable by the courts whereas evidence of high prices resulting from this process is not a necessary factor in determining whether firms should be sanctioned for having formed a cartel.[1] However, while there is consensus that direct evidence of a causal effect of the collusive agreement on prices is not necessary for sanctioning, it remains unclear to what extent there needs to be supplementary evidence that allows the presumption that such a causal relationship exists.[2] The "plus" factors often required by courts in the US (see Kovacic et al., 2011) suggest that some supportive evidence of a causal effect is necessary. In the EU, the court often refers to public distancing from the agreement or proof to the contrary by the firms as exceptions from per-se sanctioning,[3] which again suggests that evidence of a causal effect of the agreement on prices is at least implicitly considered relevant.

Thus, while the economic harm caused by cartels is not the main legal argument for courts to sanction them, it certainly plays some role in their judgment. This explains why there is a long-standing debate on what makes a price-fixing cartel agreement among firms explicit enough to trigger liability. As Kaplow (2011b) puts it, "various seemingly clear rules [...] are entirely unclear upon examination. Furthermore, when one looks at what the courts actually do – that is, what sorts of facts they find adequate or insufficient to support a finding of agreement – the picture becomes even mukier." Despite the obvious relevance of this debate to the work of antitrust authorities around the world, there are

[1] In Interstate Circuit v. U.S. (1939), the court even argued that mere participation in a meeting or even just uncontradicted knowledge of a collusive plan are sufficient to assume that there was a sufficiently clear intention to participate in price-fixing. Similarly, in their antitrust guidelines, the Federal Trade Commission (2000) states that the "courts conclusively presume such agreements, once identified, to be illegal, without inquiring into their claimed business purposes, anticompetitive harms, procompetitive benefits, or overall competitive effects." In the EU, it has been similarly argued that an agreement with the intention to fix prices is already caught by Article 101 of the TFEU even if the agreement had no effect on prices at all, for example in Lombard Club, C-125/07, ECLI:EU:C:2009:576 and in the European Government Bonds decision (2021). For a more detailed discussion, see Kaplow (2011a,b), Viscusi et al. (2018), and Harrington (2020).

[2] In the Airfreight (2010) case, this causality assumption is made explicit by the commission: "Although in terms of Article 101 of the TFEU the concept of a concerted practice requires not only concertation but also conduct on the market resulting from the concertation and having a causal connection with it, it may be presumed, subject to proof to the contrary, that undertakings taking part in such a concertation and remaining active in the market will take account of the information exchanged with competitors in determining their own conduct on the market [...]."

[3] For distancing, see, e.g., Eturas, C-74/14, ECLI:EU:C:2016:42, where the court argues that even passive participation in an anticompetitive agreement without the firm "clearly opposing" the agreement or "publicly distancing itself from its content" is captured by Article 101. In Icap, T-180/15, ECLI:EU:T:2017:795, the court "held that, subject to proof to the contrary, which the economic operators concerned must adduce, it must be presumed that the undertakings [...] take account of the information exchanged with their competitors in determining their conduct on that market."

no clear criteria as to what evidence on the organization of the meeting and the content of the communication is sufficient to presume that firms facilitated price coordination (see Kaplow, 2013; Page, 2009; Whinston, 2008; Posner, 1969).

In this paper, we provide experimental evidence that shows which aspects of the meeting and the communication content justify the assumption that they had a causal effect on the prices they set by the firms. Our findings offer guidance to courts in showing what makes a price-fixing agreement between firms explicit enough to have the intended anti-competitive effect. Regarding the meeting itself, we test whether information about the mutual willingness to communicate about prices already has a signaling value that leads to higher prices. Regarding the content of the communication, we use two complementary approaches. Firstly, a treatment variation incentivizes more or less explicit communication. Secondly, we use machine learning to cluster the communication protocols according to how explicit they are in terms of price-coordination. This allows us to examine whether such explicitness leads to higher prices compared to more indirect communication content. In addition, we investigate whether explicit communication occurs more frequently when firms are informed in advance about each other's willingness to meet.

In the laboratory experiment, we compare 2×2 treatments of a simple duopoly experiment. In all treatments, firms individually decide if they would like to communicate about prices. The treatments differ in whether information about the competitors' willingness to talk about prices is displayed (Info treatments) or not (NoInfo), and whether the availability of a communication channel depends on the firms' mutual willingness to communicate or not: in ChooseChat treatments, a chat window opens and the firms can coordinate their behavior only if both firms agree to communicate. As soon as the chat window opens, the cartel counts as being formed and is sanctioned with some probability, regardless of the communication content or whether the firms succeed in restricting competition. In AlwaysChat treatments, the chat window opens automatically, irrespective of the decisions made. However, communication per se does not yet constitute a cartel. Instead, we rely on the communication content and the resulting prices to determine sanctions. Thus, the first treatment variation targets the signaling value of the willingness to communicate by highlighting the intention to chat in the Info treatments. The second treatment comparison induces exogenous variation in the degree of explicitness by creating incentives to avoid explicit cartel talk in the AlwaysChat treatments.

Our results indicate that coordination at high prices is equally driven by both, the mutual signaling of the willingness to communicate and the communication content. When there is communication but no distinct information that both firms wanted to communicate, prices are higher than without communication at all. Display of the information that both wanted to communicate further increases prices up to the joint-profit maximizing level. Conversely, communication under the shadow of the information that there is no

mutual willingness to communicate does not have any effect on prices. Using machine learning to cluster the communication into conversations that are more or less explicit about price coordination, we can show that the positive effect of communication on prices rests entirely on its explicitness.

While it is well documented that communication, in particular free-form communication, facilitates collusion (Friedman, 1967; Isaac et al., 1984; Davis and Holt, 1998; Fonseca and Normann, 2012; Engel, 2015; Dijkstra et al., 2021; Freitag et al., 2021; Andres et al., 2023), the effect of a binary communication decision on cartel formation and communication has to the best of our knowledge not been studied so far in the experimental literature. The study by Gillet (2021) is related to our research by showing in a symmetric homogeneous three-firm Bertrand game that, if a majority of firms voted in favor of a profit-maximizing price-fixing agreement, those firms who voted for the agreement pick higher prices than those who voted against it. Similarly, Fischer and Normann (2019) find no difference in the mean market outcome between treatments with imposed and chosen communication in an asymmetric duopoly experiment.

Our study furthermore contributes to the discussion about the external validity of laboratory experiments when it comes to firm behavior. Experimental studies are an important method for the evaluation of various competition policies such as the leniency program because they allow the observation of the whole universe of detected and undetected cartels, which is a great advantage compared to empirical studies on the behavior of real firms (see Miller, 2009; Bigoni et al., 2012; Calvano et al., 2020; Hinloopen et al., 2023, and the literature therein). However, experimental studies on firm behavior have the potential disadvantage that their external validity may be limited (see, e.g., Guala and Mittone, 2005; Schram, 2005; Marvão and Spagnolo, 2014). We focus on a specific aspect of market experiments that may limit external validity, the experimental implementation of firms' decision to form a cartel. In experiments, a cartel typically counts as being formed as soon as all firms agree to communicate with each other, regardless of the communication content and whether they succeed in restricting competition or not (see, e.g., Apesteguia et al., 2007; Hinloopen and Soetevent, 2008; Bigoni et al., 2012). This procedure has the practical advantage that it allows computerized sanctions because a simple, easily classifiable choice in form of the mutual agreement to communicate is interpreted as a successful cartel and serves as decision feature for potential sanctions. However, this approach does not take into account that sanctioning a real cartel often requires further evidence, e.g., of the circumstances of the meeting or the content of communication. From our results, we conclude that this simplification is no threat to external validity as long as the experiment provides no distinct feedback on the communication choices of the other firms.

In the following, we describe our experimental design in Section 2 and develop a theory and hypotheses in Sections 3 and 4. We then describe in Section 5 how we use machine learning to analyze our data and present our results in Section 6 before we conclude in Section 7. An appendix complements the paper with the instructions (A), supplementary information on the communication analysis (B), and additional details on the price data (C).

2 Experimental Design

In the beginning of the experiment, subjects are randomly allocated to groups of three. Each group consist of two firms and one competition authority (similar to Andres et al., 2021). The group and role composition remains fixed in all 20 rounds.

Stage Game Both firms have costs of zero. Demand is perfectly inelastic at a quantity $q = 10$ for prices up to the reservation price of 10; for prices above 10, demand drops to zero. If both firms set the same price, they share the market equally. The individual profit per round equals

$$\pi_i = \begin{cases} p_i \cdot q, & \text{if } p_i < p_j \\ \frac{p_i \cdot q}{2}, & \text{if } p_i = p_j \\ 0, & \text{if } p_i > p_j \end{cases} \tag{1}$$

The two firms simultaneously set integer prices $p \in \mathbb{Z} : 0 \leq p \leq 10$. Given the restriction to integer prices, there are two Nash equilibria, $p_i = p_j = 0$ and $p_i = p_j = 1$, where the latter payoff-dominates the former. The Nash equilibrium with $p^n = 1$ corresponds to an individual profit of $\pi^n = 5$. The joint profit maximizing price of $p^c = 10$ yields a profit per firm of $\pi^c = 50$. If the other firm chooses $p^c = 10$, the optimal undercutting price is $p^d = 9$. Deviating to $p^d = 9$ corresponds to a profit of $\pi^d = 90$, while the other firm earns a profit of $\pi^b = 0$. In each round, the firms get feedback on both prices, the own quantity sold and the resulting own profit.

Repetition Similar to Freitag et al. (2021), the total duration of 20 rounds is divided into halves, with a communication stage in between rounds 10 and 11. The first ten rounds provide a benchmark for price setting behavior absent any communication. After round 10, firms decide individually if they want to communicate with each other or not. Depending on the treatment and the communication decisions of the firms, a chat window opens for 5 minutes before round 11 starts.

Treatments We employ a between-subjects design with 2×2 treatments. The two treatment variations concern the information about and the consequences of the decision to communicate.

