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Article — Published Version

How communication makes the difference between a cartel and tacit collusion: A machine learning approach

European Economic Review

Provided in Cooperation with:

WZB Berlin Social Science Center

Suggested Citation: Andres, Maximilian; Bruttel, Lisa; Friedrichsen, Jana (2023) : How communication makes the difference between a cartel and tacit collusion: A machine learning approach, European Economic Review, ISSN 1873-572X, Elsevier, Amsterdam, Vol. 152, pp. --, <https://doi.org/10.1016/j.euroecorev.2022.104331>

This Version is available at:

<https://hdl.handle.net/10419/266561>

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Appendix

A Theoretical background

In this section, we derive the critical discount factors for a repeated game that provides the background for our experimental design.

A.1 Modeling framework

In the experiment, participants interact in groups, consisting of a market of three firms and one competition authority when sanctioning institutions are present. The interaction between the firms is characterized by Bertrand competition with differentiated products. The same firms play the following stage game repeatedly.

Stage game: We let the quantity sold by each firm i given its own price p_i and the prices of its two competitors j and k , p_j and p_k , be given by:

$$(1) \quad Q_i[p_i, p_j, p_k] = 40 - \frac{100}{9}p_i + \frac{80}{9}(p_j + p_k),$$

where firms may choose only integer prices so that $p_i, p_j, p_k \in \mathbb{N}_0$.

Per period profit for each firm is computed as $(p_i - c)Q_i$ where c is the unit cost of production that we normalize to zero for simplicity. Then firm i 's profit as a function of its own and the competitors' prices is given by:

$$(2) \quad \Pi_i[p_i, p_j, p_k] = 40p_i - \frac{100}{9}p_i^2 + \frac{80}{9}p_i(p_j + p_k)$$

Deriving the individual best-response functions and solving for the symmetric Nash equilibrium yields $p = 3$ as the equilibrium price of the stage game with a corresponding per firm profit of $\Pi = 100$. If we instead consider the maximization of joint profits, we find a symmetric joint profit maximizing price of $p = 9$, which yields a per firm profit of 180. Given that the other two firms choose a price of $p = 9$, the optimal unilateral undercutting price is $p = 5$. Deviating to $p = 5$ yields a deviation profit of 322.22 (rounded to 322 in the profit table of the experiment). The other two firms that continue to charge the collusive price $p = 9$ make a profit of only 20 in the respective period.

For the implementation in the laboratory experiment, we restrict the price setting range to the integers from 0 to 12. All prices above 12 are at least weakly dominated by those prices in the restricted range. Thus, this only helps to simplify the experiment.

Investigations and fines: A cartel can be detected and fined during its existence and after its end. In each round an investigation of the competition authority is launched with an exogenous probability of 10% or because a firm self-reported its cartel. If an investigation is launched an existing or past cartel is detected and fined with certainty.

A cartel member is fined based on its cumulative profits during the participation in a collusive agreement as judged by the competition authority. Past profits can, however, only to some extent be reduced by a fine. For the computation of the cumulative profits on which the fine is applied, profits from period t are taken into account with 100%, profits from period $t-1$ with 80%, profits from period $t-2$ with 60%, profits from period $t-3$ with 40%, and profits from period $t-4$ with 20%. Profits from period $t-5$ or earlier are only relevant for the computation of a potential fine (chosen by the authorities and the expert as 0%, 50% or 100% that will be applied to the cumulative profits), but the fine is not applied to these profits. This ensures that fine sizes in our setup correspond approximately to the magnitude of real cartel cases.

The experimental program does not know in which rounds a cartel existed because the authorities are only asked to evaluate for how many rounds since the last investigation a cartel existed but do not specify the rounds. Therefore, the program uses the following approximation: Based on the cartel duration as specified by the authority and the number of rounds that passed since the last investigation, the program computes an adjustment factor in the form of the percentage of rounds since the last investigation during which a cartel existed. This factor is then multiplied with the discounted cumulative profits from the five rounds preceding the investigation as detailed above. In the case where firms either always collude or always compete, the program yields exactly the fines specified above.

Feedback, fines, punishment of deviations: We assume that a deviation from a cartel is detected by the other firms immediately due to the complete feedback about each firm's price setting. Expected fines are increasing during the first five rounds of each cartel phase. For the computations that relate to perfectly collusive behavior, we focus on the maximum fine that a firm would incur from the optimal collusive agreement, i.e., when all members always set the joint profit-maximizing price resulting in per-period-per-firm profits of $\Pi^c = 180$. Then, using the linear depreciation of fine-relevant profits as introduced above, the fine in an infinitely repeated game when this cartels is detected equals $F = 540$ for each participating firm. We assume that deviations from the collusive agreement as well as reports will be punished by playing the Nash equilibrium of the stage game forever after.

Repetition: Suppose that time is discrete and that the stage game is repeated infinitely often with the participants discounting future payoffs with a discount factor δ .³⁹ For the analysis of the repeated game, we restrict attention to the following set of stage game payoffs: the payoff from the Nash equilibrium in the stage game, $\Pi^n = 100$, the payoff from the joint-profit-maximizing price in the stage game (the collusive or cartel payoff), $\Pi^c = 180$, the deviation payoff that is made from an optimal unilateral deviation from the collusive agreement, $\Pi^d = 322$, and the payoff that is made by the remaining cartel members when one member deviates, $\Pi^b = 20$. It holds that $\Pi^b < \Pi^n < \Pi^c < \Pi^d$.

A.2 Participation and incentive compatibility constraints

Firms will only choose the collusive equilibrium if this will yield a greater payoff than playing the Nash equilibrium. Furthermore, in a collusive equilibrium, it does not pay for any firm to deviate unilaterally in any round. In this subsection, we investigate these conditions for both treatments.

A.2.1 Collusion without sanctions

Participation constraints without sanctions: First, consider the setting without sanctioning institutions (corresponding to the treatment NOSANCTION). The participation constraint without sanctions for collusion reads as

$$(3) \quad \frac{\Pi^c - \Pi^n}{1 - \delta} > 0.$$

With the parameters in the experiment, this is clearly fulfilled because $\Pi^n < \Pi^c$.

Incentive compatibility without sanctions: Next, consider the incentive compatibility constraint of collusion without sanctioning institutions. The value of the strategy “sticking to the collusive agreement”, i.e., of setting each period the joint-profit-maximizing price is:

$$(4) \quad V^c = \frac{\Pi^c}{1 - \delta}.$$

Consider now the possibility of deviating from the collusive agreement. Any such deviation is immediately observed by the cartel members (there is feedback on all prices

³⁹We restrict attention to a standard stationary repeated game because we see our experimental design as one way to bring the repeated game to the laboratory even though it diverges from theory in certain aspects.

set in a period, making it easy to observe the deviation). We assume that a deviation is punished by reverting to the Nash equilibrium of the stage game forever after. The value from deviating once and being punished is

$$(5) \quad V^d = \Pi^d + \delta \frac{\Pi^n}{1 - \delta}.$$

Thus, the incentive compatibility constraint for collusion without sanctioning institutions is

$$(6) \quad \frac{\Pi^c}{1 - \delta} > \Pi^d + \delta \frac{\Pi^n}{1 - \delta}.$$

From this constraint, we compute the critical discount factor $\delta_{NoS} = 0.6396$ which determines the range of discount factors for which, given all the other parameters in our experiment, collusion can be sustained as an equilibrium. As the continuation probability of $2/3$ in our experiment exceeds the critical discount factor, collusion is a subgame perfect Nash equilibrium of the continuation game starting in round 25 and, therefore, also of the entire repeated game.

A.2.2 Collusion with sanctions

Participation constraints with sanctions: Second, consider the participation constraint for collusion with sanctions (corresponding to the treatment SANCTION). This reads in both the leniency and the no-leniency setting as

$$(7) \quad \frac{\Pi^c - \Pi^n}{1 - \delta} > \frac{\alpha F}{1 - \delta}$$

With the parameters in the experiment, this is clearly fulfilled because $80 > 54$. Next, consider the incentive compatibility constraints of collusion.

Incentive compatibility without a leniency rule: Without a leniency rule, the value of the strategy “sticking to the collusive agreement”, i.e., setting each period the joint-profit-maximizing price and doing so even if the cartel has been detected through the exogenous detection mechanism, is:

$$(8) \quad V^c = \frac{\Pi^c + \alpha(\delta V^c - F)}{1 - (1 - \alpha)\delta} = \frac{\Pi^c + \alpha\delta V^c - \alpha F}{1 - (1 - \alpha)\delta}$$

Solving for V^c this yields

$$(9) \quad V^c = \frac{\Pi^c - \alpha F}{1 - \delta}$$

We assume that as part of the strategy “sticking to the collusive agreement” cartel members continue to collude if their cartel has been detected due to an investigation that was triggered by the exogenous detection probability. This implies that their cartel continues to exist after such an investigation; and it also continues to face the exogenous risk of being detected and fined in every single period.

