KONKURRANSETILSYNET
Norwegian Competition Authority

Rapport 8/2023
Vedtak: 2020-4

Collusion through list prices: an experimental investigation

Tom-Reiel Heggedal, Espen R. Moen, & Christian Riis

Prosjektet har mottatt midler fra det alminnelige prisreguleringsfondet.

Collusion through list prices: an experimental investigation*

Tom-Reiel Heggedal† Espen R. Moen‡ Christian Riis§

April 19 2023

Abstract

In this paper we analyse experimentally the role of list prices as a signalling device for the producers' costs. We construct a simple model implementable in the laboratory based on the framework in Harrington and Ye (2922), in which suppliers' costs are unknown to the manufacturer *ex ante* but may be revealed through their choices of list prices. In the experiment we confirm that the suppliers signal their costs through their choice of list prices, and that this is understood by the manufacturer. According to theory the signalling mechanism may be corrupted if the threat of collusion among the suppliers when setting list prices is sufficiently severe. This is only partially confirmed in the experiment.

*We would like to thank the Norwegian Competition Authorities (Det allminnelige prisreguleringsfond) for financial support.

†Department of Economics and CESAR, BI Norwegian Business School.

‡Department of Economics and CESAR, BI Norwegian Business School.

§Department of Economics, BI Norwegian Business School.

1 Introduction

List prices, or recommended retail prices, are non-binding price quotes made by manufacturers to indicate the price level of a product. Lately, several court cases have involved list prices. Let us mention a few: In 1992, two of the largest U.S. producers of fiberglass were accused of coordinating their list prices in the period 1979-83. In 2016 The European Commission accused MAN, Volvo/Renault, Daimler, Iveco, and DAF for breaking EU antitrust rules, by exchanging list prices (and other information) for 14 years, and were imposed a record fine of almost 3 billion Euros. In on-going private litigation, four class I railroads have been accused of coordinating their fuel surcharges starting in 2003. [1]

An intriguing question is therefore if list prices, which are non-binding, can be used as a vehicle for collusion on transaction prices. Harrrington and Ye (2022) argue that suppliers may use list prices to signal their costs and thereby their attractiveness as trading partners. Hence advertisements of list prices have a clear economic rationale, and may improve efficiency. However, the flip-side of that coin is that list prices also may be used for collusive purposes. By coordinating their list prices, suppliers may be able to soften competition and obtain supra-competitive prices.

In the present paper we set up a simple model which captures the main mechanisms in the Harrington and Ye's model and at the same time is implementable in the laboratory. Our main objective is to test wether list prices may act as signalling devices for suppliers' costs, and if so, how vulnerable this mechanism is for perceived collusion between the suppliers. Our main finding is that the subjects in the experiment do use list prices as a signalling device in the absence of collusion, and that this is understood by the receivers of the signals (the manufacturers). When the buyers are informed that collusion on list prices takes place with a spec-

[1] More cases are described in Harrington and Yee (2022).

ified probability they put less weight on list prices, but the reduction is perhaps less pronounced than theory suggests.

In Harrington and Ye's model, a manufacturer observes the list prices offered by the suppliers, and may choose which supplier to approach based on these list prices. The manufacturer then gives a take-it or leave-it offer to the chosen supplier. In a separating equilibrium, buyers' beliefs are that list prices are informative about the costs of the supplier, with low list prices meaning low costs. If two suppliers offer different list prices, the manufacturer will approach the one with the lowest list price and offer a low transaction price. Hence from a supplier's point of view, posting a low list price increases the likelihood of being the chosen supplier, but reduces the offered transaction price if chosen. Hence a supplier faces a trade-off between a high probability of selling (higher sales volume) and a high price per unit sold. As sellers with low costs are more willing than sellers with high costs to trade off a high price in exchange for a high volume, a separating equilibrium may exist for a set of parameter values. In addition Harrington and Ye assume that there is an exogenous probability that the suppliers will collude and advertise a high list price independent of costs. A separating equilibrium still exists for low but not for high probabilities of collusion.

We construct a simplified version of the Harrington-Ye model, which preserves the main elements and at the same time is implementable in the laboratory. Suppliers have either high costs c_H or low costs c_L, and advertise high or low list prices. Manufacturers observe the posted list prices, and choose which of two prices p_L (low) and p_H (high) to offer, an offer which the supplier accepts or rejects. The price levels are exogenously set so that p_L exceeds c_L but not c_H while p_H exceeds both. With an exogenous probability collusion takes place. If so both list prices are set high. We set parameters such that the unique equilibrium is separating as long as the probability of collusion is less than 1/2. In the separating equilibrium, suppliers truthfully reveal their costs by setting the low list price if and only if their costs are indeed low. Manufacturers choose the supplier with the lowest cost, and offer the low price if the chosen supplier advertised a low list price and the high price otherwise. If the probably exceed 1/2, equilibrium prescribes that manufacturers should set the low price if both suppliers set high list prices.

In the experiment we run four treatments that vary with respect to the probability the sellers establish a cartel. We find that in around 80 percent of the cases, the suppliers set list prices in accordance with their underlying costs. When setting prices after observing two high list prices, the buyers do respond to the probability of collusion, but somewhat differently and arguably to a lesser extent than theory would predict.

Literature

There exists a literature on the economics of list prices. Lubensky (2017) shows that a manufacturer may use list prices to motivate uninformed customers to search if the retailers charge a too high mark-up. Puppe and Rosenkranz (2011) and Fabrizi *et. al.* (2016) argue that list prices influence the reference point for consumers, and thereby induces a kink in the demand curve facing retailers. This allows the manufacturers to use list prices to steer the price setting of retailers. Buehler and Gärtner (2013) model list prices as a communication device in vertical supply relations with private manufacturer information on production costs and consumer demand. On the empirical side, Faber and Janssen (2019) show that list prices in the oil sector have a horizontal coordinating effect in the sense that retail prices react to them.