First, we vary whether the unanimous decision to communicate is a necessary condition for the opening of the chat. In ChooseChat-treatments, the chat only opens if both firms agree to communicate. In this case, they are assumed to have formed a cartel. If at least one of the two firms decides against communication, no chat window opens and no cartel is formed. In AlwaysChat-treatments, firms decide in the same way but the chat window opens irrespective of the communication decisions.[4] A cartel counts as being formed if and only if the firms actually use the chat to agree on prices and behave in the way they agreed upon. In these treatments, the communication decisions have no consequences for the firms. We use this treatment variation as an instrument to modify how explicitly firms discuss prices in the experiment.

The second treatment dimension varies whether firms are informed about their competitor's intention to communicate or not. In Info-treatments, firms receive feedback about their own and the other's decision to communicate before the communication starts. Making the communication decisions known to both firms allows a clean comparison of communication and price setting between the ChooseChat and the AlwaysChat treatment because it makes sure that the information value of the opening of the chat window is the same in both treatments.[5] However, the distinct display of the communication decision also comes with an inherent signaling value. Therefore, we compare behavior in the Info-treatments to NoInfo-treatments, where the decision to communicate is not displayed to the firms.

Firms are informed about whether they are in a Info or NoInfo-treatment in the instructions because we want them to know the signaling value of their communication decision. However, they learn only after the communication decision–but before the communication starts–whether their mutual communication decision is decisive for the opening of the chat window. Thus, communication decisions should not be affected by the ChooseChat or AlwaysChat treatment variation but communication itself may differ between these treatments because during the communication firms know whether their sanctioning risk depends on the communication content or not.

Judgment In order to implement judgment of firms' conduct in the AlwaysChat treatments, the participants in the role of the competition authority observe all the activity (price choices and chat content) in their market in real time. Starting with round 11, they

[4]This treatment variation mimics casual communication as it may occur during coffee breaks at industry meetings or during trade fairs.

[5]In ChooseChat, a firm can infer from the fact that the chat window opens that also the other firm must be willing to communicate. In AlwaysChat, this information is lacking. It may be transmitted during the chat, but would still not be as verifiable as it is in ChooseChat.

judge whether what they observe is a cartel or not in each round.[6] Firms do not obtain direct feedback about this judgment. Subjects in the role of the authority are paid based on the overlap of their judgment with the judgment of an expert in competition law with whom we contracted to independently evaluate the chat messages and the price setting behavior of the firms in the same way as the participants in the role of the competition authority judge.[7]

In the ChooseChat treatments, authorities also judge chat and pricing activity but their judgment has no effect on the firms. In this way, we ensure that any effect of being observed while chatting on the communication content is held constant across the two treatments. For a similar reason, authorities do not know whether they are in a ChooseChat treatment or in an AlwaysChat treatment when they make their judgments so that firms can expect that the human view on their communication is the same in both treatments.[8]

Investigation and sanctions In each round, an investigation occurs with an exogenous probability of $\alpha = 0.1$.[9] If there is an investigation and a cartel was formed according to the judgment of the competition authority in that round, the firm has to pay a fine $F = 20$. Thus, firms only have to pay a fine if the random mechanism decides that an investigation takes place and a cartel was formed in that round, where the latter depends on the communication decision of the two firms in the ChooseChat treatments and on the authorities' judgment in the AlwaysChat treatments. Firms are informed about the fines they have to pay only at the very end of the experiment.[10]

Procedures The experiment was programmed in z-Tree (Fischbacher, 2007). We collected our data in 43 experimental sessions at the experimental laboratory in Potsdam. The recruitment process was conducted using ORSEE (Greiner, 2015). Assignment to both treatments was random in the sense that subjects signing up for a session did not know which treatment would be run. No specific rules have been used to restrict subjects that are registered in the database from participating in the experiments other than that they have not participated in one of the treatments of this experimental study

[6]The authority does not know the communication decisions. This is made clear to all firms in advance.

[7]The expert holds a law degree (German: "Volljurist"), is writing a dissertation in the field of competition law, and also has practical experience in this area. After each session, the expert receives the full chat protocols as well as the history of prices of both firms. A few days later, he provides us with a round-wise classification of whether a cartel was active or not.

[8]Furthermore, this requires that authorities do not observe the communication decisions of the firms because otherwise they could infer the treatment from combining the information about the communication decisions and the mere observation that a chat took place.

[9]According to Ormosi (2014), 10% constitutes a lower bound of the annual cartel detection rate in the European Union between 1985 and 2009.

[10]If we would provide immediate information on sanctions to the firms, this might impact their subsequent price setting behavior, which would impede the comparison of prices across treatments if sanctions happen to occur with different frequency depending on the treatment.

before. We collected data on 29 independent markets in Info×AlwaysChat, 52 in Info×ChooseChat, 35 in NoInfo×AlwaysChat, and 35 in NoInfo×ChooseChat, with 453 participants in total. On average, participants in the role of firms earned 21.01 euros and participants in the role of the competition authority earned 21.38 euros. The average duration of a session was about one hour.

3 Theoretical framework

As a theoretical framework, we rely on the model developed by Kreps et al. (1982) to explain cooperation in the finitely repeated prisoners' dilemma. The model assumes that players have incomplete information about the other's "rationality" in the sense that they hold some belief λ that the other plays tit-for-tat in the finitely repeated game. Based on this assumption, the model allows to derive a lower bound on the number of remaining rounds so that players might choose the cooperative action.

To apply this model to our setup, we restrict attention to a subset of stage game payoffs. The Nash equilibrium price of $p^n = 1$ corresponds to an individual profit of $\pi^n = 5$. If firms set the joint profit maximizing price of $p^c = 10$ after having communicated, they bear the risk of the expected fine of $\alpha \cdot F = 0.1 \cdot 20 = 2$. Thus, the expected profit per firm in a cartel equals $\pi^c = 50 - 2 = 48$. A unilateral deviation to $p^d = 9$ corresponds to a profit of $\pi^d = 90$, while the other firm earns a profit of $\pi^b = 0$.

Following Kreps et al. (1982), a firm holds the belief λ that the other firm plays the tit-for-tat strategy and the belief $1 - \lambda$ that other firm plays always defect. It then follows that the number of rounds that must be left so that a firm finds it optimal to play tit-for-tat in our setup equals:[11]

$$H^* = 3 + \frac{2 \cdot (\pi^d + \pi^n) - 4 \cdot \pi^b}{\lambda \cdot (\pi^c - \pi^n)} \tag{2}$$

Note that H^* is decreasing in the belief λ. The larger the belief that the other firm plays tit-for-tat, the fewer rounds have to be remaining such that a firm finds it optimal to play tit-for-tat themselves.

Solving this for λ gives:

$$\lambda^* = \frac{2 \cdot (\pi^d + \pi^n) - 4 \cdot \pi^b}{(\pi^c - \pi^n) \cdot (H - 3)} \tag{3}$$

[11] Equation (2) follows from the condition $H^* = 1 + \frac{2a - 4b + 2\lambda}{\lambda}$ in Kreps et al. (1982). In this equation, the payoff from mutual cooperation is normalized to 1 and the payoff from mutual defection is normalized to 0, a denotes the gain from defecting when the other player cooperates and b denotes the loss from cooperating when the other player defects. Applying the same normalization to the relevant stage game payoffs in our setup gives $a = \frac{\pi^d - \pi^n}{\pi^c - \pi^n}$ and $b = \frac{\pi^b - \pi^n}{\pi^c - \pi^n}$.

Thus, for H remaining rounds, the firm finds it optimal to play tit-for-tat if $\lambda \geq \lambda^*$. Using the above payoff parameters and the number of remaining rounds in our setup, $H = 10$, we obtain a critical value of $\lambda^* \approx 0.63$. The treatment variations in our experiment target at the value of λ as they change the firms' belief that the other firm will play a cooperative strategy. Both, the information that there is a mutual willingness to communicate in the Info treatments as well as a higher explicitness of communication as instrumented in the ChooseChat treatment variation, are likely to lead to a more optimistic belief λ.

4 Hypotheses

We now set up hypotheses on the communication content and price setting behavior. We consider only behavior in rounds 11-20 because this is when any treatment differences should materialize.

Hypotheses 1-3 refer to comparisons between the ChooseChat and the AlwaysChat treatments. For a clean ceteris paribus test of these hypotheses it is important to hold the signaling value of the decision to communicate constant across treatments. Therefore, our main test of these hypotheses relies on the Info treatments.

We start with the ex-ante deterring effect of the ChooseChat sanctioning rule that prevents all communication as soon as one firm prefers not to enter the chat. This hinders many firms that would potentially have formed a cartel from doing so because they have no chance to speak to and convince their counterpart, which they would have in AlwaysChat. Our estimate for this deterring effect is the treatment difference in the explicitness of communication.[12]

Hypothesis 1. *Fewer markets will exhibit explicit cartel communication in* Info×ChooseChat *than in* Info×AlwaysChat.