Consider now the possibility of deviating from the collusive agreement. Any such deviation is immediately observed by the cartel members (there is feedback on all prices set in a period, making it easy to observe the deviation). We assume that a deviation is punished by reverting to the Nash equilibrium of the stage game forever after. The value from deviating once and being punished is

$$(10) \quad V^d = \Pi^d + \delta \frac{\Pi^n}{1 - \delta} - \frac{\alpha F}{1 - (1 - \alpha)\delta}$$

The third term results from the possibility of a cartel being detected and fined with exogenous probability also after it has broken down. As the cartel is assumed to never reform, the cartel can only be detected once after the deviation.

The incentive compatibility constraint in a setting without leniency (our treatment named FINE) is therefore

$$(11) \quad \frac{\Pi^c - \alpha F}{1 - \delta} > \Pi^d + \delta \frac{\Pi^n}{1 - \delta} - \frac{\alpha F}{1 - (1 - \alpha)\delta}$$

From this constraint, we compute the critical discount factor which determines the range of discount factors for which, given all the other parameters in our experiment, collusion can be sustained as an equilibrium.

Solving the above constraint for δ , we obtain a quadratic equation which has only one solution that lies in the interval $[0, 1]$ and therefore has a unique admissible solution $\delta_N = 0.6827$.

Incentive compatibility with a leniency rule: Consider now a setting with a leniency rule, i.e., the first firm that self-reports a collusive agreement is exempt from paying a fine. This implies that any deviation from the collusive agreement is coupled with a self-report in order to pre-empt the other firms that would report the cartel once they learn about the deviation. Thus, the value from defecting from the collusive agreement

becomes:

$$(12) \quad V^d = \Pi^d + \delta \frac{\Pi^n}{1 - \delta}$$

Reporting the cartel leads to an immediate fine to the other cartel members but not the self-reporting deviator. Moreover, the self-report implies that the cartel, which is assumed not to be reformed because of the Nash reversion punishment, does not face any detection risk in the future.

Thus, the incentive compatibility constraint in a setting with a leniency rule (named LENIENCY) is

$$(13) \quad \frac{\Pi^c - \alpha F}{1 - \delta} > \Pi^d + \delta \frac{\Pi^n}{1 - \delta}$$

From this constraint, we also compute the critical discount factor given all other parameters. Setting the above incentive constraint to bind and solving for δ , we obtain the unique solution $\delta_L = 0.8829$.

Incentive compatibility with sanctions: The above shows that the critical discount factor of an infinitely repeated discounted game with punishment by Nash reversion exceeds $2/3$ in the cases with and without leniency. Thus, collusion on the symmetric joint-profit maximizing price of the stage game is not a subgame perfect Nash equilibrium (SPNE) of the continuation game starting in round 25 in the presence of sanctions and, therefore, also not of the entire repeated game, neither in FINE nor in LENIENCY.

A.2.3 Discussion

We have shown above that joint-profit maximizing collusion is not sustainable as SPNE when we have sanctions in place because it fails to satisfy the non-deviation constraint in the continuation game. Only a continuation probability larger than 88.3 percent would make the collusive agreement a subgame perfect Nash equilibrium for the continuation game, in which case the expected duration of the experiment would exceed three hours. Therefore, we opted for a lower continuation probability, which is below the critical level for both treatments with sanctions. There are two main reasons why we nevertheless expect a substantial amount of collusion in the SANCTION treatments. First, also a random continuation probability of $2/3$ blurs the end of the experiment and serves the purpose to minimize endgame effects. Second, there is evidence from infinitely repeated prisoner's dilemma games that the cooperation rate does not discretely change when the critical discount factor exceeds or falls short of the continuation probability (Blonski et al., 2011) but other aspects of the game also play a role. Indeed, for the first repeated

game that subjects play, which is the relevant comparison for our experiment where subjects only play one repeated game, [Dal Bó and Fréchette \(2011\)](#) report clearly positive cooperation rates in a setting where this is not SPNE and no significant differences to a comparison setting where this is SPNE during the first 10 rounds of play.

We further note that the experimental setting also allows for asymmetric collusive strategies. Specifically, the three firms may alternate in choosing the prices 7 – 7 – 12 yielding an average per-period profit of 217.78 for each firm. Assuming again that any deviation will be punished by reversion to the Nash equilibrium of the stage game, the incentive compatibility constraint for this strategy yields a critical discount factor clearly below $2/3$ in all treatments. Specifically, in the leniency setting, for a firm supposed to set a price of 7, the optimal unilateral deviation is $p = 5$ with a one-time deviation profit of 344.44 which – using these values in the incentive compatibility constraint (13) – yields a critical discount factor of 0.613, and for a firm supposed to set a price of 12, the optimal unilateral deviation is also $p = 5$ with a deviation profit of 233.33 which yields a critical discount factor of 0.292. The analogous critical discount factors are even lower in the setting without a leniency rule and are easily derived from the incentive compatibility constraint (11). The repeated game may have additional asymmetric equilibria that we have not identified.

In principle, collusion may occur at prices different from the jointly optimal price of 9. This will lead to lower expected profits but relaxes the incentive compatibility constraint. For the parameters of our experiment and a maximum fine in a steady state equilibrium with stable collusion of $F = 3\Pi^c$, where Π^c is the per-firm profit per period from continued collusion on the respective price, we find that a symmetric collusive agreement on an anti-competitive price below 9 – e.g. on a price of 8, 7, or 6 – yields a critical discount factor that lies below our continuation probability of $2/3$ for the FINE treatment while such an agreement is still not sustainable in LENIENCY. The exact critical discount factors can be derived directly from the incentive compatibility constraints specified above.

B Descriptive Data

	NO SANCTION	SANCTION	SANCTION before fine	SANCTION after fine
Unweighted cartelization	0.97 (0.10)	0.41 (0.32)	1.00 (0.00)	0.42 (0.45)
Average Market Price	8.84 (0.45)	6.64 (1.26)	7.92 (1.33)	6.73 (1.63)
Explicit Communication	0.32 (0.14)	0.09 (0.06)	0.17 (0.32)	0.07 (0.16)
Indirect Communication	0.04 (0.02)	0.10 (0.09)	0.32 (0.35)	0.14 (0.24)
	NO SANCTION	SANCTION	SANCTION explicit comm.	SANCTION indirect comm.
Investigations	-	0.11 (0.07)	0.11 (0.07)	0.11 (0.08)
Fines	-	0.56 (0.41)	0.83 (0.21)	0.43 (0.44)

Table 3: Descriptive means split up by treatments. Standard deviations in parentheses.

Table 3 provides descriptive means split up by treatments. To calculate the means that refer to before a fine and after a fine, respectively, we average the variable in cartelized rounds before a fine and compare them to the variable for the following three rounds or the twenty-fifth round, whichever comes first. The explicit communication and indirect communication variable before a fine and after a fine, respectively, refer to our hand-coded data. Investigations averages over the number of investigations in a market over rounds 2 to 25. Fines averages over whether a fine applies in an investigation taking place in rounds 2 to 25, overall and in the subsamples exhibiting explicit or indirect communication.

C Comparison of treatments Fine and Leniency

In this appendix, we repeat the analysis presented in Section 5.2 on the relation between sanctioning institutions and communication, comparing the data from treatment NOSANCTION to FINE and LENIENCY separately.

The average posterior probability of the topic *Explicit Agreement* is 0.05 in FINE ($N = 23$, $SD = 0.02$) and 0.06 in LENIENCY ($N = 27$, $SD = 0.06$). As in the main analysis comparing SANCTION to NOSANCTION, these separate values are significantly different from the value in NOSANCTION (in either test, $p < 0.001$). The average posterior probability of the topic *Explicit Reasoning* is 0.04 in FINE ($N = 23$, $SD = 0.03$) and 0.04 in LENIENCY ($N = 27$, $SD = 0.02$). Both values differ significantly from the value in NOSANCTION (in either test, $p < 0.001$).

When we consider the total amount of explicit communication by summing up the average posterior probabilities of *Explicit Agreement* and *Explicit Reasoning*, the average posterior probability of explicit communication is 0.09 in FINE ($N = 23$, $SD = 0.04$) and 0.10 in LENIENCY ($N = 23$, $SD = 0.07$), which is, in both cases, significantly different from the average in NOSANCTION ($p < 0.001$).

We further note that groups appear to use explicit communication slightly more often in LENIENCY than in FINE but the difference fails to reach significance at reasonable levels ($p = 0.79$). The probability of the topic *Explicit Reasoning* is statistically indistinguishable between LENIENCY and FINE ($p = 1$).

