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# **Cheap-talk Communication in Procurement: Theory and Experiment**

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## **Abstract**

In procurement, suppliers are usually better informed about technical, financial, or legal aspects of the goods and services procured. Therefore, buyers may include a dialogue in the procurement procedure which enables suppliers to provide information supporting the buyer to better specify the terms of the contract. Theoretically and in a laboratory experiment, this paper addresses the question of the value added of cheap-talk communication in procurement. Our theoretical results suggest that in a setting where the buyer's and the suppliers' interests regarding the terms of the contract are aligned, post-auction communication induces truthful information revelation, as opposed to pre-auction communication. For a misaligned-interest setting, the opposite result holds. Our experiment shows firm support for the post-auction communication's effectiveness in the aligned-interest setting. In contrast, pre-auction communication is hardly informative in either setting. Our findings offer several managerial implications for the appropriate design of procurement procedures.

*Keywords:* Cheap-talk game; procurement auctions; bidding; laboratory experiment

*“Even for rather simple contracts [...] the purchaser is seldom interested solely in price – he is interested in acquiring and providing information as well.”* Victor P. Goldberg (1977)

## **1. Introduction**

Buyers typically use auctions to procure goods and services because the suppliers often have better information on the costs of supplying the goods and services than the buyer (McAfee and McMillan, 1987). In practice, however, next to revealing the potential suppliers' costs, the buyer would like to elicit information about the technical, financial, or legal aspects of the goods and services procured from the suppliers (Goldberg, 1977). Such information will help the buyer to determine what exactly should be procured. Therefore, as part of the sourcing process, the buyer may acquire information from the suppliers about such non-price attributes.

In practice, sourcing processes regularly consist of both an auction and several request-of-information rounds (Elmaghraby, 2007). Before the start of the auction, the buyer may invite suppliers to “indicate their capabilities along possibly multiple non-price dimensions” (Elmaghraby, 2007, p. 412) and after the auction, the buyer “may negotiate certain terms of the contract that were strategically left vague before the auction” (Elmaghraby, 2007, p. 417). In the case of complex contracts, public procurement law in the European Union allows for both a ‘competitive dialogue,’ in which buyers communicate with suppliers before the latter submit their final tender, and a ‘negotiated procedure,’ where buyers may communicate with selected suppliers over the contract specifics (Directive 2014/24/EU). At the time of writing, public procurement agencies in the EU had 273 (4,261) open calls for tenders that used the competitive dialogue (negotiated procedure) according to the TED (Tenders Electronic Daily) website.

Procedures like the competitive dialogue and the negotiated procedure, and their equivalents used in the private sector, may allow suppliers to reveal valuable information to the buyer and, in turn, prevent unpleasant surprises in the future leading to substantial cost overruns or long delays. A potential downside of communication with the suppliers outside the auction is that they may have incentives to manipulate the information they provide. Much of the information transmitted in procurement boils down to ‘cheap talk’ in the sense of Crawford and Sobel (1982): The messages revealed in the communication do not directly affect payoffs but they can link decisions regarding the project made by the buyer to the information transmitted by the suppliers. This raises questions like: Under what conditions does cheap-talk communication reveal useful information for the buyer? Under what conditions does the buyer benefit from cheap-talk communication with the suppliers, before or after the auction? Under what conditions does the buyer prefer pre-auction communication over post-auction communication and the other way around? We address those questions both theoretically and in a laboratory experiment.

Our theory models procurement procedures as dynamic Bayesian games. In our framework, a number of suppliers compete to complete a project for the buyer. The project can be completed at one of multiple different ‘locations’, which can be interpreted as a (horizontal) non-price attribute of the project. Among the suppliers, it is common knowledge which location is the most valuable for the buyer, while the buyer is incompletely informed about this. We study two settings, ALIGN and MISAL, which vary in whether or not the buyer and the suppliers have aligned interests regarding the location. In setting ALIGN (MISAL), the suppliers’ costs of completing the project are higher (lower) the farther the location at which the project is completed is away from the buyer’s most valuable location. The ALIGN setting applies, for example, to a situation where the buyer’s maintenance costs are positively correlated with the suppliers’ costs of completing the project (e.g., more complicated IT systems are both costlier to build for the supplier and costlier to maintain for the buyer). The MISAL setting applies to a situation where the buyer’s maintenance costs for the project is decreasing in the suppliers’ costs of completing the project (e.g., higher-quality machines are costlier to deliver for the supplier but require less follow-up maintenance by the buyer). The MISAL setting also has a relevant vertical product differentiation interpretation in that it applies to situations where the buyer’s value for the project is increasing in the suppliers’ costs of completing the project (e.g., the quality of social-work services may be higher the more hours the suppliers invest in developing the services).

The suppliers’ cost structure is such that in the ALIGN (MISAL) setting, (1) the cost efficiency ranking among the suppliers are fixed regardless of the location at which the project is completed at, and (2) the farther away (closer) the project is from (to) the buyer’s most valuable location, the greater cost advantage the most cost-efficient supplier has over his competitors. Such cost structure matches a situation where (1) suppliers differ in their hourly (opportunity) costs, for instance because they differ in portfolios of other projects they are working on, (2) suppliers need the same number of hours to complete a particular project, and (3) the projects differ in the number of hours to complete depending on its location relative to the buyer’s most valuable location.

To study cheap-talk communication in procurement, we consider three mechanisms. Under the *no-communication mechanism*, the buyer first picks one of the three locations and allocates the project in a reverse auction. The *ex-ante mechanism*, modelled after the competitive dialogue, is the no-communication mechanism extended with a cheap-talk communication stage before the auction: The suppliers can send a non-binding location recommendation to the buyer before the buyer picks the location. The *ex-post mechanism* models the negotiated procedure: The buyer first buys an abstract project in a reverse auction; then the winning supplier sends a non-binding location recommendation to the buyer, after which the buyer chooses the location.