For the further hypotheses, we divide our data into two sub-samples, depending on whether both firms decided for communication or at least one of them decided against it. We do not further divide the latter data into those where one and where none of the firms wanted to communicate because according to the model by Kreps et al. (1982), the prediction is the same if we interpret the decision to communicate as an intention to play

[12]Note that in NoInfo×AlwaysChat, firms have an informational disadvantage compared to NoInfo×ChooseChat as the opening of the chat window provides no information about the other firm's communication decision. If the firms would just even out this informational imbalance by transmitting information about their communication decision during the chat, communication would already become more explicit because sharing information about the communication decision comes close to sharing information about price setting plans in this setting. This rather mechanic effect in NoInfo×AlwaysChat would seemingly amplify the deterring effect of NoInfo×ChooseChat sanctioning on the explicitness of communication.

tit-for-tat. When only one firm is willing to do so and learns that the other firm is not, the first firm will find it optimal to switch to a non-cooperative strategy, too.[13]

The firms in markets in which both firms decided that they want to communicate share the same chat window availability in all treatments so that the only difference between ChooseChat and AlwaysChat treatments is whether the communication content affects the risk of sanctions or not. While in ChooseChat-treatments sanctions are already guaranteed in case an investigation takes place, the risk of being sanctioned in AlwaysChat-treatments depends on the chat content and the resulting price setting behavior. Thus, we expect that firms in Info×AlwaysChat will communicate less explicitly about price setting than those in Info×ChooseChat to reduce the risk of being sanctioned:[14]

Hypothesis 2. *Given that both firms decided for communication, communication is more explicit about prices in* Info×ChooseChat *than in* Info×AlwaysChat*.*

Given that Hypothesis 2 holds, we expect that the more explicit communication in Info×ChooseChat induces more optimistic beliefs about the other firm's willingness to collude. This is because explicit communication is likely to facilitate coordination and enhance trust among the firms (see Andres et al., 2023). In the model, this is reflected in an increase of λ, leading to higher prices in Info×ChooseChat than in Info×AlwaysChat.[15]

Hypothesis 3. *Given that both firms decided for communication, prices are higher in* Info×ChooseChat *than in* Info×AlwaysChat*.*

Next, we compare prices in the two treatments for markets in which at least one firm decided against communication. In both ChooseChat-treatments, we expect that pricing will be rather competitive because the firms cannot communicate if one or both of them decided against. Furthermore, irrespective of the information setting, they can infer from the fact that the chat window does not open that at least one of them voted against the chat. Again, the decision not to chat can be interpreted as a signal that the firm is not willing to play a cooperative strategy. Thus, $\lambda \to 0$. In both AlwaysChat-treatments, firms have the automatic possibility to communicate, which may facilitate coordination and lead to a more optimistic belief (see Andres, 2024) and, thus, higher prices compared to no communication at all. This prediction holds for both the Info and the NoInfo version of the treatments.

[13] In line with this argument, the mean prices in rounds 11-20 in markets where none of the firms wanted to communicate do not differ significantly from the mean prices in markets where one of the two firms decided for communication in any of the treatments.

[14] Note that a clean test of this hypothesis should again rely on the Info-treatments only. If firms in NoInfo×AlwaysChat communicate more explicitly than in NoInfo×ChooseChat simply because they share information on their communication preference, this would work against the effect postulated in Hypothesis 2.

[15] As Hypothesis 3 conditions on Hypothesis 2, the same restriction to Info-treatments applies.

Hypothesis 4. *Given that one or both of the firms decided against communication, (i) prices are lower in* Info×ChooseChat *than in* Info×AlwaysChat*, and (ii) prices are lower in* NoInfo×ChooseChat *than in* NoInfo×AlwaysChat*.*

The Info and the NoInfo version of the AlwaysChat-treatment allow us to study the interaction of the pure effect of communication with the signaling effect of the information that either both firms wanted to communicate or that at least one of the firms did not want to communicate. As the firms in NoInfo×AlwaysChat are not informed about the (lack of) mutual willingness to communicate, the belief λ will not change compared to the initial belief when the chat window opens. In contrasts, in Info×AlwaysChat, the information is displayed so that beliefs will become more optimistic compared to NoInfo×AlwaysChat if the signal is positive and more pessimistic if the signal is negative. This will likely lead to higher prices in Info×AlwaysChat than in NoInfo×AlwaysChat if both firms decided to communicate and to lower prices in Info×AlwaysChat than in NoInfo×AlwaysChat if not.

Hypothesis 5. *Given that both firms decided for communication, prices are higher in* Info×AlwaysChat *than in* NoInfo×AlwaysChat*.*[16]

Hypothesis 6. *Given that one or both of the firms decided against communication, prices are lower in* Info×AlwaysChat *than in* NoInfo×AlwaysChat*.*[16]

5 Communication

As input for our analysis, we use the chat messages from all four treatments as our "corpus," considering communication in one market as one observation ("document"). Before the analysis, we apply a systematic natural language processing procedure: we correct spelling mistakes, remove stop words to clean the text, and reduce all strings ("tokens") which occur in the text to their linguistic stem. Next, we transform the chat communication into a term-frequency-inverse-document-frequency matrix with $tfidf_{\alpha,\beta} = tf_{\alpha,\beta} \cdot idf_{\alpha}$.[17]

[16] Hypotheses 5 and 6 were not preregistered.

[17] The term-frequency–inverse-document-frequency has been proven useful to weight the importance of tokens at the corpus level (see Feinerer et al., 2008; Gentzkow et al., 2019, and the literature therein). In this matrix, the rows represent documents and the columns represent tokens. The entries in the matrix are computed as the product of two terms, the term frequency $tf_{\alpha,\beta}$ and the inverse document frequency $idf_{\alpha} = \log_2 \frac{|D|}{|\{d|t_{\alpha} \in d\}|}$. D is the total number of documents in the corpus and $|\{d \mid t_{\alpha} \in d\}|$ the number of documents in which the token t_{α} occurs. The term frequency $tf_{\alpha,\beta}$ is the absolute frequency of token t_{α} in document d_{β}. The inverse document frequency weights tokens according to how specific they are for single documents. If a token is very rare in the total corpus, it will have a low $tfidf_{\alpha,\beta}$ score because $tf_{\alpha,\beta}$ will be low. If a token is very common and occurs in many documents, $tfidf_{\alpha,\beta}$ will be low because idf_{α} will be low.

After having transformed the chat messages into this matrix, we analyze the communication content using a hierarchical cluster analysis (HCA), a common method that has proven useful to cluster documents.[18] To apply the HCA, we use an agglomerative algorithm: the algorithm starts by treating each document as a cluster by itself and then repeatedly extends the clusters until only one cluster exists. At each extension iteration, the two less distant ones form a new cluster, where we measure the distance between clusters by their euclidean distance: $d_{i,j} = \|X_i - X_j\|^2$. We run the algorithm on a binary dissimilarity matrix using the term-frequency-inverse-document-frequency of tokens that are not more sparse than 95% to consider only the most important tokens.

The result of the HCA is represented in Figure 1.[19] The figure illustrates the relative frequency rankings of the 50 most frequent tokens in the two clusters. A low rank indicates that a token occurs frequently in the respective cluster. Tokens outside the shaded area are those that are most distinct between clusters. Tokens above the shaded area contain words like "agreement," "equal," "profit," and numbers relating to relevant prices, quantities and profits. Thus, we name the cluster where these tokens rank relatively high the *explicit* cluster. Below the shaded area are mainly less specific tokens like "high" and smileys, but no numbers. Therefore, we name this cluster *indirect*.

Across treatments, we observe 39 markets in the explicit cluster (14 in ChooseChat and 25 in AlwaysChat) and 35 in the indirect cluster (0 in ChooseChat and 35 in AlwaysChat). In the remaining 77 markets (73 in ChooseChat and 4 in AlwaysChat), firms do not communicate.

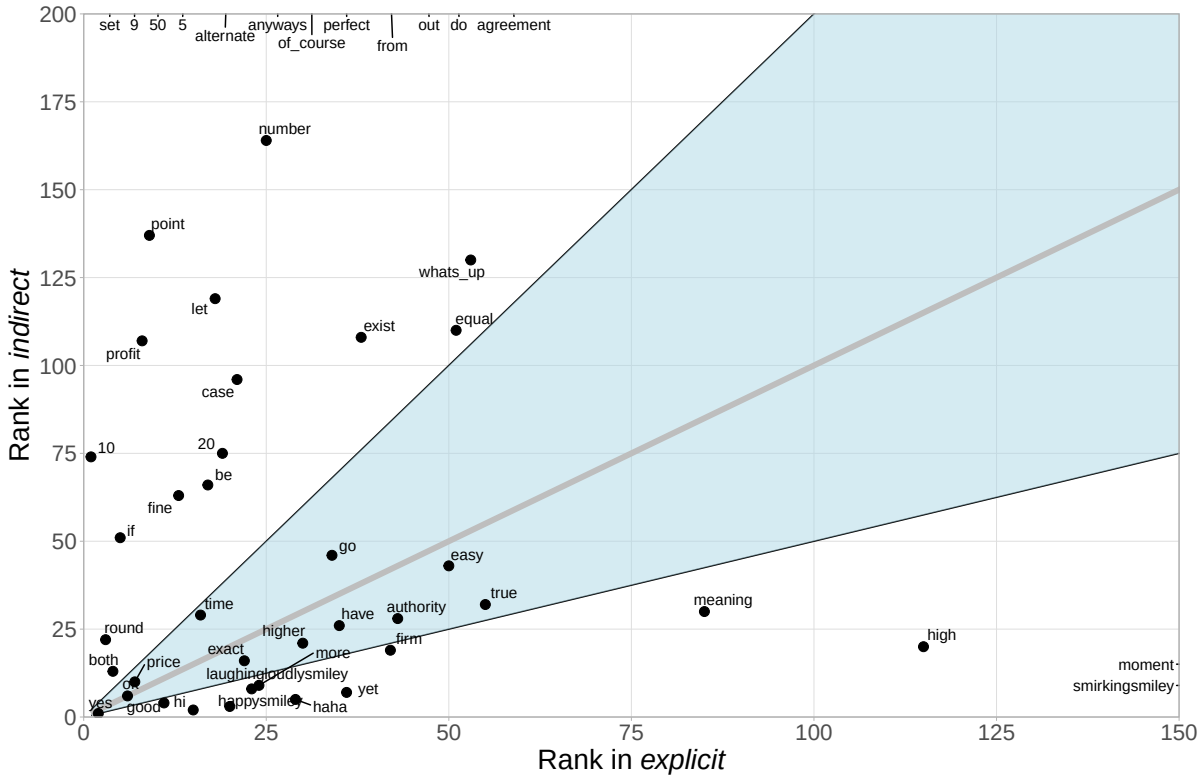
6 Results

We start this section with a brief summary of cartel formation rates. We then compare communication content and prices across treatments, conditioning on the decision to communicate. Finally, we report findings on the interaction of these variables and their relative importance.