D Additional analyses on hand-coded communication data

D.1 Example for communication strategies

Attempt to “hide incriminating evidence in innocuous talk” (translated to English) Communication patterns in many groups appear consistent with this idea but one group spells it out explicitly:

Round 15, firm 2: “here on page 4 [in the instructions] it says that they investigate our entire communication [...] we can simply spam the chat as we like”

Thereafter, they indeed spam the chat, sometimes with meaningful sentences but most of the time with super short messages that contain only gibberish, e.g., “asfjha”, “asfasf”, “sdg”, or nouns, meaningless without context. In Figure 12, the bars marking the number of messages of group 52 are censored as the spamming leads to close to 60 individuals messages per round in certain rounds.

Two attempts to “talk once to collude and remain silent thereafter” (translated to English) We see several groups for which the communication pattern suggests they are following this idea. The following two spell it out explicitly but then do not follow through.

Round	Firm	Message
2	2	All 9
3	1	Say nothing and do something else afterwards
3	3	I thought so too
4	1	Lol that was perfect
4	1	But one can do better
4	2	again all a little higher the same
4	2	I also join in
4	1	Say nothing..
5	1	you could take the better but ok
5	1	there is a super price, let’s try?
Communication in further rounds omitted here.		

Table 4: Excerpt from chat protocol of group 3 in treatment LENIENCY. See also Figure 12.

Round	Firm	Message
3	1	And?
3	2	The profit is too small for me and you?
3	1	higher!
5	2	Rightly firm 1 that was a rotten number
6	2	Who initiated the last audit?
6	1	nobody
6	1	Coincidence
7	2	No further agreements ;)
7	1	the educating effect of an audit ;)
9	2	was coincidence again or?
Communication in further rounds omitted here.		

Table 5: Excerpt from chat protocol of group 1 in treatment LENIENCY. See also Figure 12.

D.2 Figures with communication and outcomes over time at the group-level

Figures 11, 12, and 13 depict the development of communication, cartelization, and fines at the market level over time. We depict the total number of messages sent in a group in a given round in thin dark gray bars; these are measured on the right y-axis, ranging from 0 to 25 per round.⁴⁰ In addition, the figures show the share of indirect messages (black dashed) and the share of explicit messages (solid black) in the number of total messages per group per round; the scale for these lines is on the left y-axis. We further include the extent of cartelization as derived from the weighted expert measure in wide light gray bars. Lastly, we include markers for the average fines that was decided on by the actual authorities in the experimental sessions for each group in those rounds, where an investigation took place; triangles indicate that the fine resulted from an investigation triggered by a self-report and circles indicate that the fine resulted from a random investigation.

⁴⁰For group 52 in treatment LENIENCY, this variable is censored at 25 but the true values reach up to close to 60 messages per round. See also discussion on spam strategy in previous subsection.

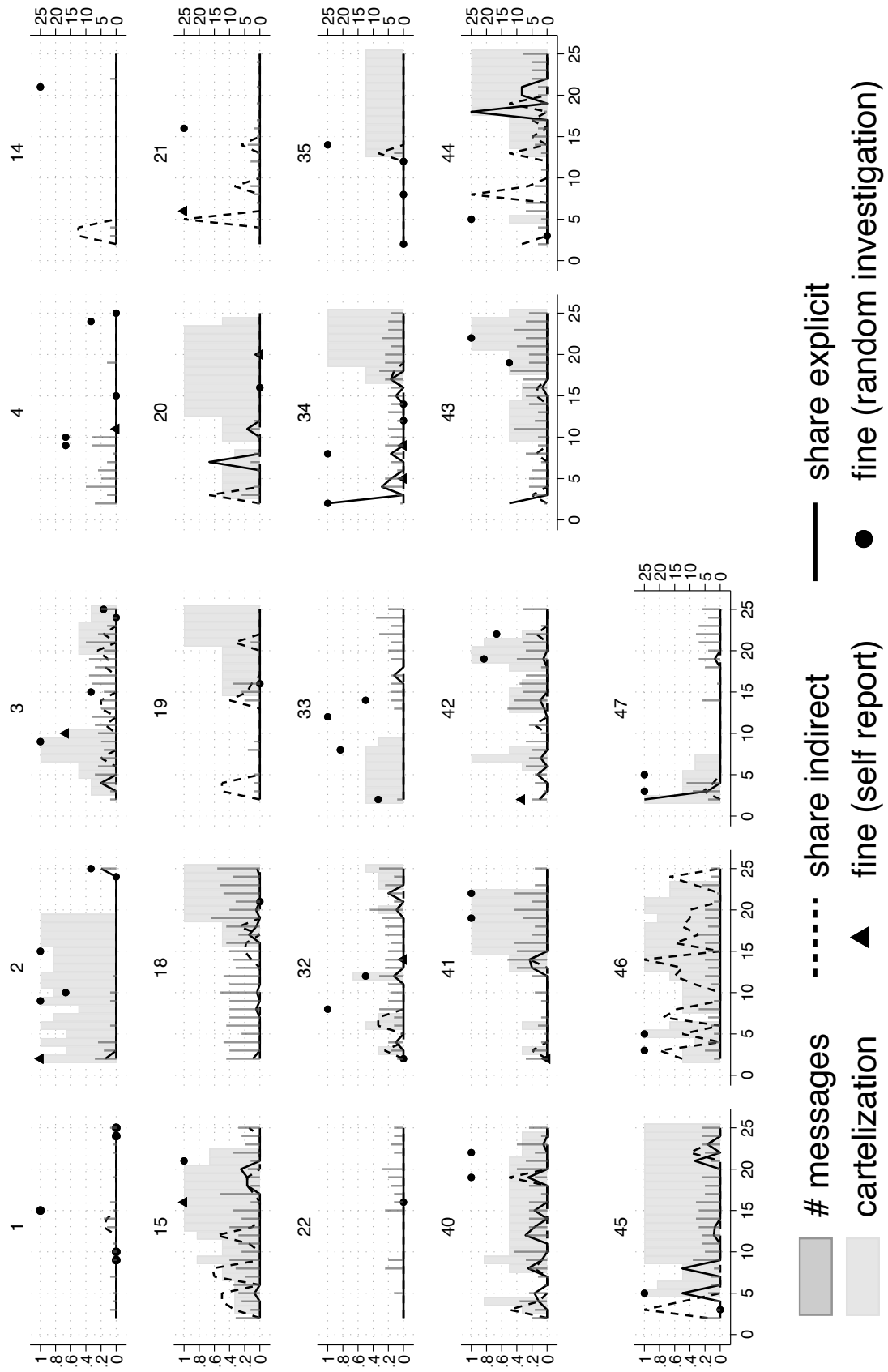


Figure 11: Communication and cartelization over time in FINE treatment.