We first theoretically evaluate the value-added of the ex-ante and ex-post mechanisms relative to the no-communication mechanism for the buyer in each setting. It is well known that cheap-talk games like these are often plagued by a multitude of equilibria. We use Farrell’s (1993) neologism proofness refinement to select among equilibria. Farrell (1993) defines a neologism as an out-of-equilibrium message and proposes conditions under which neologisms are credible. Intuitively, neologism proofness weeds out equilibria that admit a credible neologism. Based on the experimental evidence that we discuss below, we further restrict our attention to the most informative neologism-proof equilibrium. We find the following. In the ALIGN setting, the buyer is better off using the ex-post mechanism than the no-communication mechanism and the ex-ante mechanism. The intuition is that in the ex-post mechanism, the winning supplier has a strong incentive to reveal the buyer’s most valuable location. In contrast, in the ex-ante mechanism, suppliers prefer to hide information about the buyer’s most valuable location because competition in the auction is softened if the buyer picks a different location. Similarly, in the MISAL setting, the buyer is better off using the ex-ante mechanism than the no-communication and ex-post mechanisms.

Which equilibrium under each of the three mechanisms is most likely to be played remains an empirical question, which we address using a laboratory experiment. Our data strongly support the theoretical predictions for the ALIGN setting: The ex-post mechanism outperforms both the ex-ante mechanism and the no-communication mechanism in terms of buyer profits. However, in the MISAL setting, in contrast to our theoretical predictions, the ex-ante mechanism does not perform better than the no-communication and ex-post mechanisms. We particularly observe that the suppliers reveal hardly any information about the buyer’s most valuable location in the ex-ante mechanism, in contrast to the most informative neologism-proof equilibrium, in which the suppliers always reveal the buyer’s most valuable location.

To further understand this anomaly, we explore the equilibrium selecting properties of the quantal-response equilibrium (QRE). The QRE is an equilibrium concept that relaxes the rationality assumption by imposing that players play noisy best responses to each other’s strategies (McKelvey and Palfrey, 1995, 1998). Using the logit-agent quantal-response equilibrium (logit-AQRE), we show that (1) multiple logit-AQREs may exist, including a babbling equilibrium and a separating equilibrium, (2) a babbling logit-AQRE always exists, (3) the logit-AQRE weeds out the separating equilibrium for sufficiently noisy suppliers, and (4) under the noise parameter estimated for the suppliers in the experiment on the basis of their actual decisions, the ex-ante mechanism in MISAL does not have a separating logit-AQRE. We conclude that QRE provides a convincing behavioral underpinning as to why in MISAL, the suppliers fail to communicate useful information to the buyer in the ex-ante mechanism so that, in turn, the ex ante mechanism does not outperform the no-communication mechanism and the ex-post

mechanism. In a follow-up experiment, our observation that the buyer does not benefit from ex-ante communication in MISAL is robust to the buyer only gathering advice from a single supplier.

Overall, our results point to the limitations of allowing suppliers to communicate before or after the auction. Our experimental results suggest that communication after the auction is only valuable insofar as the buyer and the suppliers have aligned interests regarding non-price attributes. The value-added of ex-ante communication seems even more limited in that it turns out to be difficult for suppliers to communicate effectively with the buyer.

Cheap-talk games have been extensively tested in the lab.<sup>1</sup> A common finding is that among all equilibria, the most informative equilibrium explains the data best, particularly if this equilibrium survives equilibrium selection based on neologism proofness. A second common observation in the experimental cheap-talk literature is overcommunication, i.e., if experimental participants deviate from equilibrium behavior, they communicate more than predicted by the most informative neologism-proof equilibrium.<sup>2</sup> These observations motivated us to base our theoretical predictions on the most informative neologism-proof equilibrium. Our data show that behavior is by and large in line with the most informative neologism-proof equilibrium, with one major exception: In the MISAL setting, suppliers hardly reveal any information about the buyer's most preferred location, even though a fully-revealing neologism-proof equilibrium exists. This explains why in this setting, the ex-ante mechanism does not outperform the ex-post mechanism and the no-communication mechanism, in contrast to what theory predicts.

The structure of this paper is as follows. Section 2 includes the theoretical analysis. In Section 3, we present the experimental design and hypotheses. In Section 4, we discuss the experimental results and we interpret our findings in the light of the alternative behavior theories where our data are inconsistent with standard theoretical predictions. In this section, we also present the results of the follow-up experiment in which the buyer only gathers advice from a single supplier. Section 5 is a conclusion, which includes a summary of our results, management implications regarding the design of sourcing processes, and suggestions for future research.

## 2. Theory

Consider a (female) buyer that wishes to complete a project (e.g., the buyer is a business unit that is committed to build a production unit in a developing country).  $N \geq 2$  (male) suppliers, labeled  $i = 1, \dots, N$ , can complete the project at one of  $L$  different locations, labeled  $x_1 < x_2 < \dots < x_L$ , which can be interpreted as a horizontal non-price attribute in the sense of Hotelling (1929).

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<sup>1</sup> See, e.g., Dickhaut et al. (1995), Blume et al. (1998, 2001), Gneezy (2005), Cai and Wang (2006), Wang et al. (2010), De Groot Ruiz et al. (2014, 2015), and Lai and Lim (2018). Blume et al. (2019) presents a survey of this literature.

<sup>2</sup> This observation may be partly explained by people's preference for being honest (e.g., Abeler et al., 2019).

Location  $l$  is the buyer's most preferred location  $X$  with probability  $p_l$ , where  $p_l > 0$  for  $l = 1, 2, \dots, L$  and  $\sum_{l=1}^L p_l = 1$ . While the buyer is incompletely informed about  $X$ ,  $X$  is common knowledge among the suppliers.