Cartel formation Across all 302 firms, 43% decided for communication. Given the random matching, this results in 31 markets in which both firms decided for communication and 120 markets in which at least one firm decided against communication (out of which in 53 markets none of the two firms wanted to communicate). The bottom rows in Table 1 display the distribution across treatments.

[18] See Feinerer et al. (2008), Gentzkow et al. (2019), Kaufman and Rousseeuw (2009), and the literature therein.

[19] We provide support for the assumption that our chats are best grouped into two clusters in Figure 3 in Appendix B. The result of the HCA using the original German tokens is shown in Figure 4.



Note: The two black lines indicate the border where the two relative rank differentials $\frac{r_{explicit}-r_{indirect}}{r_{indirect}}$ and $\frac{r_{indirect}-r_{explicit}}{r_{explicit}}$ are equal to 1. Tokens outside the shaded area have a relative rank differential exceeding 1.

Figure 1: Frequency rankings of the 50 most used tokens in both clusters. Figure 4 in Appendix B provides the tokens in German.

As communication alone does not necessarily constitute a price-fixing cartel, the expert considers both, communication content and prices, when making the judgment whether and during which rounds a cartel was in place in a market. According to this judgment of the expert, cartels were formed in 13% of all rounds in Info×ChooseChat, in 12% of all rounds in NoInfo×ChooseChat, in 37% of all rounds in Info×AlwaysChat, and in 44% of all rounds in NoInfo×AlwaysChat (using data from rounds 11-20).[20] The incidence of cartel formation is significantly lower in the ChooseChat than in the AlwaysChat treatments (two-sided Wilcoxon Mann Whitney test with continuity correction, $p < 0.01$ in Info, $p < 0.01$ in NoInfo). This is not surprising given that communication was possible in the ChooseChat treatments only when both firms agreed (which was the case in about one sixth of all markets) while it was always possible in AlwaysChat treatments.

[20]Subjects in the role of the competition authority choose the same judgment as the expert in 85% of the cases. The difference in the two judgments is not systematic in a two-sided Wilcoxon Mann Whitney test with continuity correction ($p = 0.66$ in Info×ChooseChat, $p = 0.45$ in Info×AlwaysChat, $p = 0.61$ in NoInfo×ChooseChat, and $p = 0.48$ in NoInfo×AlwaysChat).

Communication Table 1 shows the share of explicit, indirect and no communication in the treatments, separated by the joint communication decision. Hypothesis 1 states that more markets will exhibit explicit cartel communication in Info×AlwaysChat than in Info×ChooseChat. The numbers in Table 1 are in line with the hypothesis. In Info×AlwaysChat, 38% of all markets belong to the explicit communication cluster, while this holds for only 15% of the markets in Info×ChooseChat ($p = 0.02$, one-sided Fisher exact test).[21]

Treatment	Cluster	Info			NoInfo		
		Both decided for communication			Both decided for communication		
		Yes	No	Weighted mean	Yes	No	Weighted mean
ChooseChat	Explicit	1.00 (0.00)	–	0.15	1.00 (0.00)	–	0.17
	Indirect	0.00 (0.00)	–	0.00	0.00 (0.00)	–	0.00
	No	0.00 (0.00)	1.00 (0.00)	0.85	0.00 (0.00)	1.00 (0.00)	0.83
		(N=8)	(N=44)		(N=6)	(N=29)	
AlwaysChat	Explicit	0.75 (0.46)	0.24 (0.44)	0.38	0.78 (0.44)	0.27 (0.45)	0.40
	Indirect	0.25 (0.46)	0.62 (0.50)	0.52	0.22 (0.44)	0.69 (0.47)	0.57
	No	0.00 (0.00)	0.14 (0.36)	0.10	0.00 (0.00)	0.04 (0.20)	0.03
		(N=8)	(N=21)		(N=9)	(N=26)	

Note: Standard deviation in brackets.

Table 1: Fraction of communication cluster assignment by treatment, communication cluster and decision for communication. Note that in treatment ChooseChat, participants could not communicate if at least one of them decided against communication.

Let us now study whether the fraction of explicit cartel formation is larger in Info×ChooseChat than in Info×AlwaysChat given that both firms decided for communication. Indeed, the data in Table 1 (see columns "Yes") points into this direction. However, a one-sided Fisher exact test rejects the hypothesis that the fraction of explicit cartel formation is larger in Info×ChooseChat (100%) than in Info×AlwaysChat (75%) given that both firms decided for communication ($p = 0.23$),[22] which is likely driven by the small number of markets where both firms decided for cooperation. This result does not support Hypothesis 2.

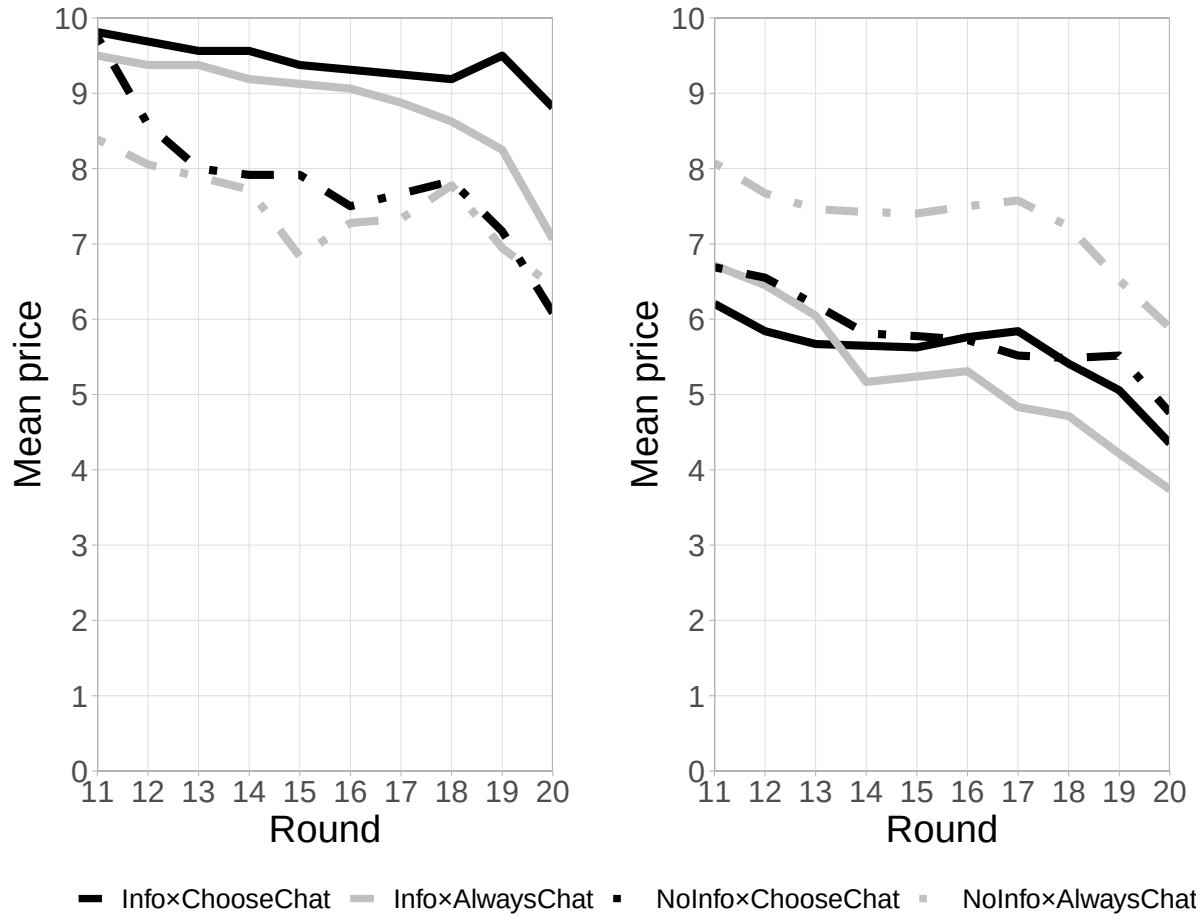
Furthermore, the information contained in Table 1 allows us to compare the fraction of explicit cartel communication across the different communication decisions in treatment

[21] The same holds for the comparison on explicit communication in NoInfo×AlwaysChat (40%) and Info×ChooseChat (17%, $p = 0.03$).

[22] NoInfo×ChooseChat: 100%, NoInfo×AlwaysChat: 78%, $p = 0.34$.

AlwaysChat, where the chat window opened irrespective of the communication decisions. The share of such explicit cartel formation is higher in markets in which both firms decided for communication than in markets in which one or both of the firms decided against it. The fraction of markets with explicit cartel talk is about three times higher when both firms wanted to communicate than when at least one of the firms did not want to communicate (one-sided Fisher exact test, $p = 0.02$ in Info×AlwaysChat, $p = 0.01$ in NoInfo×AlwaysChat).

Prices Figure 2 shows the mean prices over time split up by treatment and by the joint communication decision. Figure 2a contains data from markets where both firms agreed to communicate, Figure 2b from markets where they did not.[23] Thus, all observations represented in Figure 2a relate to markets in which firms could communicate, while in Figure 2b, only firms in the AlwaysChat treatments could communicate.



(a) Both agree to chat

(b) No agreement to chat

Figure 2: Mean prices in rounds 11 to 20 split up by the communication decision.

[23]Figure 5 and Figure 6 in Appendix C illustrate the mean prices and the mean market prices including rounds 1-10, too. The prices in rounds 1 to 10, before the treatment variation sets in, are very similar in all treatments.

Looking at Figure 2a first, we see that prices do not depend on whether the mutual agreement to chat has been necessary for the opening of the chat window: given that both firms want to communicate, mean prices[24] in rounds 11-20 do not differ between treatments Info×ChooseChat (9.41, $SD = 1.16$) and Info×AlwaysChat (8.84, $SD = 2.15$, $p = 0.17$ in a one-sided Wilcoxon Mann Whitney test with continuity correction).[25] This contradicts Hypothesis 3.