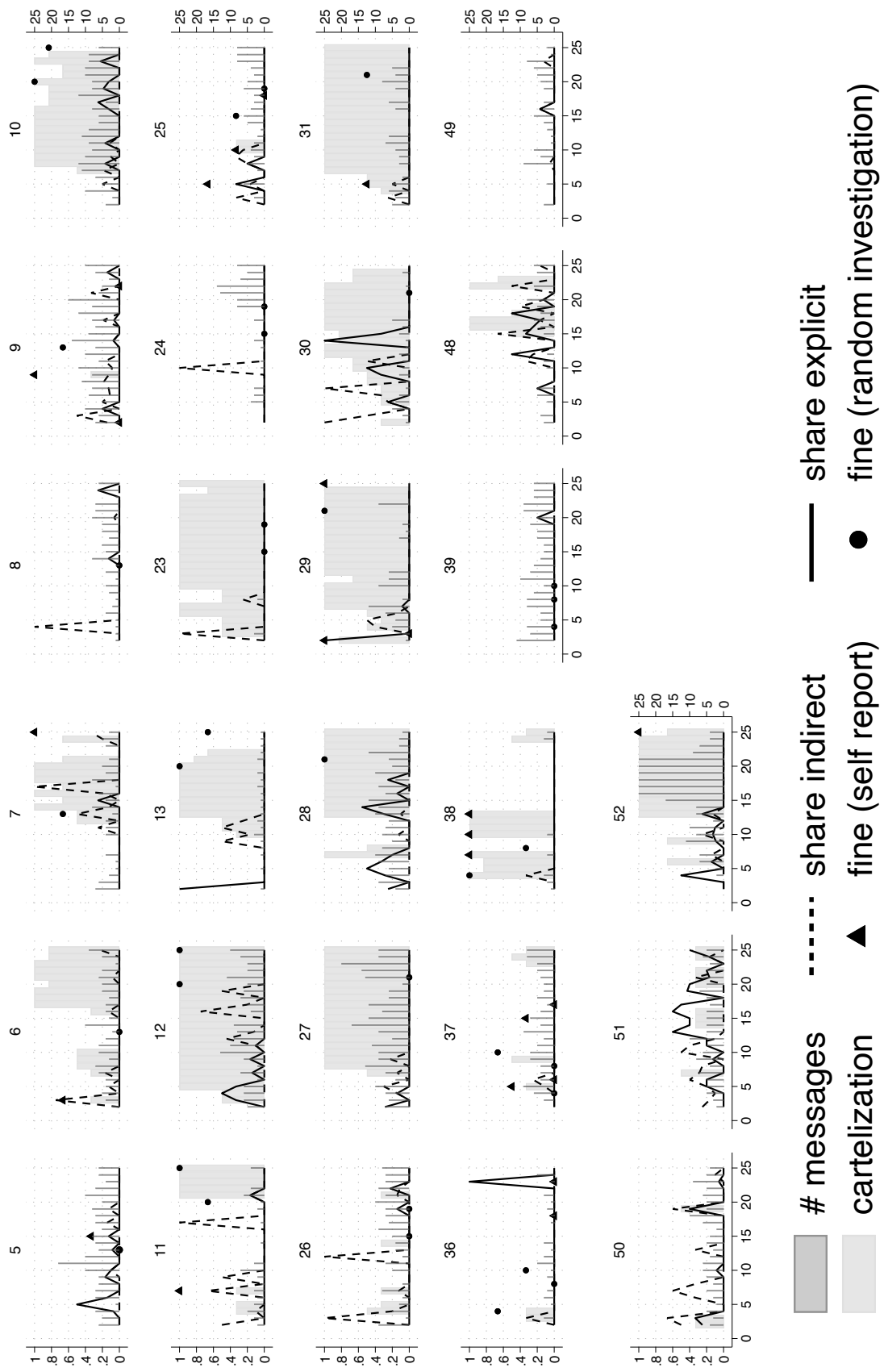


Figure 12: Communication and cartelization over time in LENIENCY treatment.

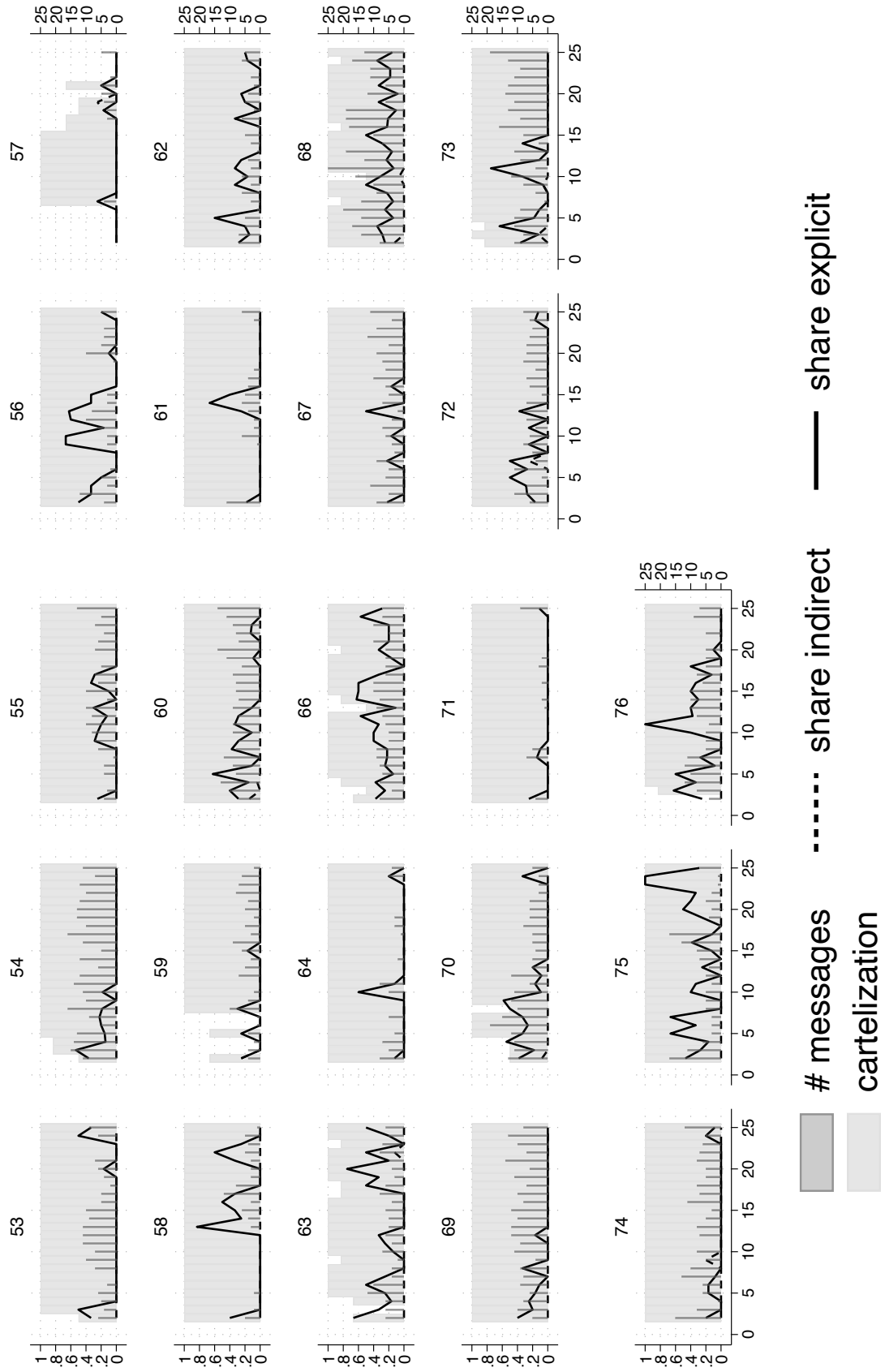


Figure 13: Communication and cartelization over time in NoSANCTION treatment.

E Instructions

In the following, we present our instructions for firms in Section E.1 and for authorities in Section E.2. Parts that appear only in the instructions of a particular treatment are clearly marked as such. Text in *italics* only appears in instructions for the LENIENCY treatment. The original instructions for the participants additionally included screenshots of the different stages in the experiment.

E.1 Instructions for firms

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

For the entire duration of the experiment it is prohibited to communicate with other participants. Therefore, we ask you not to talk to each other. Violation of this rule will result in exclusion from the experiment and payment.

If there is something you do not understand, please have another look at these instructions or give us a hand signal. We will then come to your seat and answer your question personally.

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

$$\mathbf{125\ Points = 1\ euro}$$

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

On the following pages we will explain the exact procedure of the experiment to you, starting with the general procedure. We will then familiarize you with the procedure on the screen. Then, you will have the opportunity to familiarize yourself on the computer screen with the calculation of profits in the experiment before the experiment begins.

The experiment

At the start of the experiment, you will be matched randomly into a group with two [**Fine and Leniency:** three] other participants. During the experiment, you will make decisions within this group of three [**Fine and Leniency:** four] persons in total. The composition of your group remains the same throughout the entire experiment. Neither you nor the other participants will be informed about the identity of the participants in the group – neither during nor after the experiment.

The experiment consists of at least 25 rounds. You will receive more information on the number of rounds on page 5 of this document.

[**NoSanction only:** Every participant in your group represents a firm. There are three firms (firm 1, 2 and 3). At the start of the experiment, you will be informed onscreen about which firm you are. You will be the same firm during the entire experiment.]

[**Fine and Leniency only:** Every participant in your group represents either a firm or the competition authority. There are three firms (firm 1, 2 and 3) and one competition authority. **In all rounds, you take the role of a firm.** At the start of the experiment, you will be informed onscreen about which firm you are. You will be the same firm during the entire experiment.]

The firms 1, 2 and 3 sell the same (fictional) good on the same market. Production of this good is costless for the firms. All firms decide simultaneously what price they want to charge for the good in a round. The price must be an integer between 0 and 12. If a firm does not enter its own price and clicks the OK button within 30 seconds (60 seconds in the first round only), a price of 0 is automatically set for this firm.

Your profit depends on your own price and the average price of the other two firms. Your profit is larger the higher the prices of the other two firms are. Your own price has two effects on your own profit: If you increase your own price, the quantity you sell decreases, but at the same time your earnings per unit sold increases. Depending on which effect is larger, your profit increases or decreases. The table on the following page shows your profit, depending on your own price and the averages prices of the other two firms. (This table is the same for all three firms, read from their perspective.)