Using a descending reverse auction, the buyer selects one supplier to complete the project. Descending reverse auctions are the equivalent of ascending auctions that are commonly used to sell goods. By Myerson's (1981) revenue equivalence theorem, our theoretical results extend to a large range of auction mechanisms. In our theoretical exposition and in our experimental design, we use the descending format for the following reasons. First of all, descending auctions are commonly used in procurement (Elmaghraby, 2007). Second, they are 'credible' mechanisms in the sense that the auctioneer cannot deviate from the rules without at least one bidder detecting the deviation (Akbarpour and Li, 2020). Third, they are strategically straightforward in that for suppliers, it is a weakly dominant strategy to bid value, regardless of risk attitude, in contrast to most other auction formats. In fact, such auctions are 'obviously strategy proof' in the sense of Li (2017), which is supported by ample experimental evidence on the ascending auction (see Li, 2017, and the references cited therein). Kagel et al. (1987) and Li (2017) find that, in the ascending auction, the auction outcome converges quickly to the outcome resulting from the weakly dominant strategy of exiting the auction at a price equal to value. Moreover, deviations are not systematic (no systematic overbidding or underbidding is observed). Breitmoser and Schweighofer-Kodritsch (2021), using data from Li (2017) and their own experiment, find that the mean absolute deviations of bids from values is less than 2% of the price range after a very short learning period. This suggests that the descending reverse auction is strategically easy to grasp for experimental participants, which minimizes the noise caused by suppliers' learning how to bid in the auction allowing us to focus in the analysis of the experimental data on the effect of communication between the suppliers and the buyer.

If the winning supplier completes the project at location  $x$  for price  $p$ , the buyer's utility equals  $U_0(X, x, p) = v_0(X, x) - p$  where  $v_0(X, x)$  is the project's value when built at location  $x$  while the most valuable location is  $X$ . We assume that the buyer's utility is single peaked with a maximum at  $x = X$ , i.e.,

$$\begin{aligned} v_0(X, x_l) &> v_0(X, x_{l-1}) \text{ for } l \geq 2: x_l \leq X \\ v_0(X, x_l) &> v_0(X, x_{l+1}) \text{ for } l \leq L-1: x_l \geq X \end{aligned}$$

Additionally, we assume that the buyer's utility is symmetric around  $X$ , i.e.,  $|X - x| = |X - y| \Rightarrow v_0(X, x) = v_0(X, y)$  for all  $x, y \in \{x_1, x_2, \dots, x_L\}$ . Supplier  $i$ 's utility equals

$$U_i(X, x, p) = \begin{cases} p - t_i f(|X - x|) & \text{if supplier } i \text{ wins} \\ 0 & \text{otherwise} \end{cases}$$

where  $t_i$  represents supplier  $i$ 's 'travel costs.' The factor  $f(|X - x|)$ , common for all suppliers, depends on how far the chosen location deviates from the most valuable location.  $f(\cdot)$  is a



monotonic function, with  $f(d) > 0$  for each distance  $d \geq 0$ . Before the procurement auction, each supplier  $i$  is privately informed about his travel costs  $t_i$ . We assume that the suppliers' travel costs  $\{t_1, t_2, \dots, t_N\}$  are i.i.d. drawn from the same smooth distribution function  $F$  that has all its mass on the interval  $[\underline{t}, \bar{t}]$  where  $0 \leq \underline{t} < \bar{t}$ . We will let  $t^{(k)}$  denote the  $k$ -th (highest) order statistic from  $N$  draws from  $F$ .

We make the following technical assumptions on the parameters.

**Assumption A1**  $\max_{x \in \{x_1, x_2, \dots, x_L\}} \sum_l p_l v_0(x_l, x)$  has a unique solution  $x^*$ .

**Assumption A2**  $\sum_l p_l v_0(x_l, x^*) \geq \sum_l p_l f(|x_l - x^*|) E\{t^{(N-1)}\}$

Under Assumption A1, without further information about  $X$ , the buyer strictly prefers to locate the project at  $x = x^*$ . Assumption A2 ensures that the buyer's expected payoffs are non-negative in equilibrium.

We study the following three mechanisms:

**No-communication mechanism:** The mechanism is a two-stage game with the following stages:

1. The buyer picks a project from the set  $\{x_1, x_2, \dots, x_L\}$
2. The buyer auctions the project in a descending reverse auction

The no-communication mechanism models procurement auctions in which bidders can only communicate through the auction.

**Ex-ante mechanism:** The mechanism is a three-stage game with the following stages:

1. All suppliers send a message to the buyer from the set  $\{x_1, x_2, \dots, x_L, \emptyset\}$
2. The buyer picks a project from the set  $\{x_1, x_2, \dots, x_L\}$
3. The buyer auctions the project in a descending reverse auction

The ex-ante mechanism models important features of request-of-information rounds in the private sector and the 'competitive dialogue,' used in European public procurement.

**Ex-post mechanism:** The mechanism is a three-stage game with the following stages:

1. The buyer auctions an abstract project in a descending reverse auction
2. The winning supplier sends a message to the buyer from the set  $\{x_1, x_2, \dots, x_L, \emptyset\}$
3. The buyer picks the project from the set  $\{x_1, x_2, \dots, x_L\}$

The ex-post mechanism models important features of after-auction communication, used, for example, in the 'negotiated procedure' in European public procurement.