In our paper, list prices are not binding, and our analysis therefore speaks to the literature on cheap talk. There is large experimental literature on cheap talk, see Blume et al. (2020) for a recent survey. A key issue has been to analyze information transmission between a sender and a receiver. The literature documents systematic over-communication relative to the most informative equilibria, see for instance Wilson and Vespa (2020) and Fréchette et al. (2022) for recent work on this issue. We quantify the level of information transmission in a context with two sellers and one buyer.

A broad experimental literature study price and quantity competition. A main objective has been to identify conditions under which collusion can be established and maintained over time. The bulk of these experiments focus on monitoring and endogenous threat structures that can stabilize cartel agreements (Potters & Suetens 2013, with references). A smaller set of experiments study how different learning processes may lead sellers to cooperate on setting prices (quantities) above (below) competitive levels (Friedman et al. 2015 and Huck et al. 2000, with references). To the extent that explicit communication and cheap talk has been investigated, focus has been on communication between sellers in order to coordinate on transaction prices or volumes directly (Harrington et al. 2016, with references). An exception is Davis & Holt (1998) who investigates the effects of seller-to-seller communication about suggested prices in a market where rebates are permitted. The main finding is that cartel discipline is difficult to establish and maintain when rebates are permitted. However, Davis & Holt (1998) does not generate hypothesis through an explicit model of cheap talk, and in contrast to seller to seller communication, our paper focus on seller to buyer communication. Papers on communication and collusion also investigate the effects of communication protocols. The main finding is that a combination of free-form ("chat") combined with opportunities to change prices- or quantities in near continuous time facilitates collusion (Bignoni et al. 2018, with references). In cartel experiments the buyer side is usually represented by robots rather than human subjects. This in order to isolate seller behavior for given buyer behavior. In contrast, investigating collusion through belief formation as we do requires both sides of the experimental market to be populated by human subjects.

Models of cheap talk has also been applied to a variety of other industrial organizational topics. Heggedal et al. (2018) test the effect of cheap-talk with two-way communication in a market with network effects, endogenous timing of moves and incomplete information. The cheep talk equilibrium is clearly present in data. Agranov et al. (2020) investigate theoretically and experimentally the effects of communication in a market game, using the framework of psychological game theory. Arganov & Yariv (2018) study experimentally the effect of communication on collusion in auctions.

2 Theoretical framework

We analyze a market with two sellers (suppliers) and one buyer (manufacturer). The model structure is simple. We assume that the costs of each individual seller are private information and can be either high, c_H, or low, c_L, with a given probability for each outcome. We denote by q the probability that the cost is high.

The buyer has a willingness to pay denoted v for the purchase of the good. The buyer chooses one of the firms and makes a directed offer to that firm. The offer is formulated as a "take it or leave it" offer, meaning that a trade occurs at the offered price if it is acceptable for the seller - that is, if the offered price exceeds the seller's unit cost. If the offer is not acceptable, no trade occurs. In both cases, the game is over.

The buyer's price decision is formulated as a choice between two alternatives, a high price, p_H, and a low price, p_L, with $p_H > c_H$ and $c_L < p_L < c_H$. Before the seller chooses which supplier to give an offer, the seller may costlessly send a signal, in the form of a list price, to the market. Through the signal, the firm can indicate whether its cost is low or high, and we refer to the two alternative signals as h and l, respectively (a high or a low list price). The signals are cheap talk, as both seller types can send any of the two signals without incurring any costs. Based on the observed signals, the buyer rationally updates the information the signal carries about the sellers' true costs, as a basis for choosing which seller to make an offer to.

With a certain probability the sellers form a *cartel*, in which case they commit to send a signal of high cost regardless of their actual cost realizations. We do not model cartel formation as such, but assume that the cartel is established with an exogenous probability s known to the buyer.

To sum up, the structure of the game is as follows:

1. With probability s the sellers establish a cartel.
2. Each seller draw independently their type, H or L, where q is the probability of high type. A high type has production cost c_H, the low type has production cost c_L. Type is private information.
3. Sellers simultaneously and independently make announcements, h or l. A cartel always announces h, h
4. The buyer observes the announcements, chooses a seller, and offers either p_H or p_L.
5. The seller accepts or rejects the offer.

A challenge is that, depending on the parameter values in the model, there exist equilibria in the form of pooling equilibria, separating equilibria, and equilibria in mixed strategies and a combination of those. It is not part of the experiment's purpose to analyze the process of equilibrium selection, and we therefore choose parameter specifications in which complications associated with multiple equilibria are minimized. In particular we require that

$$\frac{p_L - c_L}{p_H - p_L} \quad : \quad = \kappa \geq 1 \tag{1}$$

$$\frac{p_H - p_L}{v - p_L} \quad : \quad = \Delta \geq q \tag{2}$$

Condition (2) ensures that the buyer sets a low price in the absence of any informative signals, in which case the posterior is equal to the prior q. If the signals are empty, the buyer offers the low price p_L if and only if

$$v - p_H < (1 - q)(v - p_L).$$

That is

$$q \leq \Delta,$$

Condition (1) ensures that a low-cost supplier has an incentive to break out of a HH equilibrium and post L if recognized as a low-cost firm by the buyer. If collusion does not take place, this will be profitable if

$$p_L - c_L > \frac{1}{2}(p_H - c_L),$$

which gives (1). Given (1) and (2), it follows readily that the model has a separating equilibrium as long as the collusion probability is not too high. The probability that there is collusion given HH is equal to $\frac{s}{s+(1-s)q^2}$. The probability that costs are high given collusion is q, and given no collusion (and HH) is 1. Hence the probability is given by

$$\Pr[c_L | HH] = \frac{sq + (1-s)sq^2}{s + (1-s)q^2}$$

The buyer offers p_H after observing HH whenever $s \leq \Delta$, that is, whenever

$$s \leq \frac{q^2(1-\Delta)}{\Delta(1-q^2) - q(1-q)} \tag{3}$$

and p_L otherwise. In the appendix we show that (1) ensures that if (3) is satisfied, there exists no equilibrium in which the suppliers randomize between the pooling and the separating equilibrium.