		Average price of the other two firms												
		0	1	2	3	4	5	6	7	8	9	10	11	12
Your own price	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	1	29	38	47	56	64	73	82	91	100	109	118	127	136
	2	36	53	71	89	107	124	142	160	178	196	213	231	249
	3	20	47	73	100	127	153	180	207	233	260	287	313	340
	4	0	18	53	89	124	160	196	231	267	302	338	373	409
	5	0	0	11	56	100	144	189	233	278	322	367	411	456
	6	0	0	0	0	53	107	160	213	267	320	373	427	480
	7	0	0	0	0	0	47	109	171	233	296	358	420	482
	8	0	0	0	0	0	0	36	107	178	249	320	391	462
	9	0	0	0	0	0	0	0	20	100	180	260	340	420
	10	0	0	0	0	0	0	0	0	0	89	178	267	356
	11	0	0	0	0	0	0	0	0	0	0	73	171	269
	12	0	0	0	0	0	0	0	0	0	0	0	53	160

From the second round on, you have the option to communicate with the other firms via chat messages at the beginning of each round. The duration of a chat cannot exceed 60 seconds in one round. In this chat, you can write anything you want with the exception that you are not allowed to reveal hints on your identity.

[Fine and Leniency only: §1 GWB of the Act against Restraints of Competition prohibits price agreements and the attempt of price agreements (for the exact wording, see the box).

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

At the end of a round, the chat messages can be subject to an audit. In an audit, the competition authority judges whether the texts you and the other firms wrote in the chat are in accordance with §1 GWB. Such an audit can be initiated in two ways, by a random mechanism and by the firms:

- In each round, a random mechanism decides whether an audit takes place or not. This random mechanism is programmed so that an audit takes place with a probability of 10% (i.e. on average in 10 out of 100 cases).
- In addition, in each round the firms have the opportunity to initiate an audit themselves, both while setting their price and after they have learned the prices of the other firms. You can initiate an audit by clicking on a small white box at the bottom left of the screen. Initiating an audit cannot be undone. As soon as you click on the small white box, the box for that round disappears and an audit will definitely take place. The same applies to the other two firms in your group.

When an audit takes place, the competition authority has insight into all communication in the previous chats in your group as well as into the pricing since the first round. The competition authority imposes penalties on firms that have violated §1 GWB. It decides on the individual penalties for each of the three firms and for how long an agreement has been in place.

The penalty may be 0%, 50% or 100% of a firm's accumulated pecuniary profit during the agreement. 0% (no penalty) means that the firm has acted in accordance with §1 GWB, 100% means a clear, serious violation. 50% should be chosen for less serious violations.

The pecuniary profit is measured according to your profit that you have earned and the duration of the agreement. However, if the agreement has been in place for more than five rounds, the penalty will only be applied to the profits of the last five rounds. Previous rounds are included in the calculation of the penalty, but will not be punished themselves.

The competition authority has three minutes to reach its decision.]

[Leniency only: *The active initiation of an audit by a firm leads to the possibility that that firm is exempted from punishment. If only one firm has initiated the audit, that firm will automatically receive full amnesty. If two or three firms have initiated an audit, the penalty will only be waived for the firm that first initiated the audit.*]

[NoSanction only: After each round, the firms are informed about their own price and their profit. In addition, each firm is informed about the prices set by the other two firms in the current round.]

[Fine and Leniency only: After each round, the firms are informed about their own price, their profit and, if applicable, their penalty. In addition, each firm is informed about the prices set by the other two firms in the current round and, if applicable, their penalties. **[LENIENCY only:** *You will also be informed on whether a firm has initialized an audit by the competition authority and has thus received an exemption of its penalty.*])

From the 25th round on, a random mechanism decides in each round whether the experiment ends with the last round completed. With a probability of 33.3% (i.e. in an average of 1 out of 3 cases) the experiment ends with the last round completed. With a probability of 66.7% (i.e. in 2 out of 3 cases) another round takes place. In addition, it is ensured that the experiment does not last longer than 2 hours and 30 minutes.

After the last round, you will see an overview screen showing you how many points you have earned in total. You will receive all points converted into euro directly after the experiment.

If something is not clear to you, please give a clear hand signal. We will then come to your seat.

After the experiment we will ask you to fill out a short questionnaire on the computer. You will then receive your payment.

E.2 Instructions for authorities (Fine and Leniency only)

Today you are participating in a decision-making experiment. If you read the following instructions carefully, you can earn money. The amount of money you receive depends on your decisions.

For the entire duration of the experiment it is prohibited to communicate with other participants. Therefore, we ask you not to talk to each other. Violation of this rule will result in exclusion from the experiment and payment.

If there is something you do not understand, please have another look at these instructions or give us a hand signal. We will then come to your seat and answer your question personally.

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

$$\mathbf{125\ Points = 1\ euro}$$

As an exception, this time you will not receive your payment for today's experiment in cash at the end of the experiment, but in about 2-3 weeks via bank transfer. You will receive more information on the bank transfer on page 6 of these instructions. In addition to your other earnings in this experiment, you will receive 10 euro in cash.

On the following pages we will explain the exact procedure of the experiment to you, starting with the general procedure. We will then familiarize you with the procedure on the screen. Then, you will have the opportunity to familiarize yourself on the computer screen with your task in the experiment before the experiment begins.

The experiment

At the start of the experiment, you will be matched randomly into a group with three other participants. During the experiment, you will make decisions within this group of four persons in total. The composition of your group remains the same throughout the entire experiment. Neither you nor the other participants will be informed about the identity of the participants in the group – neither during nor after the experiment.

The experiment consists of at least 25 rounds. You will receive more information on the number of rounds on page 6 of this document.

Every participant in your group represents either a firm or the competition authority. There are three firms (firm 1, 2 and 3) and one competition authority. **In all rounds, you take the role of the competition authority.**

The firms 1, 2 and 3 sell the same (fictional) good on the same market. Production of this good is costless for the firms. All firms decide simultaneously what price they want to charge for the good in a round. The price must be an integer between 0 and 12. If a firm does not enter its own price and clicks the OK button within 30 seconds, a price of 0 is automatically set for this firm.

The profit of a firm depends on its own price and the average price of the other two firms. The profit is larger the higher the prices of the other two firms are. The own price has two effects on the profit of a firm. If the own price increases, the quantity sold by this firm decreases, but at the same time the earnings per unit sold increases. Depending on which effect is larger, a firm's profit increases or decreases. The table on the following page shows the profit of a firm, depending on its own price and the averages prices of the other two firms. (This table is the same for all three firms.)

		Average price of the other two firms												
		0	1	2	3	4	5	6	7	8	9	10	11	12
Your own price	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	1	29	38	47	56	64	73	82	91	100	109	118	127	136
	2	36	53	71	89	107	124	142	160	178	196	213	231	249
	3	20	47	73	100	127	153	180	207	233	260	287	313	340
	4	0	18	53	89	124	160	196	231	267	302	338	373	409
	5	0	0	11	56	100	144	189	233	278	322	367	411	456
	6	0	0	0	0	53	107	160	213	267	320	373	427	480
	7	0	0	0	0	0	47	109	171	233	296	358	420	482
	8	0	0	0	0	0	0	36	107	178	249	320	391	462
	9	0	0	0	0	0	0	0	20	100	180	260	340	420
	10	0	0	0	0	0	0	0	0	0	89	178	267	356
	11	0	0	0	0	0	0	0	0	0	0	73	171	269
	12	0	0	0	0	0	0	0	0	0	0	0	53	160

From the second round on, the firms have the option to communicate via chat messages. The duration of chat cannot exceed 60 seconds.

§1 GWB of the Act against Restraints of Competition prohibits price agreements and the attempt of price agreements (for the exact wording, see the box).

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

At the end of a round, the chat messages can be subject to an audit. In an audit, you as the competition authority judge whether the texts the firms wrote in the chat are in accordance with §1 GWB. Such an audit can be initiated in two ways, by a random mechanism and by the firms:

- In each round, a random mechanism decides whether an audit takes place or not. This random mechanism is programmed so that an audit takes place with a probability of 10% (i.e. on average in 10 out of 100 cases).

- In addition, in each round the firms have the opportunity to initiate an audit themselves, both while setting their price and after they have learned the prices of the other firms. A firm can initiate an audit by clicking on a small box on the screen.

When an audit takes place, you will not be informed on how it was initiated. You have insight into all communication in the previous chats in your group as well as into the pricing since the first round. Your task is to impose penalties on firms that have violated §1 GWB. You decide on the individual penalties for each of the three firms and for how long an agreement has been in place. The duration is the number of all rounds since the last audit (or since the start of the experiment) in which, in your opinion, an agreement had a visible effect on the prices.

The penalty may be 0%, 50% or 100% of a firm's accumulated pecuniary profit during the agreement. 0% (no penalty) means that the firm has acted in accordance with §1 GWB, 100% means a clear, serious violation. 50% should be chosen for less serious violations.