Cheap-talk games typically have many equilibria, including a 'babbling equilibrium' in which the winning supplier does not reveal any information about  $X$ . We say that a supplier plays a 'babbling strategy' in the message stage if his message strategy does not depend on  $X$ . Examples of a babbling strategy include mixing uniformly over the set  $\{x_1, x_2, \dots, x_L\}$  and always sending the

message  $\emptyset$  independently of  $X$ . We will use Farrell's (1993) neologism-proofness for sender-receiver games to weed out equilibria. Farrell (1993) assumes that the sender can send 'neologisms,' i.e., out-of-equilibrium messages that literally mean "my type is in set  $S$ ". A neologism is 'credible' if and only if all sender types in  $S$  prefer the receiver's best response  $b$  to the sender type being in  $S$  over the receiver's equilibrium action  $a$ , and all types not in  $S$  prefer  $a$  over  $b$ . An equilibrium is neologism proof if and only if it does not admit to a credible neologism. Notice that neologism proofness is defined for a single-sender environment. In the ex-ante mechanism, there are multiple senders. We extend neologism proofness in a natural way to multiple senders by checking whether coalitions of senders can send credible neologisms. We label an equilibrium group neologism proof if and only if no coalition of senders exists that can send a credible neologism. An interpretation of a neologism proof equilibrium in the case of multiple senders is that it is impossible for coalitions of senders to (tacitly) collude by sending a credible neologism. In the case of multiple (group) neologism proof equilibria, we focus our analysis on the most informative neologism-proof equilibrium. The most informative equilibrium is the equilibrium in which the buyer can deduce the highest amount of information regarding  $X$ .

We first derive equilibrium behavior for the no-communication mechanism as that serves as a benchmark for the 'informativeness' of the ex-ante and ex-post mechanisms.<sup>3</sup>

**Proposition 1.** *The no-communication mechanism has a unique perfect Bayesian Nash equilibrium in weakly dominant strategies in which the buyer chooses location  $x^*$  and where each supplier  $i$  bids (i.e., quits the auction at the price of)  $t_i f(|X - x^*|)$ .*

For the suppliers, it is a weakly dominant strategy to remain in the auction up to the point that the price reaches their costs. As a result, the most cost-efficient supplier wins and is paid the lowest costs among his competitors. The buyer has no reason to deviate to projects other than  $x = x^*$  because, according to Assumption A1, this will decrease her expected utility.

We study the ex-ante and the ex-post mechanisms in settings where the buyer's and the winning supplier's preferences regarding the location are aligned or misaligned. In the aligned-interest setting, the suppliers' costs are increasing in the distance to the buyer's most preferred location  $X$ , i.e.,  $f(d)$  is increasing in  $d$ . It turns out that in the aligned-interest setting, the buyer will not benefit from the message stage in the ex-ante mechanism.

**Proposition 2.** *In the aligned-interest setting, the ex-ante mechanism has a perfect Bayesian Nash equilibrium in which all suppliers play a babbling strategy, the buyer chooses location  $x^*$  regardless of the messages the suppliers send, and each supplier  $i$  bids  $t_i f(|X - x^*|)$ . This equilibrium is*

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<sup>3</sup> Proofs of propositions are in Appendix A.

*neologism proof. No (group) neologism-proof perfect Bayesian Nash equilibrium exists in which the buyer can deduce useful information from the suppliers' messages.*

Intuitively, the winning supplier's payoff equals the difference between the runner-up's costs and his own costs. Therefore, he prefers to *maximize* the cost differences between the suppliers, which he does when the buyer locates as far away as possible from his most valuable location. In turn, suppliers have an incentive to hide information about  $X$ . Notice that the ex-ante mechanism has equilibria in which the suppliers do reveal information about  $X$ : It is readily verified that an equilibrium exists where all suppliers send the message  $X$ . Neologism proofness weeds out this equilibrium because the suppliers are jointly better off using a babbling strategy.

In the aligned-interest setting, the ex-post mechanism has an equilibrium in which the winner reveals information. After winning the project, a supplier has good reason to reveal the most valuable location because doing so will minimize his costs if the buyer acts upon it.

**Proposition 3.** *In the aligned-interest setting, the ex-post mechanism has a perfect Bayesian Nash equilibrium in which each supplier  $i$  bids  $t_i f(0)$ , the winning supplier sends message  $X$ , and the buyer chooses location  $X$ . This equilibrium is neologism proof.*

Now, we compare the mechanisms in terms of expected profits. Clearly, the supplier's expected equilibrium payoffs are the same in the no-communication mechanism and the ex-ante mechanism. The ex-post mechanism outperforms the no-communication mechanism and the ex-ante mechanism in terms of buyer profits because (1) the ex-post mechanism always implements the most valuable project, in contrast to the other mechanisms, and (2) the buyer pays less to the winning supplier. Let  $\pi_{no}$ ,  $\pi_{ex\ ante}$ , and  $\pi_{ex\ post}$  denote the buyer's expected profits in the ex-post mechanism, in the ex-ante mechanism, and in the no-communication mechanism respectively.

**Proposition 4.** *In the aligned-interest setting,  $\pi_{ex\ post} > \pi_{ex\ ante} = \pi_{no}$ .*

We now turn to settings where  $f(\cdot)$  is decreasing, i.e., where the buyer and the winning supplier's interests regarding the location are misaligned. This assumption is in line with what is commonly assumed in models with vertical product differentiation (e.g., Herweg and Schwarz, 2018) that the most efficient supplier's cost advantage is increasing in product quality. In such settings, under some conditions, the ex-ante mechanism has a truthful equilibrium, i.e., a perfect Bayesian Nash equilibrium in which all suppliers reveal the most valuable location to the buyer:

**Proposition 5.** *Consider the misaligned-interest setting. If  $v_0(X, X) - v_0(X, x) \geq (f(0) - f(|X - x|))E\{t^{(N-1)}\}$ , for all  $X, x \in \{x_1, x_2, \dots, x_L\}$ , the ex-ante mechanism has a perfect Bayesian Nash equilibrium in which all suppliers send message  $X$ , the buyer chooses location  $X$ , and each supplier  $i$  bids  $f(0)t_i$ . This equilibrium is group neologism proof.*

The suppliers have an incentive to reveal the most valuable location to the buyer despite the fact that this maximizes their costs is that at that location because the costs *differences*, and hence the auction winner's equilibrium payoffs (which is the difference between the runner up's costs and her own costs), are maximized too. The condition  $v_0(X, X) - v_0(X, x) \geq (f(0) - f(|X - x|))E\{t^{(N-1)}\}$  expresses that the buyer's increased value for location  $X$  over another location  $x$  (the left-hand side of the inequality) should exceed the increased costs (the right-hand side). If this condition fails to hold for some  $X, x \in \{x_1, x_2, \dots, x_L\}, X \neq x$ , the buyer is strictly better off by choosing location  $x$  instead of location  $X$  so that the equilibrium displayed in the proposition does not exist. Under the experimental parameters, the condition holds true.