Now turn to Figure 2b that displays data from cases in which the firms do not agree to communicate, i.e., when at least one of them decides against communication. The mean prices in rounds 11-20 are not lower in Info×ChooseChat (5.54, $SD = 2.97$) than in Info×AlwaysChat (5.24, $SD = 2,72$, $p = 0.64$ in a one-sided Wilcoxon Mann Whitney test with continuity correction). This is surprising because it implies that the automatic availability of the communication option in Info×AlwaysChat does not have any positive effect on prices compared to Info×ChooseChat if the firms are distinctly informed that at least one of them was not willing to use the communication option. However, the mean price in rounds 11-20 is lower in NoInfo×ChooseChat (5.80, $SD = 3.07$) than in NoInfo×AlwaysChat (7.28, $SD = 2.81$, $p = 0.05$ in a one-sided Wilcoxon Mann Whitney test with continuity correction). Thus, the data contradicts the first part of Hypothesis 4 but supports the second part of the hypothesis.

While the comparison between the ChooseChat and the AlwaysChat conditions delivers rather ambiguous findings, the signal provided by the Info setup has a more clear-cut effect. In Figure 2a, the mean price in rounds 11-20 seems higher in Info×AlwaysChat than in NoInfo×AlwaysChat ($p = 0.09$ in a one-sided Wilcoxon Mann Whitney test with continuity correction),[26] which is in line with Hypothesis 5. Thus, the positive Info signal that both firms decided to communicate seems to make mutual beliefs about the other's willingness to adopt a tit-for-tar strategy sufficiently high to sustain full co-operation.

Furthermore, in Figure 2b, when not both firms want to communicate, the mean price in rounds 11-20 is significantly lower in Info×AlwaysChat (5.24, $SD = 2.72$) than in NoInfo×AlwaysChat (7.28, $SD = 2.81$, $p = 0.01$ in a one-sided Wilcoxon Mann Whitney test with continuity correction), supporting Hypothesis 6. This again points towards a high importance of the signal about the missing willingness to adopt a cooperative strategy if the decision not to communicate is distinctly shown to the firms.

Taken together, the analysis of prices confirms that communication generally has a cooperation-enhancing effect. Information about the mutual communication decision am-

[24] All results on prices are very much the same if we do not look at mean prices in rounds 11-20 but at mean market prices, or at mean prices or mean market prices in round 11 only. Therefore, we do not report them separately.

[25] NoInfo×ChooseChat: 7.84, $SD = 3.23$, NoInfo×AlwaysChat: 7.47, $SD = 2.44$, $p = 0.76$.

[26] Info×ChooseChat vs. NoInfo×ChooseChat: $p = 0.10$.

plifies this effect of communication on cooperation and, thus, collusion in prices. In turn, this effect of communication is entirely offset by the negative signal contained in the distinct information that at least one of the firms was not willing to use the communication option.

Treatment	Cluster	Info		NoInfo	
		Both decided for communication		Both decided for communication	
		Yes	No	Yes	No
ChooseChat	Explicit	9.41 (1.16) (N=8)	–	7.84 (3.23) (N=6)	–
	Indirect	–	–	–	–
	No	–	5.54 (2.97) (N=44)	–	5.80 (3.07) (N=29)
AlwaysChat	Explicit	9.75 (0.26) (N=6)	4.97 (2.90) (N=5)	8.06 (2.01) (N=7)	9.14 (1.74) (N=7)
	Indirect	6.13 (3.50) (N=2)	5.82 (2.81) (N=13)	5.40 (3.54) (N=2)	6.48 (2.88) (N=18)
	No	–	3.20 (1.25) (N=3)	–	8.50 (0.00) (N=1)

Note: Standard deviation in brackets.

Table 2: Mean price in round 11 and 11 to 20 by treatment, communication cluster and decision for communication.

Communication and prices Let us now explore the link between the decision to communicate, the communication content, and prices. Table 2 summarizes the mean prices in rounds 11 to 20 depending on the treatment, the communication decision, and the explicitness of communication as clustered in the HCA. In the ChooseChat treatments, where the firms' mutual agreement is a necessary condition for communication to take place, all communication is clustered as explicit. Accordingly, prices are considerably higher when both firms agreed to communicate and end up communicating very explicitly than when they do not communicate.

In the AlwaysChat treatments, the picture is richer. In particular, the sanctioning based on communication content produces a lot of indirect communication, and the automatic opening of the chat window leads to some explicit communication even after the firms did not mutually agree to communicate. Prices are higher in markets with explicit communication than in ones without explicit communication, except if not both decided

to communicate and they are informed about it. Thus, the effects of the decision to communicate and the display of this decision as well as communication and its explicitness seem to have overlapping effects on prices. To disentangle these effects, Table 3 shows the results of an OLS regression explaining the mean price in round 11-20 with both the signal contained in the mutual decision to communicate and the explicit communication content.

	Dependent variable:				
	Mean prices in round 11 to 20				
	(1)	(2)	(3)	(4)	(5)
Both agree to chat	2.47	1.12		0.69	-0.31
	(0.58)	(0.82)		(0.87)	(0.98)
	$p < 0.01$	$p = 0.18$		$p = 0.43$	$p = 0.76$
INFO		-1.05		-0.92	-0.91
		(0.52)		(0.52)	(0.52)
		$p = 0.05$		$p = 0.09$	$p = 0.08$
Both agree to chat × INFO		2.56		2.42	2.41
		(1.14)		(1.14)	(1.12)
		$p = 0.03$		$p = 0.04$	$p = 0.04$
Communication			1.73	0.78	0.30
			(0.47)	(0.54)	(0.58)
			$p < 0.01$	$p = 0.16$	$p = 0.61$
Explicit					1.71
					(0.80)
					$p = 0.04$
Constant	5.93	6.50	5.59	6.15	6.14
	(0.26)	(0.38)	(0.33)	(0.45)	(0.45)
	$p < 0.01$	$p < 0.01$	$p < 0.01$	$p < 0.01$	$p < 0.01$
No. of Observations	302	302	302	302	302
No. of Groups	150	150	150	150	150
R^2	0.11	0.15	0.08	0.16	0.18

Note: Standard errors in brackets.

Table 3: OLS regression on mean prices depending on the signal and communication.

Columns (1) and (2) in Table 3 confirm that the effect of the mutual decision to communicate on prices is not just selection, but driven by the distinct display of this information: the positive effect of the variable *Both agree to chat* reduces considerably when the interaction with the information of the other firm's decision is added to the regression in column (2). This supports the view that a large part of the effect of communication

on cartelization is already driven by the signal sent with the mutual invitation to discuss prices.

Furthermore, columns (3)-(5) support the view that it is the explicitness of communication, in combination with the above signal, that matters for price coordination, not just communication in general. While the variable *Communication*, that captures whether firms wrote something to the chat at all, is highly significant without further controls in column (3), its effect reduces already when we control for the signaling part in column (4), and it disappears when we include the explicitness of communication as a separate variable in column (5). Thus, we confirm that communication needs to be explicit in order to influence prices.

7 Conclusion

What behavior should reasonably be considered a cartel? Given the difficulties to find forensic proofs for price-fixing agreements, it is highly relevant to figure out which pieces of evidence are sufficient to assume that firms entered such an unlawful agreement. We contribute to answering this question by means of a laboratory experiment, which has the advantage that it allows to fully observe firms' communication and price setting behavior and to manipulate the decision environment in a very clean way. Furthermore, we use an innovative machine learning approach to quantify the communication content in terms of its explicitness about collusion.

The treatments vary in two dimensions. Firstly, we vary whether the individual decision about communication is displayed to the other firm or not. Secondly, we vary whether the firms have to make a distinct decision for communication before they are allowed to chat or whether the chat window opens irrespective of their decision. In one variation, the decision to communicate counts as a cartel and is subject to sanctions. In the other, firms can chat irrespective of the communication decision and will only be sanctioned if they actually agree on prices during the chat and act accordingly.

Our results show that both, communication itself and information about each other's willingness to communicate, increase prices substantially. Regarding the question on what behavior should be considered a cartel, this implies a two-fold answer: communication has to be explicit about prices in order to have an effect, and signaling the intention to collude is already as important as communication itself. As a third result, we find strong evidence that communication under a distinct signal that at least one of the two firms does not want to collude has no effect on prices at all.

These findings provide information that may help to define the boundaries of an agreement, which is an important discussion in competition law (see Kaplow, 2013). Our results show that a meeting with the intention to discuss prices almost certainly leads to cartel

prices. Furthermore, they show that communication without such explicit intention still results in a price increase that makes about half of the effect of communication with the explicit intention. Finally, they support the approach of courts in the EU to consider public distancing, i.e. a firm publicly declaring that it does not want to participate in a price-fixing agreement, as sufficient proof to avoid prosecution.

Moreover, these findings have implications for the ongoing discussion on the optimal burden of proof (see Calvano et al., 2020; Kaplow, 2011c,d). The difficulties of identifying collusive pricing rules have led courts to rely on a per-se punishment for a meeting in a collusive context. This approach considerably lowers the burden of proof but it can only be justified if such meetings almost always make the market outcome less competitive. Our experiment provides evidence that such a per-se rule targets cartels well. If both firms in our setup agree to enter a collusive meeting, this almost always results in very explicit cartel talk and subsequent cartel prices.

Finally, our findings have implications for the design of market experiments. They support the common experimental practice to count a cartel as being formed as soon as all firms agree to communicate. Our data indicates that this simplification of legal practice captures actual cartel formation remarkably well as long as the communication decisions are not displayed to the firms. Under this condition, the resulting price level is very similar to a more complex setting in which sanctions are based on the communication content and its effect on prices instead.

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Appendix

A Instructions

In the following, we present our instructions for firms in Section A.1 and for authorities in Section A.2. Text in *italics* only appears in instructions for the INFO treatments. The original instructions for the participants additionally included screen-shots of the different stages in the experiment.

A.1 Instructions for firms

Instructions

Today you are taking part in a decision-making experiment. If you read the following explanations carefully, you can earn money. The amount you receive depends on your decisions and the decisions of other participants.