A final restriction on parameter values is to ensure that firms, *ex ante*, have an incentive to initiate a cartel arrangement. Collusion increases ex ante expected profit if

$$\begin{aligned} & \frac{1}{2}\left[q\left(p_H - c_H\right) + (1-q)\left(p_H - c_L\right)\right] \\ \geq\ & \frac{1}{2}q^2\left(p_H - c_H\right) + (1-q)\left[\frac{1}{2}(1-q) + q\right]\left(p_L - c_L\right) \end{aligned}$$

which yields the condition

$$q(1-\tau) + 1 \geq 0$$

where

$$\tau = \frac{c_H - c_L}{p_H - p_L}$$

Note that collusion disturbs the informational content of signals, and creates a loss due to misallocation if a high cost seller serves the buyer and the other seller has low costs. The higher the cost difference $c_H - c_L$ is, the more severe is the misallocation. The gain from collusion is increasing in the price margin $p_H - p_L$. The cost-benefit ratio τ, and q, jointly determine the profitability of collusion.

2.1 Main Predictions of the Model

The following summarizes the main predictions of the model:

- **Model prediction 1**. Suppose s satisfies (3). Then the equilibrium is separating,with suppliers advertising their true costs.

- **Model prediction 2**. If both sellers signal h, then then the buyer offers p_H to a random seller if $s \in \left[0, \frac{(1-\Delta)q^2}{\Delta(1-q^2)-q(1-q)})\right)$ while the buyer offers p_L to a random seller if $s \in \left[\frac{(1-\Delta)q^2}{\Delta(1-q^2)-q(1-q)}, 1\right]$.

3 Experimental Design

The experiment is designed to test the main predictions of the model. To do so we have four treatments that vary with respect to the probability the sellers establish a cartel s. Based on model prediction 1, we predict that sellers signal their true type when allowed to choose signal, and that this behavior is invariant to s. Further, based model prediction 2, we predict that buyers' offer conditional on observing two high signals depend on whether s is above or below the separation cut-off $\frac{(1-\Delta)q^2}{\Delta(1-q^2)-q(1-q)}$.

3.1 Lab Implementation and Treatments

It is straight-forward to implement a parameterized version of the market game in the lab. First, we want to avoid mixed strategy equilibria. To this end, we choose parameters such that

$$\kappa := \frac{p_L - c_L}{p_H - p_L} > 1.$$

This condition also rules out pooling equilibria, and supports a separating equilibrium in states where collusion does not occur. Observe that truth-telling is very robust if $\kappa > 1$, as it the unique equilibrium for every q, given the intuitive criterion.

Second, we let the cost-type distribution be fifty-fifty,

$$q = 0.5,$$

which makes interpretation easier for participants in the experiment. The other parameters of the model are as follows: $p_H = 80$; $p_L = 50$; $c_H = 55$; $c_L = 10$; $v = 100$. With these parameters we have $p_L - c_L > \frac{1}{2}(p_H - c_L)$, and pooling equilibria does not exits. Further, the cut-off $\frac{(1-\Delta)q^2}{\Delta(1-q^2)-q(1-q)} = 0.5$, and, hence, collusion is effective when $s \leq 0.5$.

Subjects' choices in the experiment are as follows: i) If there is no cartel, sellers send a signal of their own cost. This signal is either "high cost" or "low cost". In case a cartel is realized, there is no choice and both sellers send signal "high cost", ii) The buyer in the market observes the cost signals and decides on which of the two sellers to make an offer to as well as the price offer. The price offer is either a "high price" that is equal to 80 ECU or a "low price" that is equal to 50 ECU, iii) The seller receiving the price offer observes the offer and accepts this offer or not.

Our treatment variation is the probability the sellers establish a cartel s, and we implement the following probabilities: $s = 0$, $s = 0.25$, $s = 0.50$, and $s = 0.75$. Our main treatment measures are the signals chosen by sellers (conditional on types) and the price offers from buyers (conditional on signals). In particular, let $\theta \in \{0, 1\}$ be an indicator variable for the event that the seller signal is true, taking the value 0 if the signal is not true and 1 if the signal is true. A true signal is a signal that corresponds to the cost of a seller, i.e., high or low. Further, let $p|_{h,h}$ denote the price offer from a buyer receiving two high signals. We also measure sellers' profits, and whether buyers makes an offer to the seller with the lowest signal. The following table gives an overview of the four treatments and equilibrium predictions:

Treatment:	$S00$	$S25$	$S50$	$S75$
θ :	1	1	1	U.D.
$p\|_{h,h}$:	p_H	p_H	U.D.	p_L

where U.D denotes undecided. In this case theory does not give much guidance regarding subjects behaviour. At $s = 0.5$, the buyer is indifferent between setting p_L and p_H. Note also that if $s = 0.75$, a high-price supplier is indifferent between signalling H or L. However, we assume that in case of a tie, the suppliers tell the truth. We use blocks of 9 subjects. Subjects stay within blocks, and unique subjects are used in all treatments. In our analysis we regard average behavior within blocks as independent observations. A session may include several blocks.[2] Subjects play 30 games. Prior to the first game subjects randomly draw roles so that there are 3 buyers and 6 sellers in each block. These roles are fixed for all games. Before each game, subjects in a block are randomly matched into markets consisting of 1 buyer and 2 sellers.

A pre-study plan for the experiment was posted at the AEA RCT-registry on January 17 2018 (after data from the pilot was collected).[3] The plan covers our treatments and we report results in accordance with the plan. Based on a pilot included in the pre-study plan, a power of more than 95 percent for a treatment effect between $S00$ and $S75$ on the price offer $p|_{h,h}$ was calculated to require a total of 10 matching blocks (given a 5 percent significance level and a Wilcoxon rank test).[4] Data from the pilot is included in the analysis in this paper.