The pecuniary profit is measured according to the profit of the respective firm and the duration of the agreement. However, if the agreement has been in place for more than five rounds, the penalty will only be applied to the profits of the last five rounds. Previous rounds are included in the calculation of the penalty, but will not be punished themselves. You, in the role of the competition authority, nevertheless enter the entire duration of the cartel; the computer program proportionally calculates the penalties for the last five rounds.

Your payment as an competition authority depends on the consistency of your penalty decisions with those of a real competition law expert. After today's experiment, in the same way as you do today, this expert (a licensed lawyer specialized in competition law) will see the chat messages and prices and will assess the extent to which they contain violations of §1 GWB. You will receive 900 points for each match between your decision and the expert's decision. You will also receive 900 points if you have correctly specified the duration of a possible agreement. Since you make four decisions for each penalty decision (one for each of the three firms and one for the total duration of the agreement), you can earn up to 3600 points. You will only receive points if you make exactly the same decision as the expert, otherwise (e.g. if you impose a 50% penalty on a firm and the expert would impose 100%) you will not receive any points for this partial decision. At the end, the **average** score of all rounds in which you were able to impose penalties is determined. This then determines your payment, which we will transfer to your bank account within 2 to 3 weeks. If there is no audit during the entire experiment, you will receive a fixed bank transfer of 15 euro in addition to your cash payment of 10 euro.

You have 3 minutes for each of your penalty decisions. If you do not specify the height of the penalty during this time, you will not receive any payment for your judgment and

the computer program will assume for the calculation of the firms' profits that you have not imposed any penalties. **Please remember to submit your decision at the end by clicking the OK button.**

[Leniency only: *The active initiation of an audit by a firm leads to the possibility that that firm is exempted from its punishment. If only one firm has initiated the audit, that firm will automatically receive full amnesty. If two or three firms have initiated an audit, the penalty will only be waived for the firm that first initiated the audit. This exemption will also be automatically implemented by the computer program, if necessary, and will not be relevant to your penalty decisions.*]

After each round, the firms are informed about their own price, their profit and, if applicable, their penalty. In addition, each firm is informed about the prices set by the other two firms in the current round and, if applicable, their penalties. **[Leniency only:** *The firms will also be informed on whether a firm has initialized an audit by the competition authority and has thus received an exemption of its penalty.*]

From the 25th round on, a random mechanism decides in each round whether the experiment ends with the last round completed. With a probability of 33.3% (i.e. in an average of 1 out of 3 cases) the experiment ends with the last round completed. With a probability of 66.7% (i.e. in 2 out of 3 cases) another round takes place. In addition, it is ensured that the experiment does not last longer than 2 hours and 30 minutes.

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

If something is not clear to you, please give a clear hand signal. We will then come to your seat.

After the experiment we will ask you to fill out a short questionnaire on the computer. You will then receive your payment.

E.3 Assistance for participants in the role of a competition authority | How does the expert punish?

What counts as an agreement?

- If a firm explicitly suggest a price above 3 and then charges this price, the firm gets a 100% penalty.
- Convolved descriptions of prices are punished in the same way as if the corresponding price was given as a number.
- Agreements on prices not higher than 3 do not distort competition and therefore do not count as an agreement.
- If a firm does not write anything in the chat (but of course can read what the others write) it can still be punished.⁴¹ The amount of the penalty depends on the price and can be up to 100%, e.g. if the other two firms make a clear agreement and this firm sets exactly the price agreed by the other two firms over a long period of time.
- If the firms make an agreement that no one will abide by afterwards, there will be no penalty.
- Prices above 3, which have come about without any agreement, cannot be punished.

For determining the duration:

- For determining the duration of a cartel, all rounds in which the agreement was visibly effective in the prices count.
- If a company receives a 50% penalty for part of the total duration of the cartel and a 100% penalty for the remainder of the total duration, then the amount of the penalty that applies for a longer period will apply for the total duration (because the computer program does not allow for further gradation).
- If a firm joins an agreement already in place between the two other firms at a later round (or leaves the agreement earlier than the others), the longer overall duration of the cartel still applies to it. In order to prevent the fine from becoming unreasonably high, the amount of the fine can then be adjusted accordingly. (Example: Anyone who was involved in a 100% agreement in 5 out of 10 rounds receives a 50% penalty for the duration of 10 rounds.)

⁴¹Note that this rule follows the legal practice that a market participant who does not agree to take an expressed action but behaves as if she did, can be assumed to be part of the concerted practice (Albors-Llorens, 2006; European Union, 2019; Odudu, 2010; Whish and Bailey, 2015)

- If, after a penalty, prices remain at the same level as before the audit, a penalty may be imposed again at a later audit, even if there has been no new agreement.

F Text mining results

In this section, we present our text mining results. Figure 14 shows the token frequency per treatment. Figure 15 shows the tokens-per-topic distributions for all 25 topics and Figure 16 shows the average posterior distribution of the 25 topics by treatment using a LDA.

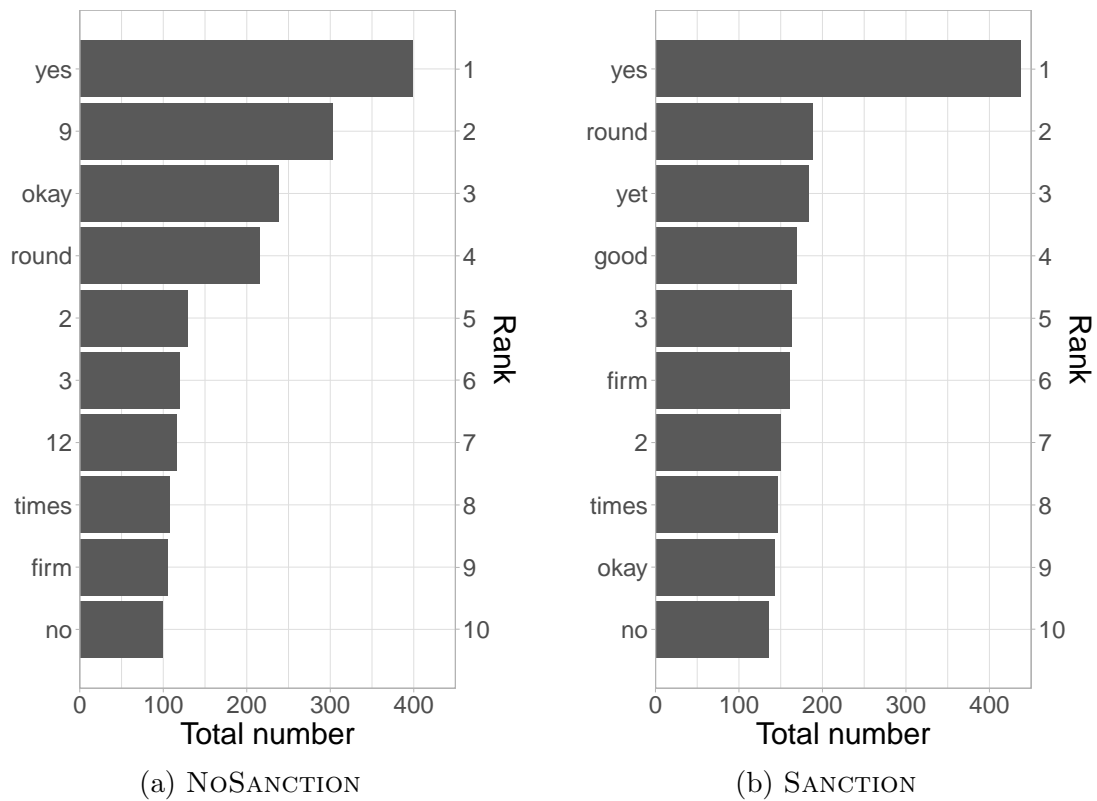


Figure 14: Token frequency per treatment.