You are not allowed to communicate with other participants for the entire duration of the experiment. We therefore ask you not to talk to each other. Violation of this rule will result in exclusion from the experiment and payment.

If there is anything you do not understand, please refer to these experiment instructions again or give us a hand signal. We will then come to you and answer your question personally.

During the experiment we do not talk about euros, but about points. The number of points you obtain during the experiment will be converted into euros as follows:

30 Points = 1 Euro

At the end of today's experiment, you will receive the points you have obtained from the experiment converted into euros plus 5 euros in **cash** as basic endowment.

On the following pages, we will explain the exact procedure of the experiment. First we will explain the basic procedure. Then we will familiarize you with the procedure on the screen. After that, you will first have the opportunity to familiarize yourself with the calculation of earnings in the experiment on the computer screen before the experiment begins.

The experiment

At the beginning of the experiment, you will be randomly assigned to a group with two other participants. During the experiment you will make decisions within this group of three participants. The composition of your group remains the same throughout the experiment. Neither you nor the other participants learn anything about the identity of the participants in the groups – neither before nor after the experiment.

The experiment consists of 20 rounds.

Each participant in your group represents either one of two firms or the competition authority. **You have the role of a firm in all rounds.**

The two firms sell the same (fictitious) good in the same market. It costs the firms nothing to produce the good. Both firms simultaneously make a decision about what price to charge for the good in a round. The price must be an integer between 0 and 10. To do this, enter your price in the field provided and click the OK button at the bottom left.

Your profit depends on your own price and the price of the other firm in the following way:

- **If you enter a price that is lower than the other firm's price**, your profit will be equal to 10 times your price. (So, for example, with a price of 2, your profit would be equal to 20, and with a price of 8, your profit would be equal to 80.) The other firm has a profit of zero in this situation.
- **If you enter the same price as the other firm**, your profit is equal to 5 times your price. (So, for example, if your price is 2, your profit would be equal to 10; if your price is 8, your profit would be equal to 40.) The other firm has the same profit as you in this situation.
- **If you enter a price that is higher than the other firm's price**, your profit will be zero. The profit of the other firm in this situation is equal to 10 times the price of the firm.

At the end of each round, you and the other firm will be informed about your two prices and your own profit.

After you and the other firm have entered prices in this way for 10 rounds, you will have the opportunity to communicate with the other firm in writing via chat. To do this, first you and the other firm will be asked on the screen if you want to use the chat. After that, the following procedure will determine whether you will actually be allowed to chat. First, a random mechanism decides whether the answer you and the other firm gave is relevant for opening the chat at all:

a) With 50 % percent probability, the chat window will open in any case, regardless of your answers.

b) With the other 50 % probability, your answers decide about the opening of the chat window. In this case, the chat window opens only if you both decide for it. If you and/or the other firm decides against, the chat window remains closed.

Regardless of the decision of the random mechanism, you and the other firm will be informed whether the other firm has indicated that it wants to use the chat or not.

The duration of the chat is limited to 5 minutes. You are allowed to write whatever you want in the chat, with the only restriction that you are not allowed to give any hint about your identity.

After the chat, you and the other firm will enter prices for another 10 rounds. The rules for calculating the profits remain the same as in the first 10 rounds.

According to §1 GWB (Act against Restraints of Competition), price fixing and attempted price fixing are prohibited (see box for wording).

> §1 Prohibition of Agreements Restricting Competition
>
> Agreements between undertakings, decisions by associations of undertakings and concerted practices which have as their object or effect the prevention, restriction or distortion of competition shall be prohibited.

The participant in the role of the competition authority has the task of judging whether the contents of the chat and the prices that you and the other firm enter are in line with §1 GWB. For this purpose, the competition authority sees the prices that you and the other firm enter in each round; the competition authority can also read the chat messages that you may have sent to each other before round 11. In rounds 11 to 20, the competition authority will judge in each round whether or not the messages from the chat and the prices you entered in each round are in line with §1 GWB.

The competition authority's payout depends on the consistency of the judgments with those of a real competition law expert. This expert (a qualified lawyer specialized in competition law) will look at the chat messages and prices after today's experiment, just like the competition authority, and judge the extent to which they contain violations of §1 GWB. The payout of the competition authority will be higher, the more the two judgments match.

In each round, another random mechanism decides whether an investigation will take place. This random mechanism is programmed in such a way that with a probability of 10 % (i.e. on average in one out of 10 cases) an investigation takes place. **The**

consequences of such an investigation depend on whether and how you have used the chat:

a) If the chat window has opened regardless of your answers, you will have to pay a fine of 20 points if the competition authority found a violation of §1 GWB in this round. If the competition authority did not find any violation in this round, you do not have to pay any fine.

b) If the chat window has only opened because you both decided for the chat, you automatically have to pay a fine of 20 points, regardless of the judgment of the competition authority in this round. If the chat window remained closed, you do not have to pay a fine.

Whether an investigation takes place is decided by the random mechanism in each round regardless of possible investigations in the previous rounds. So it can happen that several investigations take place or that no investigation takes place at all. You will only find out after round 20 if and when investigations have taken place.

After the last round, you will see an overview screen that shows how many points you have earned in total, what prices you and the other firm have set, how the competition authority has judged, and whether you have had to pay any fines. You will be paid all the points converted into euros right after the experiment.

Now please turn to the screen. There you will immediately have the opportunity to familiarize yourself with the experiment with the help of a profit calculator. We will also ask you to answer some control questions. This is to make sure that all participants have understood the instructions.

If something is unclear to you, please give a clear hand signal. We will then come to your place.

After the experiment we will ask you to fill in a short questionnaire on the computer. After that you will receive your payout.

A.2 Instructions for authorities

Instructions

Today you are taking part in a decision-making experiment. If you read the following explanations carefully, you can earn money. The amount you receive depends on your decisions and the decisions of other participants.

You are not allowed to communicate with other participants for the entire duration of the experiment. We therefore ask you not to talk to each other. Violation of this rule will result in exclusion from the experiment and payment.

If there is anything you do not understand, please refer to these experiment instructions again or give us a hand signal. We will then come to you and answer your question personally.

During the experiment we do not talk about euros, but about points. The number of points you obtain during the experiment will be converted into euros as follows:

30 Points = 1 Euro

At the end of today's experiment, you will receive the points you have obtained from the experiment converted into euros plus 5 euros in **cash** as basic endowment.

On the following pages, we will explain the exact procedure of the experiment. First we will explain the basic procedure. Then we will familiarize you with the procedure on the screen. After that, you will first have the opportunity to familiarize yourself with the calculation of earnings in the experiment on the computer screen before the experiment begins.

The experiment

At the beginning of the experiment, you will be randomly assigned to a group with two other participants. During the experiment you will make decisions within this group of three participants. The composition of your group remains the same throughout the experiment. Neither you nor the other participants learn anything about the identity of the participants in the groups – neither before nor after the experiment.

The experiment consists of 20 rounds.

Each participant in your group represents either one of two firms or the competition authority. **You have the role of the competition authority in all rounds.**

The two firms sell the same (fictitious) good in the same market. The production of the good costs the firms nothing. Both firms simultaneously make a decision about what price to charge for the good in a round. The price must be an integer between 0 and 10.

The profit of a firm depends on its own price and the price of the other firm in the following way:

- If a firm enters a price that is lower than the other firm's price, that firm's profit is equal to 10 times its own price. (So, for example, if the price is 2, the profit would be equal to 20; if the price is 8, the profit would be equal to 80.)
- If both firms enter the same price, the profit per firm is equal to 5 times the price. (For example, if the price is 2, the profit of one firm would be 10, if the price is 8, the profit would be 40.)
- If a firm enters a price that is higher than the price of the other firm, the profit of this firm is equal to zero.

At the end of each round, the firms are informed about both prices and their own profit.

You, as the competition authority, observe the prices, but otherwise have nothing to do at first.

After the firms have entered prices in this way for 10 rounds, they will have the opportunity to communicate in writing with the other firm via chat. To do this, the two firms will first be asked on screen if they would like to use the chat. After that, the following procedure will determine whether they will actually be allowed to chat. First, a random mechanism decides whether the answers they have given are relevant for opening the chat at all:

a) With 50 % probability, the chat window will open in any case regardless of the answers.

b) With the other 50 % probability, the answers decide about the opening of the chat window. In this case, the chat window opens only if both have decided for it. If at least one firm decided against, the chat window remains closed.

Regardless of the decision of the random mechanism, the firms are informed whether the other firm has indicated that it wants to use the chat or not. You as the competition authority do **not** find out how the firms have responded and how, if applicable, an opening of the chat window has come about.

The duration of the chat is limited to 5 minutes. The firms are allowed to write whatever they want in the chat, with the only restriction that they are not allowed to give any hint about their identity.

After the chat, the firms enter prices for another 10 rounds. The rules for calculating the profits remain the same as in the first 10 rounds.

According to §1 GWB (Act against Restraints of Competition), price fixing and attempted price fixing are prohibited (see box for wording).

> §1 Prohibition of Agreements Restricting Competition
>
> Agreements between undertakings, decisions by associations of undertakings and concerted practices which have as their object or effect the prevention, restriction or distortion of competition shall be prohibited.

You, as the competition authority, have the task of judging whether or not the content of the chat and the prices that the firms enter in rounds 11-20 are in line with §1 GWB. For this purpose, you will continue to see the prices that the firms enter in each round; you will also be able to read the chat messages that the firms may have sent to each other before round 11.

In rounds 11 to 20, you will judge in each round whether the messages from the chat and the prices entered by the firms in that round are in line with §1 GWB or not. You enter your judgment on the screen in each round. You have to confirm your entered judgment by clicking the OK button at the bottom right. You have 60 seconds to do this. If you do not enter your judgment within 60 seconds and click on the OK button, the computer program will assume that there is no violation of the law.