3.2 Data Collection

Data was collected in the Research Lab at BI Norwegian Business School in Oslo in the period October 2022 to March 2022. Subjects were recruited from the general student populations of BI Norwegian Business School. Recruitment and subject management was administered through ORSEE (Greiner 2015). On arrival subjects were randomly allocated to cubicles (to break up social ties). Written instructions were handed out and read aloud by the administrator (to achieve public

[2] A session consists of a set of subjects present in the lab at the same day and time.

[3] https://www.socialscienceregistry.org/trials/9622

[4] This estimate was obtained using the method described in Bellmare et al. (2016).

knowledge of the rules). A full set of instructions is provided in the supplementary online materials. All decisions were taken anonymously in a network of computers. The protocol was implemented in zTree (Fischbacher 2007).

In the experiment, costs, price-offers, and payoffs are denominated in experimental currency units (ECU). The exchange rate is set to equalize expected payoffs between treatments. At the conclusion of the session subjects are paid privately based on accumulated payoffs in ECU from all games played. A high-cost seller that accepts to sell when offered the low price incurs a loss of 5 ECU in the experiment. As an insurance against negative payoffs, all subjects were allocated 150 ECU before play started.

A total of 207 subjects participated in the experiment, distributed on five independent blocks in treatment $S00$, and six independent blocks in treatments $S25$, $S50$, and $S75$.

4 Treatment Effects

We primarily focus on two outcomes from the experiment; sellers' true signals θ and buyers' price offers conditional on receiving two high signals $p|_{h,h}$. We compare differences across treatments using matching block averages as units of observation. Reported p-values are based two-sided non-parametric (Wilcoxon) rank-sum tests.

4.1 Seller behavior

Figure 1 displays the average of sellers' true signals over treatments when there was no cartel. Recall that $\theta = 1$ if the signal is true and 0 otherwise.

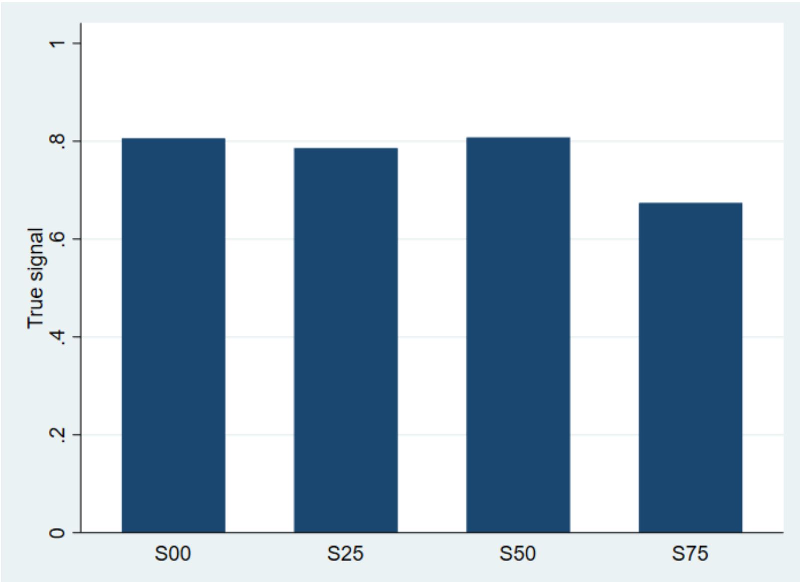

Figure 1. Observed mean of true signals over treatments.

Obervations from cartel markets are exluded.

From the figure we see that the θ is approximately 0.8 in treatments $S00$, $S25$, and $S50$, and 0.67 in treatment $S75$.[5] Hence sellers largely play as prescribed in the separating equilibrium predicted by the model in the three first trails. In treatment $S75$, the sellers signal their true cost less often than in the other treatments. In appendix $B.2$ we show that most subjects consistently choose the true signal in all games, except for in treatment $S75$ where the frequency of sellers' signals are more spread out.[6] In appendix $B.3$ we show that the lower rate of true signals in treatment $S75$ is driven by sellers with low costs.

Table 1 lists p-values (exact) of Wilcoxon rank-sum tests of treatment differences on sellers' true signals.

[5] In appendix $B.1$ we display the observed mean of true signals for the latter half of the games. The pattern for the latter half of the games is similar to that of all games.

[6] See appendix $B.2$ for frequency plots of subjects' mean true signals over costs.

	$S25$	$S50$	$S75$
$S00$	0.632	1	0.022
$S25$		0.818	0.058
$S50$			0.061

Table 1. p-values from WRS tests on true signals.

Observations from cartel markets are excluded.

Table 1 confirms that sellers signal true costs less often in treatment $S75$ than in the other treatments.

Turning to acceptance, sellers almost always accept advantageous price offers (98.5 percent over all sellers). However, high cost sellers facing a disadvantageous low price offer also accept in 15.9 percent of these case (as an average over high cost sellers). See appendix $B.4$ for details on price offers to high cost sellers and acceptance.

4.2 Buyer behavior

Figure 2 displays the average of buyers' price offers conditional on receiving two high signals across treatments. Recall that the price offer is a choice between a price of 80 and and a price of 50.

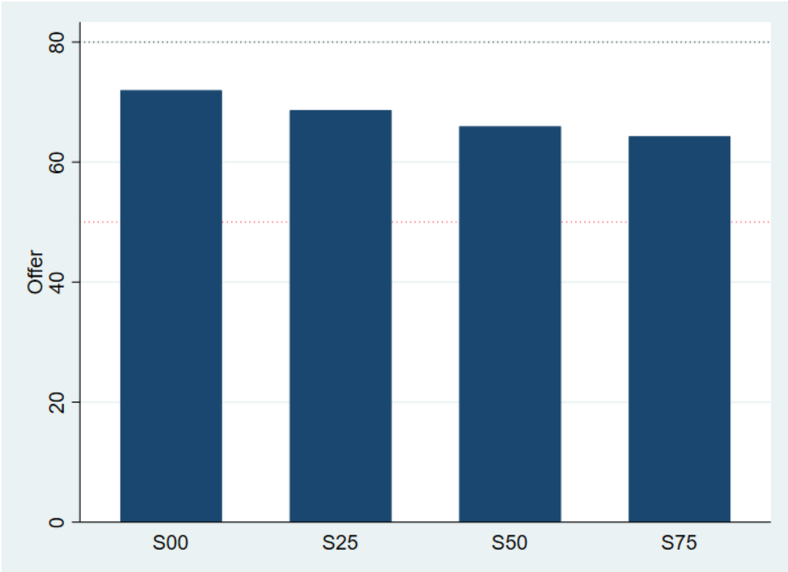

Figure 2. Observed mean of buyers' price offer over treatments. Includes only observations from markets with two high signals.