In the case of misaligned interests regarding the location, the winner has no reason to reveal the most valuable location to the buyer. A babbling equilibrium emerges. As a result, the ex-ante mechanism has the same equilibrium outcome as the no-communication mechanism.

**Proposition 6.** *In the misaligned-interest setting, the ex-post mechanism has a perfect Bayesian Nash equilibrium in which supplier  $i$  bids  $f(|X - x^*|)t_i$ , the winning supplier plays a babbling strategy, and the buyer chooses location  $x^*$  regardless of the message sent. This equilibrium is neologism proof. No neologism-proof perfect Bayesian Nash equilibrium exists in which the buyer can deduce useful information from the winning supplier's message.*

The ex-ante mechanism outperforms the no-communication mechanism and the ex-post mechanism under the conditions displayed in Proposition 7.

**Proposition 7.** *Consider the misaligned-interest setting. If  $v_0(X, X) - v_0(X, x) > (f(0) - f(|X - x|))E\{t^{(N-1)}\}$  for all  $X, x \in \{x_1, x_2, \dots, x_L\}, X \neq x$ ,  $\pi_{ex\ ante} > \pi_{ex\ post} = \pi_{no}$ . If  $v_0(X, X) - v_0(X, x) \leq (f(0) - f(|X - x|))E\{t^{(N-1)}\}$  for all  $X, x \in \{x_1, x_2, \dots, x_L\}$ ,  $\pi_{ex\ ante} = \pi_{ex\ post} = \pi_{no}$ .*

From Proposition 7, it becomes clear that allowing for ex-ante communication need not be universally beneficial for the buyer. More precisely, there is a trade-off between the benefits from ex-ante communication in terms of choosing the most valuable location (the left-hand side of the inequality) and the costs of decreased competition yielding higher expected costs for the buyer (the right-hand side). As  $E\{t^{(N-1)}\}$  is decreasing in  $N$ , the conditions for ex-ante communication to be beneficial are relaxed. So, ex-ante communication is particularly useful for the buyer in competitive settings. Similarly, ex-ante communication is more attractive for the buyer, (1) the more she cares about getting the location right, i.e., the greater the difference between  $v_0(X, X)$  and  $v_0(X, x)$ , and (2) the lower the suppliers' cost differences across locations, i.e., the lower the difference between  $f(x)$  and  $f(|X|)$ . For the experiment, we choose parameters such that equilibria exist in which the buyer benefits from allowing for ex-ante communication.

Table 1 presents, for both settings, the equilibrium outcome under each communication mechanism, and which mechanism maximizes the expected buyer's payoff.

**Table 1.** Summary of the Predicted Results of Different Communication Mechanisms

Setting	Communication mechanism	Suppliers' recommendation	Buyer's choice	Best communication mechanism (for buyer) for each setting
Aligned interests	No communication	-	0	√
	Ex ante	Babbling/ $\emptyset$	0	
	Ex post	"X"	X	
Misaligned interests	No communication	-	0	√
	Ex ante	"X"	X	
	Ex post	Babbling/ $\emptyset$	0	

### 3. Experimental design and hypotheses

#### 3.1. Procedures and parameters

We ran the experiments at the Lingnan College of Sun Yat-Sen University in Guangzhou, China. Using public announcements, we recruited 160 students from the undergraduate population of the college who participated in seven sessions. Including a 16 RMB show-up fee, subjects earned an average income of 104.6 RMB. Each session lasted between 110 and 140 minutes. Online appendix B contains an English translation of the experimental instructions.

In each of the 40 rounds of a session, participants are randomly assigned into groups of four. For statistical reasons, participants interacted within the same group throughout the experiment (no rematching; see Goeree and Offerman, 2002, 2004, for a similar approach in an auction setting). Additionally, interaction with the same group facilitates suppliers to coordinate on a group neologism-proof equilibrium in the ex-ante mechanism, which is based on the assumption that coalitions of senders cannot send credible neologisms (see Section 2). Of course, repeated interaction may give rise to collusion and reputation effects ignored by the theory, which is based on one-shot interaction. In experimental practice, collusion in auctions is rarely observed among groups of three or more players, unless the bidders are allowed to communicate before the auction (see, e.g., Hu et al., 2011, and Hinloopen et al., 2020) or in dynamic non-binding reverse auctions (Fugger et al., 2016). To minimize opportunities for collusion and reputation building, we did not label the suppliers, which made it impossible for subjects to track individual behavior history, thus very hard for them to collude or to build a reputation for telling the truth about the buyer's most valuable location. Participants in our experiment tended to fail to collude or build a reputation in that (1) on average, suppliers do not earn more than in the one-shot equilibrium and (2) buyers do not improve in terms of distilling information from the cheap-talk messages over time. Details are in Appendix C.