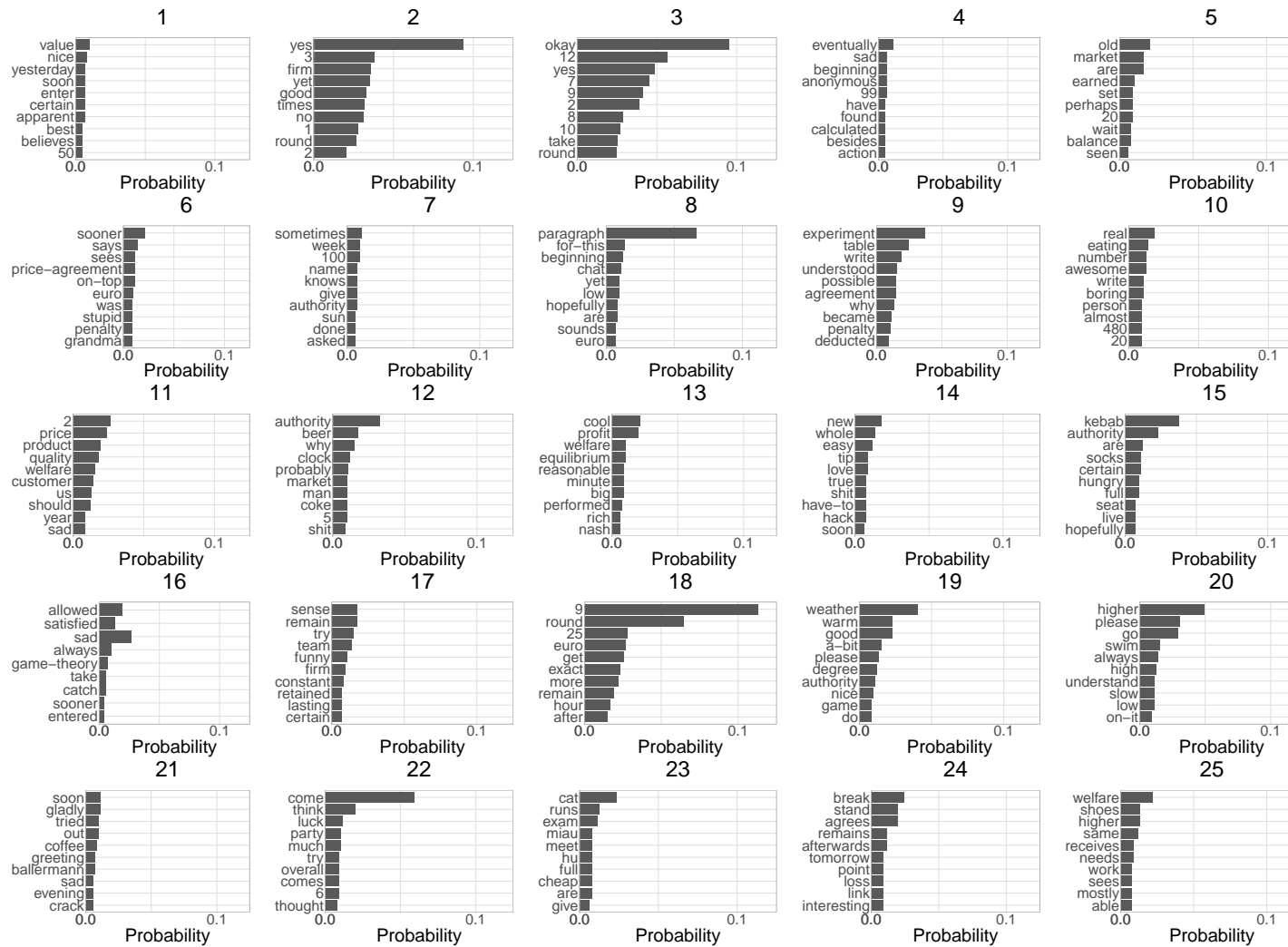


Figure 15: Token-per-Topic distributions of the top ten tokens for all 25 topics.

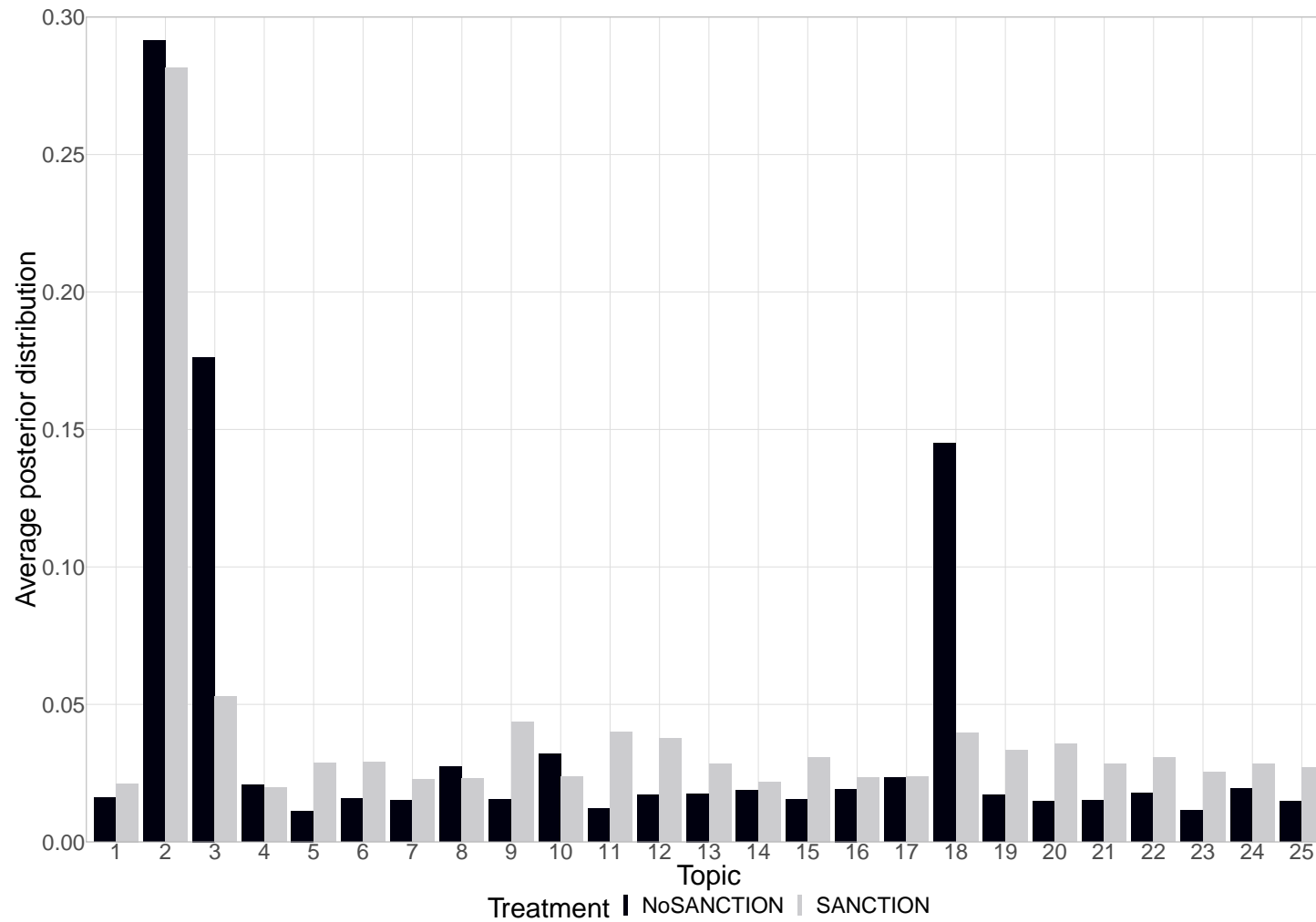


Figure 16: Average posterior distribution of the 25 topics by treatment.

G Original German tokens in their corresponding Figure

In the following, we present the original German tokens in their corresponding figure. We translated the tokens only after the analysis.⁴²

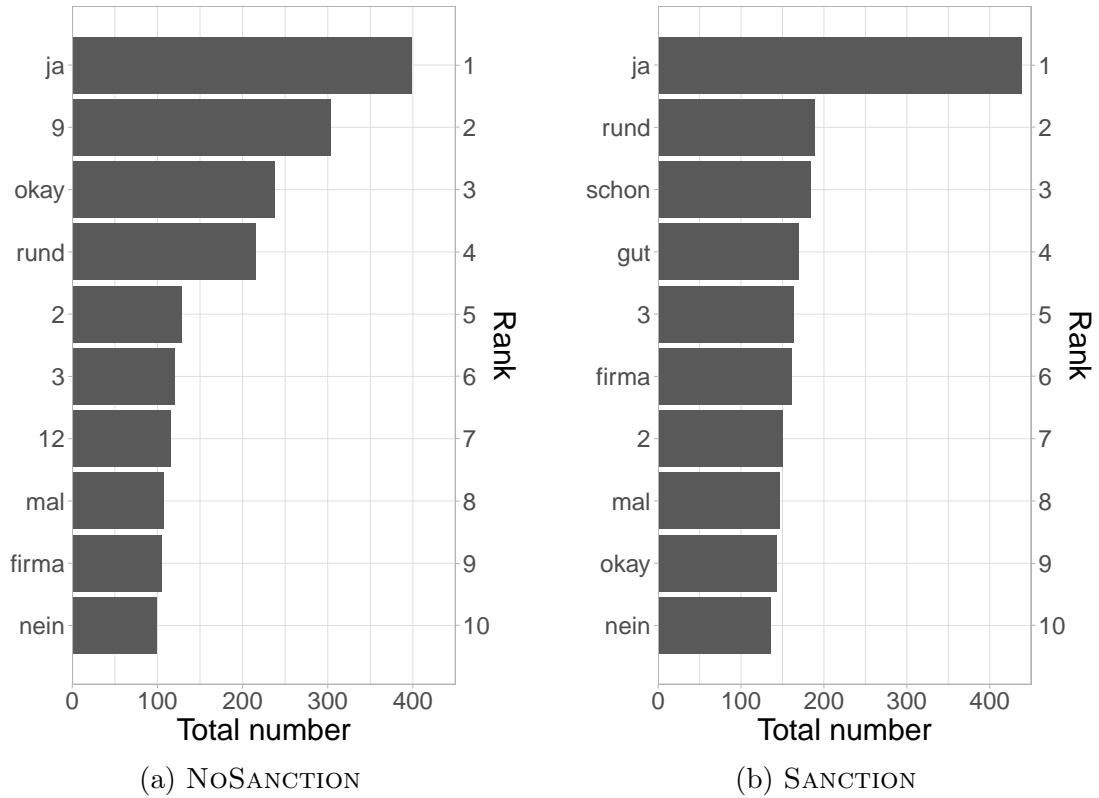


Figure 17: Token frequency per treatment in German.