The amount of your payout as the competition authority depends on the consistency of your decisions with those of a real competition law expert. After today's experiment, this expert (a qualified lawyer specialized in competition law) will look at the chat messages and prices just like you do and judge the extent to which they contain violations of §1 GWB. For each agreement of a decision of yours with the corresponding decision of the

expert you will receive 40 points. Your payout will be transferred to your bank account within a few weeks.

In each round, another random mechanism decides whether an investigation will take place. This random mechanism is programmed in such a way that with a probability of 10% (i.e. on average in one out of 10 cases) an investigation takes place. The consequences of such an investigation depend on whether and how the firms have used the chat:

a) If the chat window has opened regardless of the answers, the firms will have to pay a fine of 20 points if you, as the competition authority, have found a violation of §1 GWB in this round. If you did not find any violation in this round, the firms do not have to pay any fine.

b) If the chat window has only opened because both firms decided for the chat, they automatically have to pay a fine of 20 points, regardless of your judgment. If the chat window remained closed, they do not have to pay any fine.

Whether an investigation takes place is decided by the random mechanism in each round regardless of possible investigations in the previous rounds. So it can happen that several investigations take place or that no investigation takes place at all. You will only find out after round 20 if and when investigations have taken place.

After the last round, you will see an overview screen that shows you all the prices again, the chat messages from the firms, and your respective verdict. You then have a maximum of 10 minutes to review your decisions and correct them if necessary. Only after that you will find out if and when investigations have taken place and if your judgment was decisive for possible fines.

Now please turn to the screen. There you will immediately have the opportunity to familiarize yourself with the experiment. To do this, we will ask you to answer some control questions. This is to make sure that all participants have understood the instructions well.

If something is unclear to you, please give a clear hand signal. We will then come to your place.

After the experiment we will ask you to fill in a short questionnaire on the computer. Then you will receive your payout.

Directly after the experiment you will receive 10 euros in cash. Your further earnings from the experiment will be transferred to your bank account. Please fill in your name and address as well as your bank details in the form provided and sign the form. (You are welcome to fill in the form already during the experiment, if you have nothing to do on screen at the moment).

A.3 Handout - How does the expert decide?

- If the two firms agree on a price higher than zero and subsequently set it, this counts as a violation of the law.
- Paraphrases of prices will be judged as if the corresponding price was mentioned as a number.
- If a firm does not write anything in the chat (but of course, can read what the other firm writes) it can still violate the law if it sets the suggested price.
- If the firms come to an agreement that at least one firm does not adhere to, it does not count as a violation of the law.
- Prices that have been set without any agreement do not count as a violation of the law.

B Communication Analysis

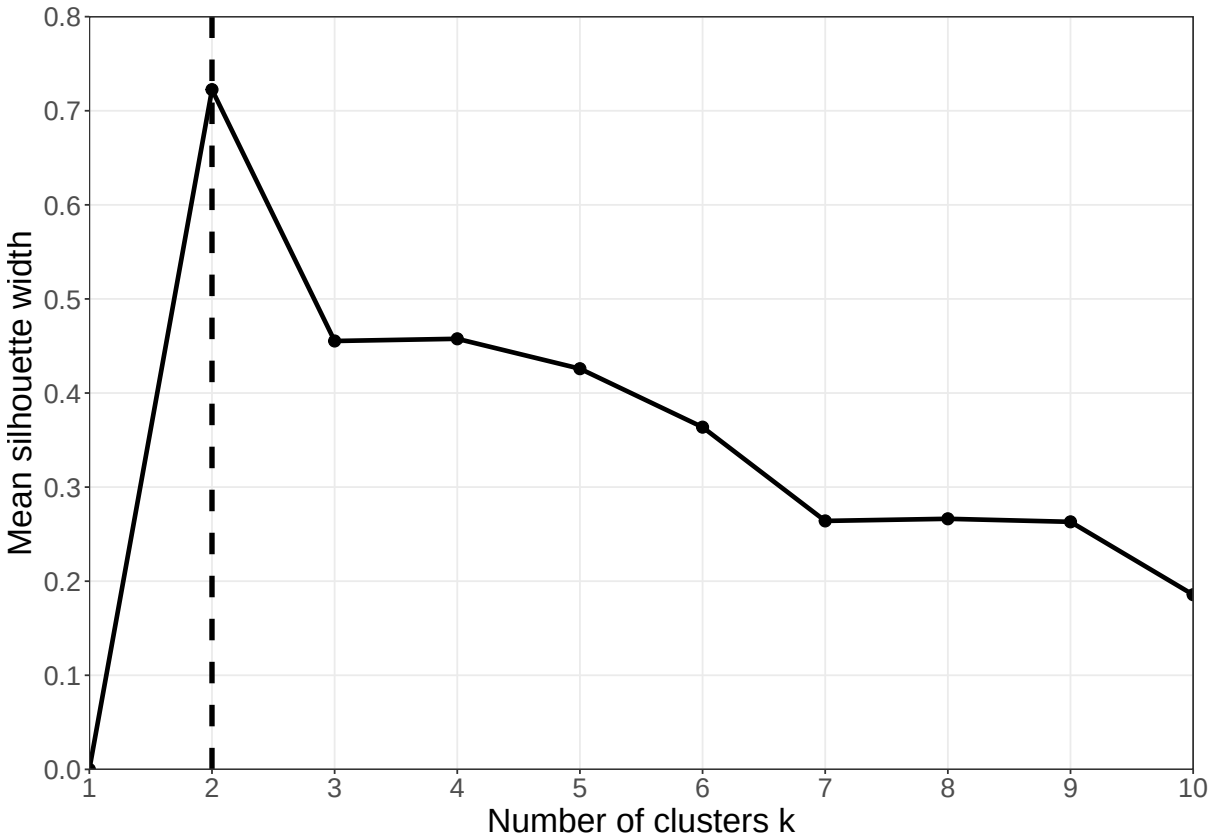


Figure 3: Mean silhouette width across number of clusters k for our corpus.
Notes: The mean silhouette width is a measure of how similar a document d is to its own cluster compared to other clusters. The silhouette ranges from -1 to $+1$. A high value indicates that a document d lies well within its own cluster (see Rousseeuw, 1987). The coefficient is reasonable (0.72) and suggests that our clustering structure with two clusters matches the data well.