One member of each group is randomly assigned the role of buyer throughout the whole session. The buyer's value for the project equals  $v_0(X, x) = v_0 - t_0|X - x|$ . The other three group members are suppliers who compete in auctions to complete a project on behalf of the buyer. In every round, each supplier  $i$ 's travel costs  $t_i$  is drawn from a uniform distribution on the set  $\{\underline{t}, \underline{t} + 1, \dots, \bar{t} - 1, \bar{t}\}$ , independently of the travel costs of the other suppliers, the most valuable location, and the draws in other rounds. We kept draws constant across treatments for the sake of comparability of the results. The project has three potential locations,  $-1, x^* \equiv 0$ , and  $1$ , which are relabeled Left, Middle, and Right respectively in the instructions. Project costs and earnings are in experimental points (pt), with an exchange rate of  $30 \text{ pt} = 1 \text{ RMB}$  (about  $\$0.14$  when the experiment was conducted) for the buyer and  $1 \text{ pt} = 1 \text{ RMB}$  for the suppliers. At the end of the experiment, 15 out of 40 rounds are randomly selected for payment. Potential losses are subtracted from a participant's starting capital, as is common in auction experiments.

The supplier that completes the project is selected in a descending reverse auction. The price starts at the reserve price  $p_{max}$ , which is set at the highest possible cost for the project, i.e.,  $p_{max} = 3\bar{t}$ . The price is decreased successively with discrete steps of 1 point per  $1/3$  second. Using such a clock auction design may avoid 'irrational' bidding behavior such as jump bidding caused by suppliers' impatience (Elmaghraby et al., 2012). Suppliers can indicate at any price that they wish to quit. The auction stops as soon as all but one supplier has quit the auction. Ties are resolved randomly. The remaining supplier wins the project and receives the final price.

We consider two experimental settings.

**Setting Aligned Interests (ALIGN)**  $f(d) = 1 + d$  (i.e., the suppliers' costs are increasing with the project's distance from the most valuable location; *ceteris paribus*, the suppliers prefer the same location as the buyer)

**Setting Mis-Aligned Interests (MISAL)**:  $f(d) = 3 - d$  (i.e., the suppliers' costs are decreasing with the project's distance from the most valuable location; *ceteris paribus*, the suppliers prefer to be as far away from the buyer's most valuable location as possible)

**Table 2.** Experimental Design and Parameters

Treatment	#groups	Setting	Communication	$v_0$	$t_0$	$\underline{t}$	$\bar{t}$	$p_{max}$
ALIGN_ante	10	ALIGN	Before the auction	260	60	10	60	180
ALIGN_post	10	ALIGN	After the auction	260	60	10	60	180
MISAL_ante	10	MISAL	Before the auction	300	120	10	40	120
MISAL_post	10	MISAL	After the auction	300	120	10	40	120

To compare the performance of the various mechanisms, we use a 2x2 between-subjects experimental design in which we vary the mechanism (ex ante or ex post) and the setting (ALIGN and MISAL). At the start of the experiment, suppliers and buyers were informed about the setting

in which they would interact. The experimental parameters are chosen such that theoretically, the ex-post and ex-ante mechanisms differ substantially in terms of expected buyer profits so that the experiment is likely to identify effects if they exist. We also made sure that the suppliers' expected total payoffs from auctions are similar across the settings ALIGN and MISAL under both the ex-ante mechanism (107 and 101 points, respectively) and the ex-post mechanism (82 and 86 points, respectively). Table 2 summarizes the experimental design, including the number of observations per cell and the parameters used in the experiment.

Each session consists of three parts. In part 1, the project is auctioned for all 9 possible combinations of the most valuable location and the actual location. The buyer is passive in this part in that she cannot choose the location. However, she does get information on the outcomes of the auction. Part 2 consists of 7 rounds in which the suppliers and the buyer interact in the no-communication mechanism. The main purpose of parts 1 and 2 is to let the suppliers get acquainted with the auction format, so that the buyer learns how suppliers' payoffs may vary as the project's location departs away from the most valuable location, hence how the suppliers may be willing to share with her where the most valuable location is. The data collected in part 2 under the no-communication mechanism also serve as a benchmark for the 'informativeness' of the ex-ante and ex-post mechanisms. Part 3 consists of 24 rounds. In all these rounds, the auctions are conducted under either only the ex-ante mechanism or only the ex-post mechanism, depending on the treatment.

In the message stage, each of the suppliers (in the ex-ante mechanism) or the winning supplier (in the ex-post mechanism) is asked to send a message from the set {Left, Middle, Right, No Recommendation} to the buyer. Equilibrium requires a common understanding of the meaning of messages. We use the term 'recommendation' instead of 'message' in the experiment because we believe the former makes the interpretation of messages easier for the participants so that their behavior is more likely to converge to equilibrium. While three messages would suffice for any equilibrium to emerge, we added the option "no recommendation" so that the suppliers do not have to lie about what is the most valuable location if they wish to coordinate on a babbling equilibrium. Previous experiments have revealed that experimental participants are reluctant to lying, which may result in overcommunication compared to the equilibrium predictions (see Sánchez-Pagés and Vorsatz, 2007, 2009, for evidence from cheap-talk games). After each round, both the buyer and the suppliers are informed about (1) the most valuable location, (2) the actual location choice, (3) the suppliers' recommendations (in part 3 only), (4) the payoffs of the buyer, and (5) the winning supplier's costs, bid, and payoffs.