⁴²Note for Figure 18: the German word “wohl”, written in small letters, translates to “probably”. Written with a capital letter, “Wohl”, the word means “welfare”. Both versions are used in the chats. However, the second translation better fits to the context of topic 25, *Joint Benefit*. Hence, we use the latter translation.

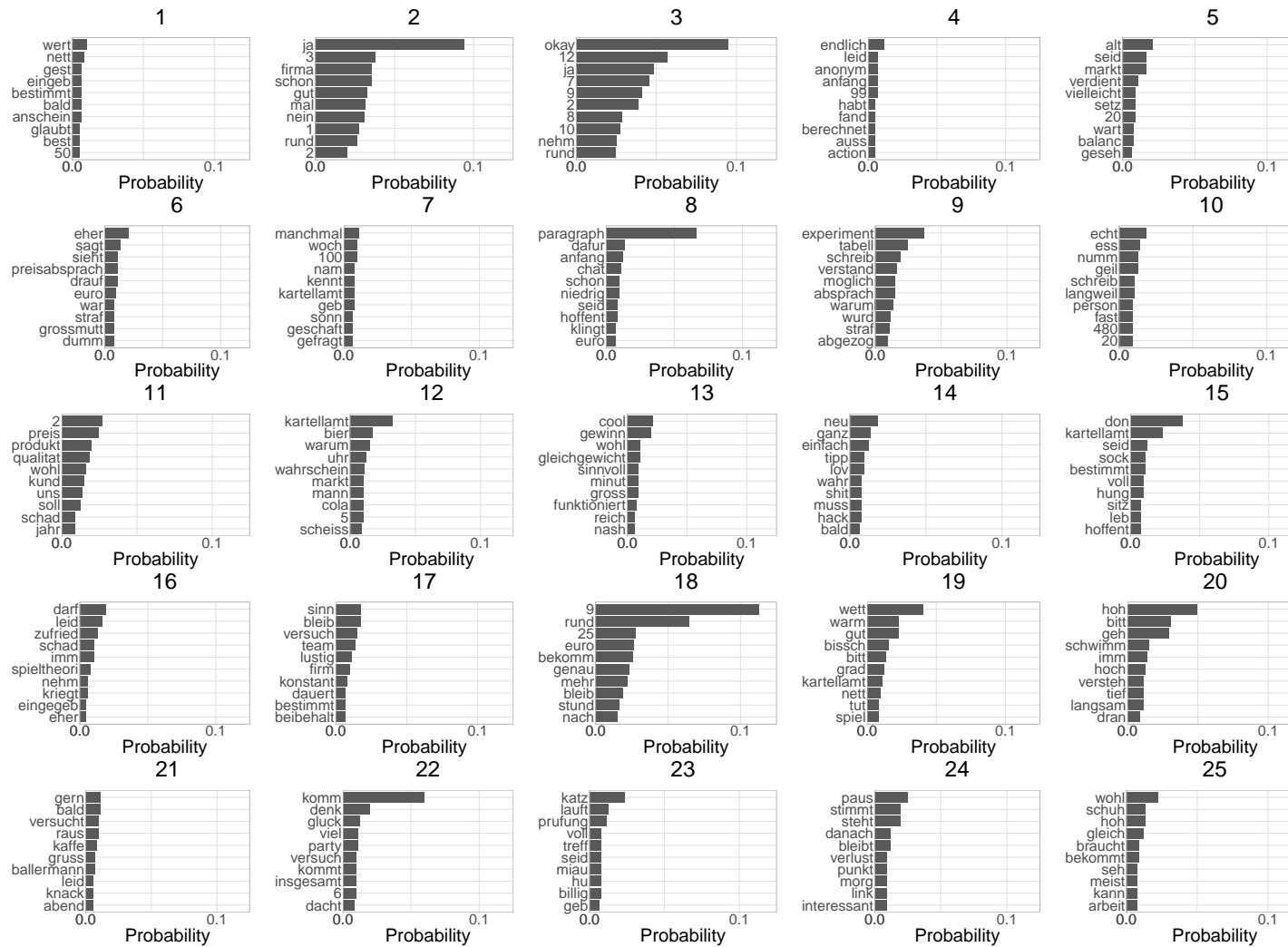


Figure 18: Token-per-Topic distributions of the top ten tokens for all 25 topics in German.

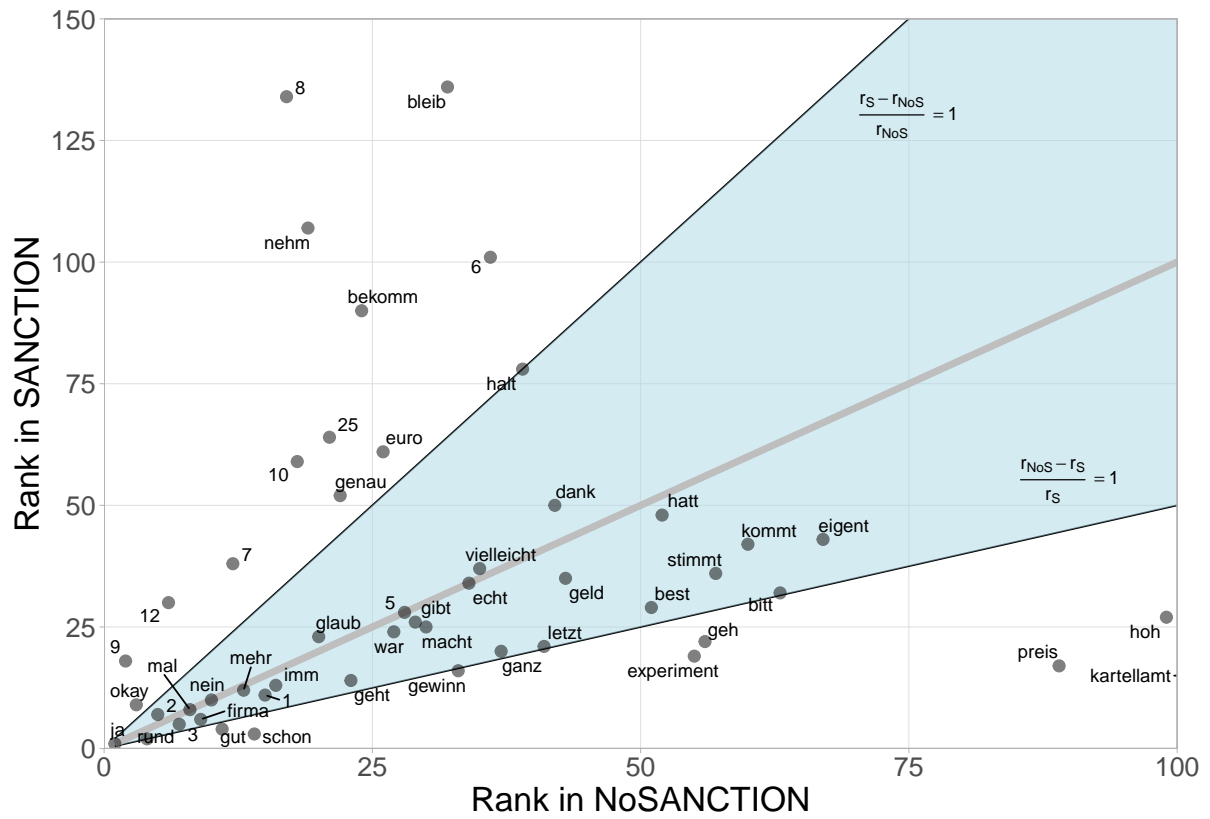


Figure 19: Frequency rankings of the 50 most used tokens in both treatments in German. Tokens that appear outside or at the border of the shaded area in Figure 19 have a relative rank differential weakly exceeding 1.