From the figure we see that the price offers are slightly decreasing in the probability of a cartel, from an offer of 72 in treatment $S00$ to an offer of 64 in treatment $S75$.[7] That price offers are lower in treatments $S50$ and $S75$ than price offers in the other treatments is in line with the predictions of the model. This observation gains support from significance testing. Table 2 lists p-values (exact) of Wilcoxon rank-sum tests of treatment differences on buyers' price offers.

[7] In appendix $B.1$ we display the observed mean of buyers' price offers for the latter half of the games. The pattern for the latter half of the games is similar to that of all games.

	$S25$	$S50$	$S75$
$S00$	0.329	0.091	0.082
$S25$		0.240	0.178
$S50$			0.699

Table 2. p-values from WRS tests on price offers.

Includes only observations from markets with two high signals.

From Table 2, we see that the only significant difference between treatments is arguably between treatment $S00$ and the two treatments $S50$ and $S75$. P-values of 9.1 percent and 8.2 percent are perhaps not that convincing, but from theory we expect price offers to be lower in the event with two high signals in treatments $S50$ and $S75$ compared to in treatment $S00$. Thus, one-sided tests could be more appropriate than two-sided tests, and if so, the relevant p-values are 4.55 percent and 4.1 percent, respectively.

Further, the model also predicts that there should be no difference in price offers between treatment $S00$ and treatment $S25$, nor does theory predict any difference in price offers between treatment $S50$ and $S75$. Neither of these hypotheses are rejected by the Wilcoxon rank-sum tests.

However, the model also predicts that price offers should be higher in treatment $S25$ than in $S75$. We cannot confirm this hypothesis in the data. In appendix $B.5$ we report frequency plots of subjects' mean of price offers. They show that subjects consistently choose the high price offer in treatment $S00$, and that the use of the high price is gradually decreasing in the probability of a cartel. This gradual approach to price offers in the data is in contrast to the sharp theoretical cut-off at $s = 0.5$ given by the model. Though, in treatment $S50$ buyers are indifferent between the high price offer and the low price offer in cases when they observe two high signals. In these cases, incentives to stay in the Nash equilibrium are weak and behavior has been shown to deviate from Nash in experiments where subjects have (close to) alternative best responses.[8]

Last, the model predicts that buyers should never offer the high price unless they observe two high signals. Table 3 lists average price offers conditional on signals received over treatments.

	$S00$	$S25$	$S50$	$S75$
Two high signals	72.0	68.7	65.9	64.2
One high signal	55.2	53.5	55.4	54.4
No high signal	55.2	53.1	54.6	55.6

Table 3. Observed mean of buyers' price offer over signals and treatments.

The table reveals that the low price is predominately offered when buyers receive one or two low signals, as predicted by the model.

4.3 Information transmission

We compute correlations between state and action to quantify the information transmitted between sellers and buyers. Such correlations has been widely used in the experimental literature on cheap talk.[9] For each treatment we correlate the price offer from buyers with the cost types of sellers that got a price offer. Table 4 lists the state-action correlations between sellers and buyers.

[8] See for instance Heggedal et al. (2022) who show that such deviations from Nash can be explained using a Quantal Response Equilibrium approach.

[9] See for instance Forsythe et al., (1999), Cai and Wang (2006), Wang et al. (2010), and Fréchette et al. (2022).

	$S00$	$S25$	$S50$	$S75$
Correlation	0.370	0.267	0.188	0.120

Table 4. State-action correlations over treatments.

From the table we see that the state-action correlations fall in the probability that sellers establish a cartel. That is, the level of information transmitted between sellers and buyers–through the sellers' message–is smaller when sellers are more likely to be committed to send the message $High$.[10] This result follows in part from our model as buyers are assumed to use Bayesian updating, and there is less updating upon receiving a message when the probability that sellers establish a cartel is higher. In particular we note that the level of information transmission is higher in treatments $S00$ and $S25$ compared to the level in treatments $S50$ and $S75$, as predicted by the model.

5 Conclusion

In this paper we analyse experimentally the role of list prices as a signalling device for the producers' costs. We construct a simple model implementable in the laboratory based on the framework in Harrington and Ye (2922), in which suppliers' costs are unknown to the manufacturer *ex ante* but may be revealed through their choices of list prices. In the experiment we confirm that the suppliers signal their costs through their choice of list prices, and that this is understood by the manufacturer. According to theory the signalling mechanism may be corrupted if the threat of collusion among the suppliers when setting list prices is sufficiently severe. This is only partially confirmed in the experiment.

[10] Correlations between messages and action has a similar pattern.

The strongest result in our paper is that the separating equilibrium is played in the absence of collusion. In future experiments we would like to dig deeper into the signalling aspect of the model by varying the incentives to signal without introducing a threat of collusion, as the subjects did not fully apprehend the effects of collusion on the incentives to set prices. This can be done by changing $c_H - c_L$, $p_H - p_L$, and/or v. By changing the parameter values we may explore what extent the signalling behaviour of the agents vary with the underlying parameters in a way that is consistent with theory. If so this will strengthen the evidence that signalling through list prices, as proposed by Harrington and Ye as a rationale for list prices, is consistent with behaviour in the laboratory.

References

Agranov, M., U. Dasgupta & A. Schotter (2020): *Trust Me: Communication and Competition in Psychological Games.* Working Paper, SSRN.