### 3.2. Hypotheses

We present our hypotheses in light of the equilibrium predictions in Section 3.1 and summarized in Table 3 for the experimental parameters. Regarding information transmission, we derive the following hypothesis for setting ALIGN:

**Hypothesis 1ALIGN.** *In setting ALIGN, (a) the buyer's average profits under the ex-post mechanism are greater than under the no-communication mechanism; (b) the buyer's average profits are the same under the ex-ante mechanism and the no-communication mechanism; (c) the buyer's average profits under the ex-post mechanism are greater than under the ex-ante mechanism.*

**Table 3.** Theoretical Predictions

Setting	Communication mechanism	Suppliers' recommendation	Buyer's choice	Buyer's expected payoffs (in pt; 30 pt = 1 RMB)	Supplier's expected payoffs (in pt; 1 pt = 1 RMB)
ALIGN	No communication	-	Middle	162	6.94
	Ex ante	Babbling/ $\emptyset$	Middle	162	6.94
	Ex post	"X"	X	225	4.17
MISAL	No communication	-	Middle	162	5.83
	Ex ante	"X"	X	225	7.50
	Ex post	Babbling/ $\emptyset$	Middle	162	5.83

Comparing the expected buyer's payoffs yields the following hypothesis for setting ALIGN:

**Hypothesis 2ALIGN.** *In setting ALIGN, (a) the suppliers do not reveal information about the project's most valuable location under the ex-ante mechanism; (b) the winning supplier reveals information about the project's most valuable location under the ex-post mechanism; (c) the location recommendations under the ex-post mechanism are more informative than under the ex-ante mechanism.*

Analogously, we have the following two hypotheses for MISAL:

**Hypothesis 1MISAL.** *In setting MISAL, (a) the buyer's average profits under the ex-post mechanism and under the no-communication mechanism are the same; (b) the buyer's average profits under the ex-ante mechanism are greater than under the no-communication mechanism; (c) the buyer's average profits under the ex-ante mechanism are greater than under the ex-post mechanism.*

**Hypothesis 2MISAL.** *In setting MISAL, (a) the suppliers reveal information about the project's most valuable location under the ex-ante mechanism; (b) the winning supplier does not reveal information about the project's most valuable location under the ex-post mechanism; (c) the location recommendations are more informative in the ex-ante mechanism than under the ex-post mechanism.*



## 4. Results

We present our results in five parts. In Sections 4.1 and 4.2, we study the mechanisms' performance in terms of buyer payoffs, and the suppliers' communication strategies respectively. In Sections 4.3–4.5, we explore why the data are inconsistent with some of our hypotheses examining learning, the mechanism's complexity, and the quantal response equilibrium, respectively. Throughout Section 4, we use two-sided tests in our statistical analysis. Unless otherwise indicated, we take the matching group average as a unit of observation in our statistical tests. The comparison between the ex-ante mechanism and the ex-post mechanism is between subjects across ALIGN and MISAL respectively. We compare the ex-ante and the ex-post mechanisms with the no-communication mechanism within subjects.

### 4.1. Buyer payoffs across mechanisms

Table 4 presents the average buyer payoffs in each treatment. In the ALIGN setting, the data show strong support for Hypothesis 1ALIGN. In ALIGN\_post, the average buyer payoffs under the ex-post mechanism are significantly higher than under the no-communication mechanism (217.71 vs. 145.73;  $p < 0.001$ ,  $t$  test). In ALIGN\_ante, average buyer payoffs do not significantly differ between the ex-ante mechanism and the no-communication mechanism (157.95 vs. 149.96;  $p = 0.378$ ,  $t$  test). Moreover, under the ex-post mechanism, buyers' average payoffs are higher than under the ex-ante mechanisms (217.71 vs. 157.95;  $p < 0.001$ ,  $t$  test). All these experimental observations strongly support Hypotheses 1ALIGN(a)–(c).

**Table 4.** Buyers' Average Payoffs

	ALIGN		MISAL	
	Ex Ante	Ex Post	Ex Ante	Ex Post
Pre-play Stage	141.69	139.38	137.3	139.68
(Part 1)	(7.968)	(7.724)	(7.527)	(7.708)
No Communication	149.96	145.73	160.96	142.67
(Part 2)	(6.230)	(8.566)	(6.134)	(7.547)
Communication	157.95	217.71	151.57	145.02
(Part 3)	(4.541)	(1.595)	(4.234)	(4.591)

Note: Standard errors in parentheses

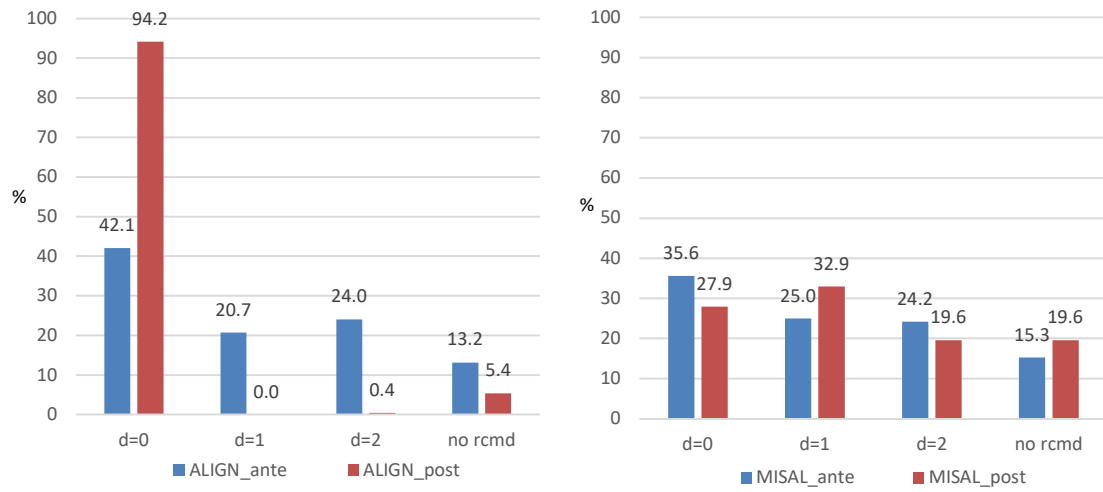
However, Hypothesis 1MISAL is not fully supported by the data. In line with Hypothesis 1MISAL(a), in MISAL\_ante, average buyer payoffs do not differ significantly between the ex-ante mechanism and the ex-post mechanism (151.57 vs. 160.96;  $p = 0.309$ ,  $t$  test). We find the buyers earn higher payoffs under the ex-ante mechanism than under the ex-post mechanism, which is qualitatively in line with the prediction, nevertheless, the difference is insignificant (151.57 vs. 145.02;  $p = 0.295$ ,  $t$  test). Moreover, in MISAL\_ante, the buyer's average payoffs under the ex-post

mechanism (part 3) are not significantly different from that under the no-communication mechanism (part 2) (145.02 vs. 142.67;  $p=0.974$ ,  $t$  test).