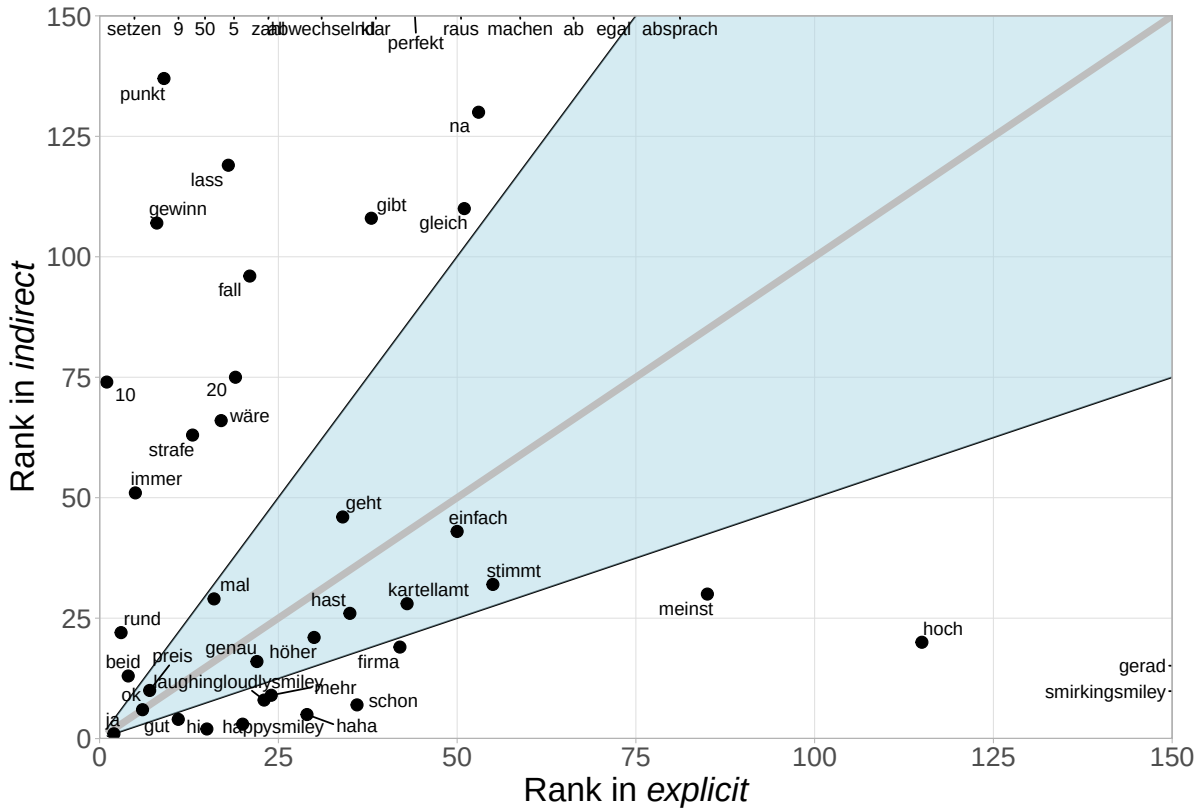
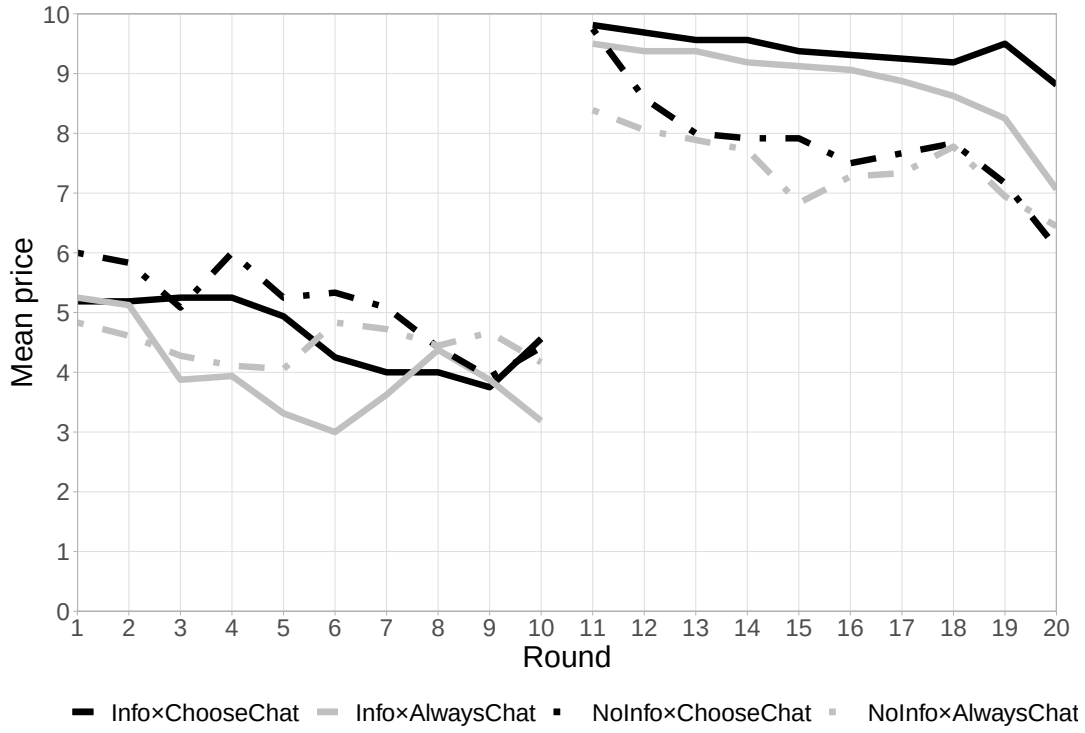
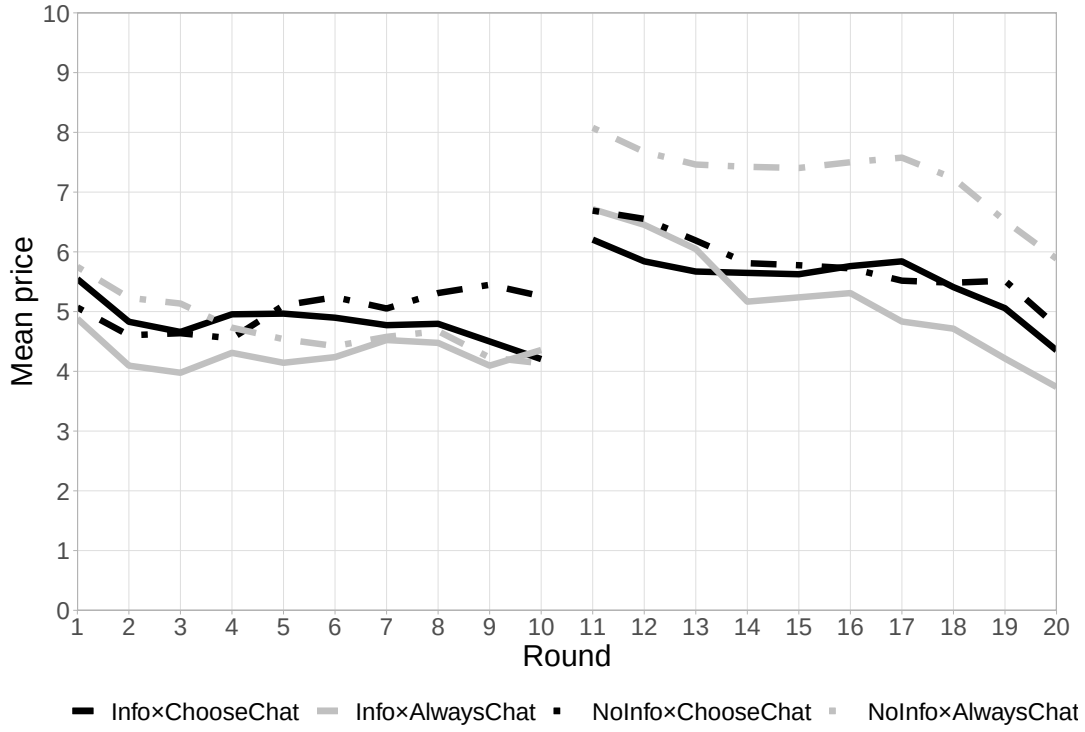


Figure 4: Frequency rankings of the 50 most used original German tokens in both clusters.

C Data

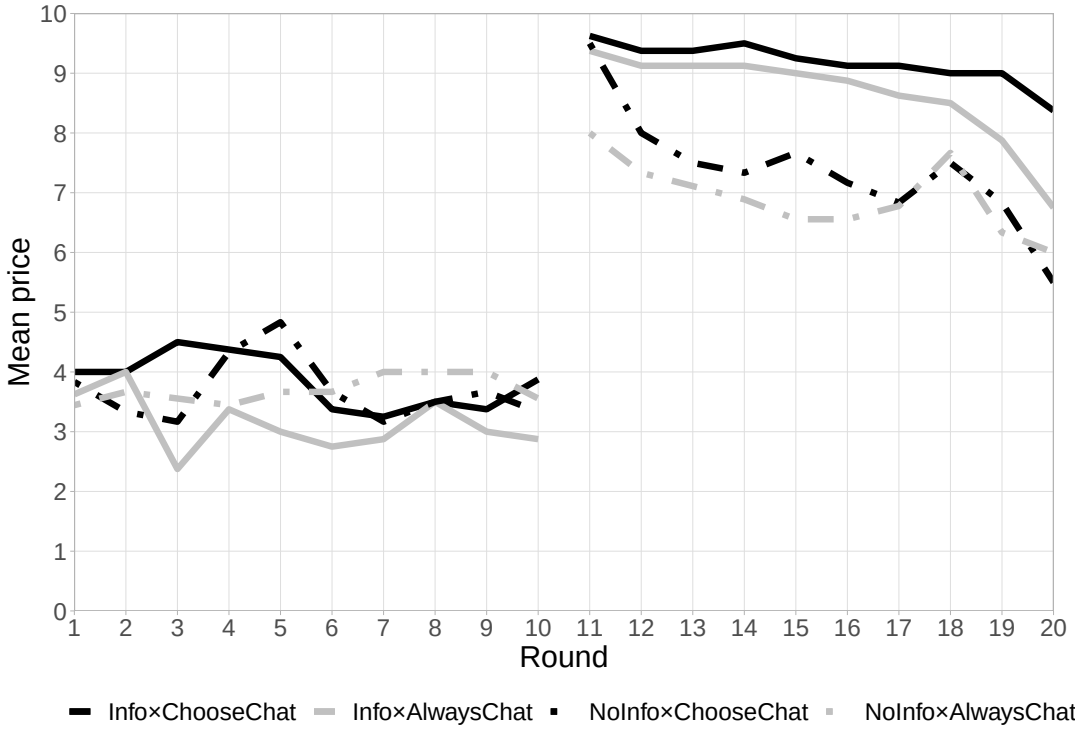


(a) Both agree to chat

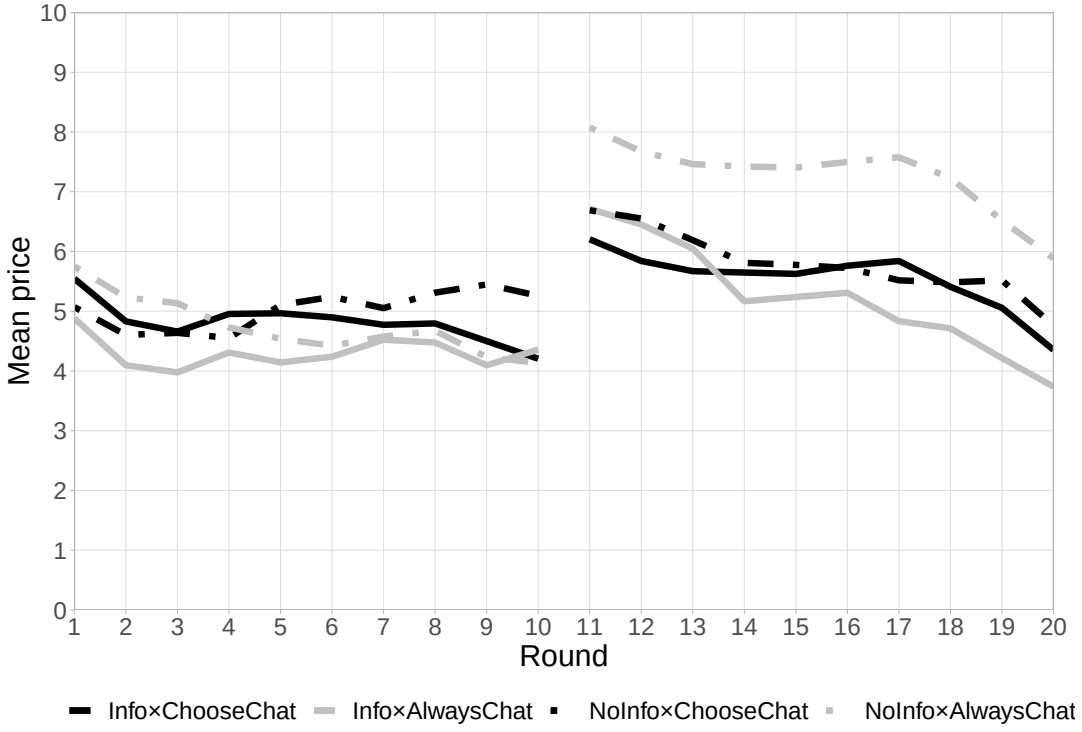


(b) No agreement to chat

Figure 5: Mean price in round 1 to 20 split up by the communication decision.



(a) Both agree to chat



(b) No agreement to chat

Figure 6: Mean market price in round 1 to 20 split up by the communication decision.