Agranov, M. & L. Yariv (2018): Collusion through communication in auctions. *Games and Economic Behavior* 107:93-108.

Bellemare, C., Bissonnette, L. & Kröger, S. (2016). Simulating power of economic experiments: the powerBBK package. *Journal of the Economic Science Association* 2, 157–168.

Bigoni, M., J. Potters & G. Spagnolo (2018): Frequency of interaction, communication and collusion: an experiment. *Economic Theory* 68(4):1-18.

Blume, A., Lai, E. K., & Lim, W. (2020). Strategic information transmission: A survey of experiments and theoretical foundations. *Handbook of experimental game theory*, 311-347.

Buehler, S. & Gärtner, D.L. (2013): Making sense of nonbinding retail-price recommendations. *American Economic Review* 103(1):335-59.

Cai, H., & Wang, J. T. Y. (2006). Overcommunication in strategic information transmission games. *Games and Economic Behavior*, 56(1), 7-36.

Cabrales, A., Feri, F., Gottardi, P., & Meléndez-Jiménez, M. (2016). Can there be a market for cheap-talk information? Some experimental evidence. Some Experimental Evidence.

Davies, D.D. & C.A. Holt (1998): Conspiracies and Secret Discounts in Laboratory Markets. *Economic Journal* 108(448):736-756.

Faber, R.P. & Janssen, M. (2019): On the effects of suggested prices in gasoline markets. *Scandinavian Journal of Economics* 121(2):676-705

Fabrizi, S., Lippert, S., Puppe, C. & Rosenkranz, S. (2016): Manufacturer suggested retail prices, loss aversion and competition. *Journal of Economic Psychology* 53:141-153.

Fischbacher, U. (2007): z-Tree Zurich Toolbox for Ready-made Economic Experiments. *Experimental Economics* 10(2):171-178.

Friedman, D., S. Huck, R. Oprea & S. Weidenholzer (2015): From imitation to collusion: Long-run learning in a low-information environment. *Journal of Economic Theory* 155:185-205.

Forsythe, R., Lundholm, R., & Rietz, T. (1999). Cheap talk, fraud, and adverse selection in financial markets: Some experimental evidence. *The Review of Financial Studies*, 12(3), 481-518.

Fréchette, G. R., Lizzeri, A., & Perego, J. (2022). Rules and commitment in communication: An experimental analysis. *Econometrica*, 90(5), 2283-2318.

Greiner, B. (2015). Subject pool recruitment procedures: organizing experiments with ORSEE. *Journal of the Economic Science Association* 1(1): 114-125

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

Harrington Jr, Joseph E., and Lixin Ye. Collusion through coordination of announcements. *The Journal of Industrial Economics* 67.2 (2019): 209-241.

Heggedal T.-R., L. Helland & K.E.N. Joslin (2018): Should I Stay or should I Go? Bandwagons in the lab. *Journal of Economic Behavior & Organization* 150:86-97.

Heggedal, T.R., Helland, L. and Morton. R. (2022). Can Paying Politicians Well Reduce Corruption? The Effects of Wages and Uncertainty on Electoral Competition. *Games and Economic Behavior*, 135, 60-73.

Huck, S., H.-T. Normann & J. Oechssler (2000): Does Information about Competitors' Actions Increase or Decrease Competition in Experimental Oligopoly Markets? *International Journal of Industrial Organization* 18:39-57.

Lubensky, D. (2017): A model of recommended retail prices. *RAND Journal* *of Economics* 48(2): 358-386.

Potters, J. & S. Suetens (2013): Oligopoly experiments in the current millennium. *Journal of Economic Surveys* 27(3):439-460.

Puppe, C. & Rosenkranz, S. (2011): Why Suggest Non-Binding Retail Prices? *Economica* 78:317-329.

Wang, J. T. Y., Spezio, M., & Camerer, C. F. (2010). Pinocchio's pupil: using eyetracking and pupil dilation to understand truth telling and deception in sender-receiver games. *American Economic Review*, 100(3), 984-1007.

Appendix A: Model

Let $\alpha \in [0,1]$ denote the probability that a low-cost firm signals high cost, and let $\beta \in [0,1]$ indicate the probability that a buyer bids a high price when both firms signal high costs. Consider a firm's incentives in the hypothetical situation where its competitor signals high cost with probability α, if its true cost is low, and a buyer bids p_H with probability β, if both firms signal h.

If the low type announces h, it obtains:

$$\begin{aligned} & (q+(1-q)\alpha)\,\frac{1}{2}\left[\beta\,(p_H-c_L)+(1-\beta)(p_L-c_L)\right] \\ = \;& (q+(1-q)\alpha)\,\frac{1}{2}\left[\frac{\beta}{\kappa}+1\right](p_L-c_L) \end{aligned}$$

If he signals l it obtains:

$$\begin{aligned} & \left[\frac{1}{2}\left(1-(q+(1-q)\alpha)\right)+(q+(1-q)\alpha)\right](p_L-c_L) \\ = \;& \frac{1}{2}\left(1+q+(1-q)\alpha\right)(p_L-c_L) \end{aligned}$$

It follows that the firm's best reply is to signal truthfully if

$$(q+(1-q)\alpha)\,\beta \leq \kappa.$$

Since the left-hand side is upper-bounded by 1, it follows that a low-type firm will always signal l, i.e., $\alpha > 0$ is incompatible with a symmetric equilibrium.

We next examine the incentives of the buyer.

First, we consider the buyer's update of information given the signals of the sellers. Observing l reveals that there is no collusion, and that the seller has low costs.

$$\Pr(L|l) = 1$$

If a buyer observes one or more l-signals, he chooses any of the l firms, and offers p_L.

If istead the buyer observes two high signals, he chooses a seller at random. The probability that the selected seller is a high cost seller is

$$\Pr(H|\{h,h\}) = \frac{q^2 + (s + (1-s)\alpha)\, q\,(1-q)}{q^2 + 2\,(s + (1-s)\alpha)\, q\,(1-q) + (s + (1-s)\alpha^2)\,(1-q)^2}.$$

To explain the expression, note that the buyer observes two high signals either if the firms collude, which happens with probability s, or if they do not collude, which happens with probability $1-s$ and one of the following events occur: i) both firms have high costs, which happens with probability q^2, ii) one firm has low cost and one has high, and they both signal h, something which occurs with probability $2\alpha q\,(1-q)$, and finally,d both firms have low cost and signal h, occuring with probability $(1-q)\,\alpha^2$.

If the buyer offers p_L he obtains the expected profit

$$(1 - \Pr(H|\{h,h\}))\,(v - p_L)$$

Offering p_H yields

$$v - p_H$$

The buyer is indifferent if

$$\Pr(H|\{h,h\}) = \frac{p_H - p_L}{v - p_L} := \Delta,$$

Inserting $\alpha = 0$ yields the following condition for the buyer to offer the high price in the event with two high signals.

$$\frac{q^2 + sq\,(1-q)}{q^2 + 2sq\,(1-q) + s\,(1-q)^2} \geq \Delta$$

It follows that there exists a critical s such that the buyer offers p_L if

$$\frac{q^2\,(1-\Delta)}{\Delta\,(1-q^2) - q\,(1-q)} \geq s$$

and p_H otherwise.

Appendix B: empirical analysis

B.1 True signal and price offer in the latter half of the games

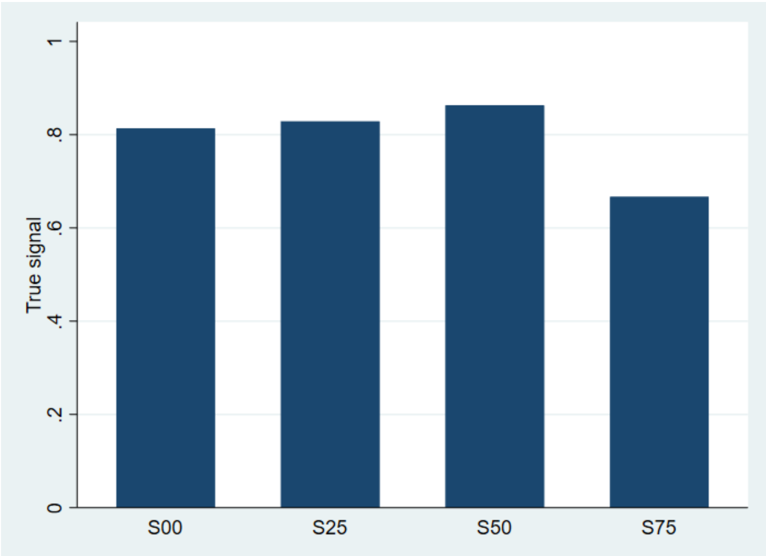

Figure B.1.1. Observed mean of true signals over treatments for last 15 games. Obervations from cartel markets are exluded.

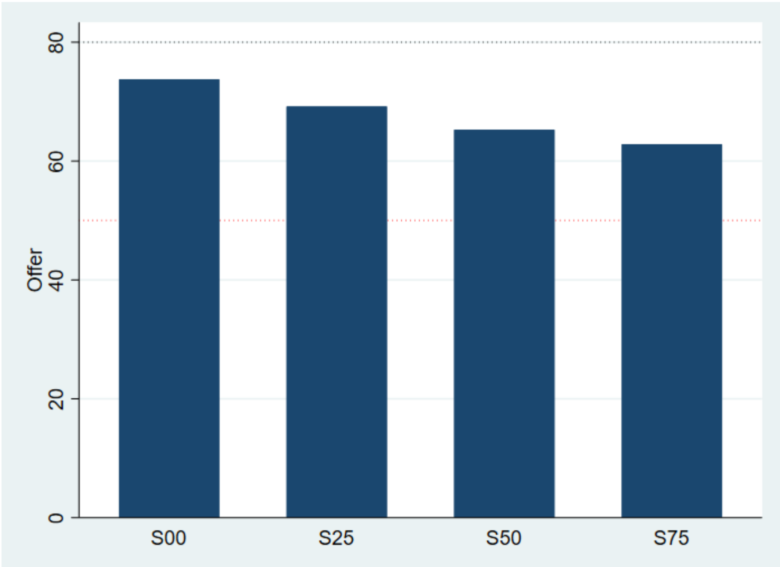

Figure $B.1.2$. Observed mean of buyers' price offer over treatment from last 15 games. Includes only observations from markets with two high signals.

5.1 B.2 Frequency of subjects' mean of true signal

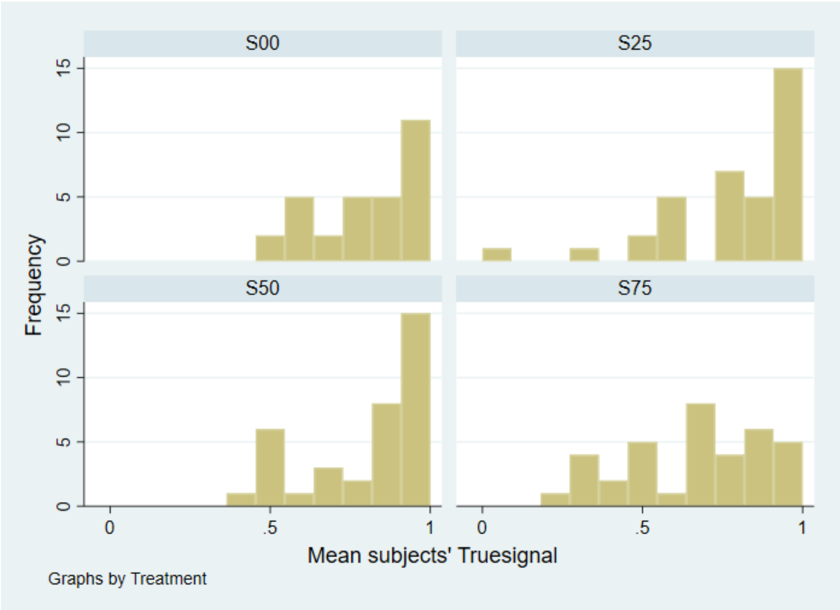

Figure $B.2.1$ Frequency of subjects' mean of true signal over treatments. Obervations from cartel markets are exluded.

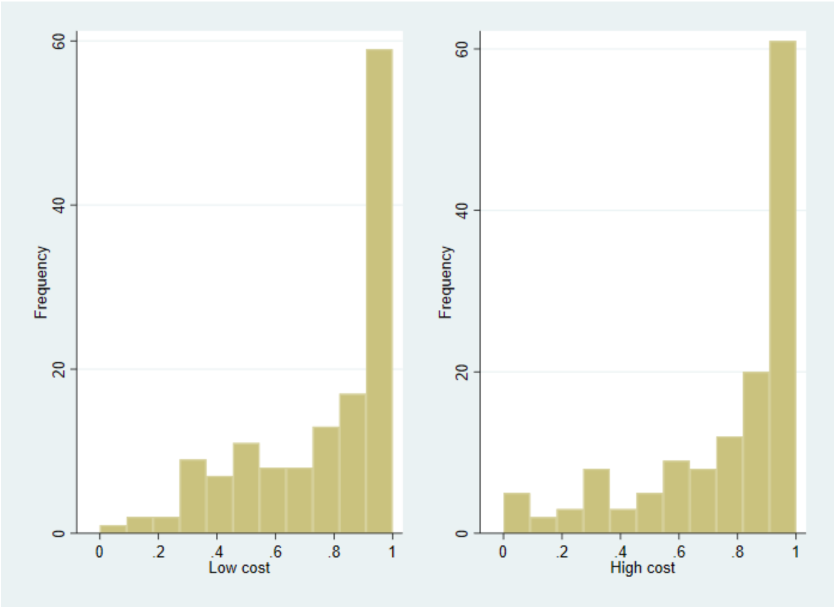

Figure $B.2.2$ Frequency of subjects' mean of true signal over costs. Obervations from cartel markets are exluded.

5.2 B.3 True signal over cost type

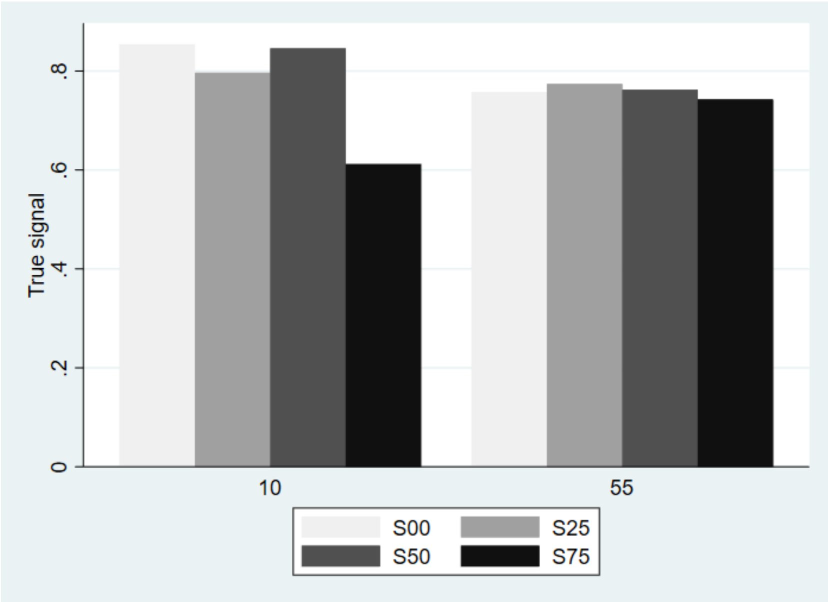

Figure $B.3$. Observed mean of true signals over costs and treatments. Obervations from cartel markets are exluded.

5.3 B.4 Price offers to high cost sellers and acceptance

	$S00$	$S25$	$S50$	$S75$
Accept advantageous offers	99.1	98.0	97.7	98.2
Accept disadvantageous offers	15.2	18.3	16.9	13.5

Table $B.4$ Shares of price offers to high cost sellers over treatments.

5.4 B.5 Frequency of subjects' mean price offers

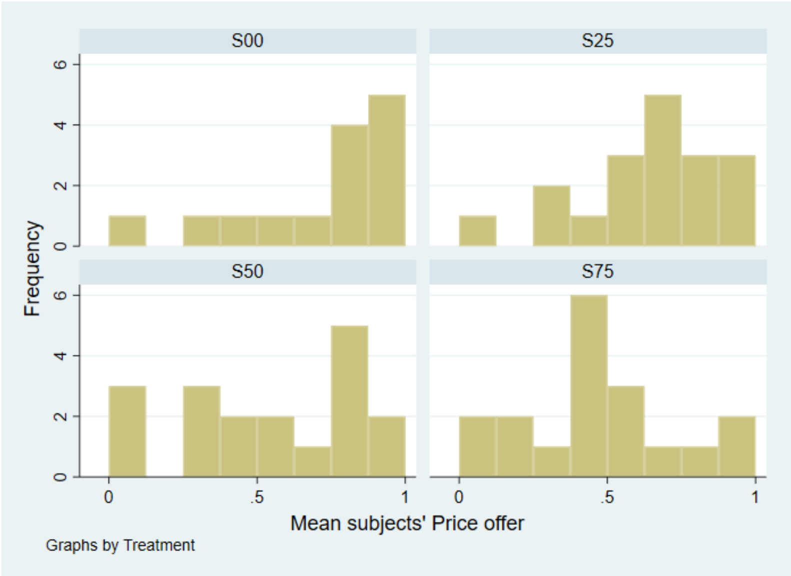

Figure $B.5$ Frequency of subjects' mean price offers over treatment. The low price is coded 0, wheras the high price is coded 1. Includes only observations from markets with two high signals.