#### 4.2. Suppliers' communication strategies

To study suppliers' communication strategies and to test the related Hypotheses 2ALIGN and 2MISAL, we look at variable  $d \in \{0, 1, 2\}$  measuring the distance between the recommended location and the most valuable location:  $d > 0$  means a supplier tries to mislead the buyer to deviate from the most valuable location; As  $d = 0$  can be both a truthful recommendation and be part of a babbling strategy, the fraction of  $d = 0$  is an upper bound of the incidence of truth-telling.

**Figure 1.** Histogram of Recommendation's Deviation from the Most Valuable Location



Note: The right-most bars denote the fraction of suppliers who chose “no recommendation.”

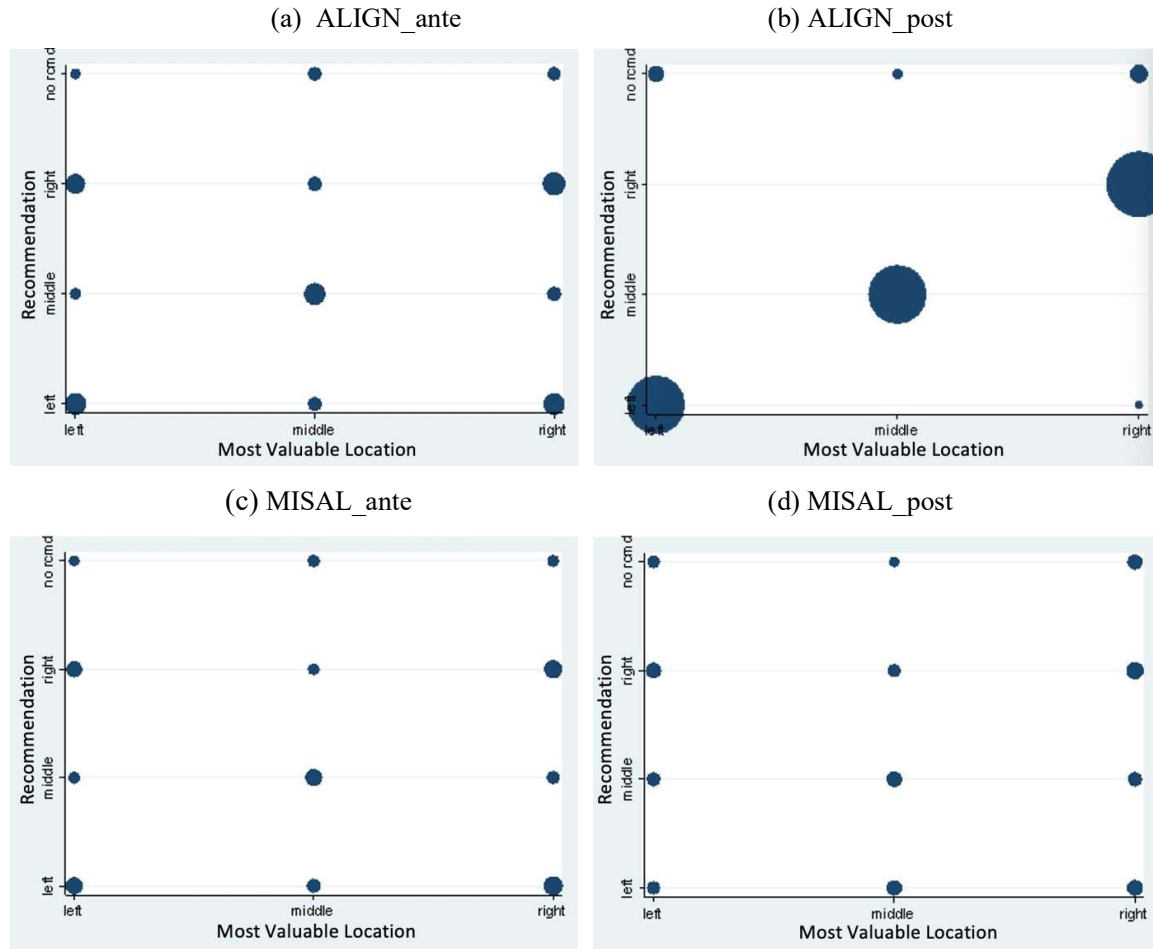
Figure 1 provides the suppliers' recommendation deviations in each treatment. The left panel for the ALIGN setting shows that in ALIGN\_ante, 42.1% of the suppliers recommended the most valuable location. The majority did not, however: 44.7% chose to recommend a location that deviates from the most valuable one, and the remaining 13.2% chose “no recommendation.” Among the suppliers who did send a recommendation (excluding the “no recommendation” ones), the distribution of the recommendations is not significantly different from the uniform distribution ( $p=0.707$ , Kolmogorov-Smirnov test). These results suggest that suppliers do not reveal the most valuable location to the buyer, which supports Hypothesis 2ALIGN(a).

In ALIGN\_post, the vast majority (94.2%) of the winning suppliers, who had opportunities to make recommendations, truthfully recommended the most valuable location to the buyer, while only 5.4% chose not to give a recommendation and 0.4% misled (Figure 2b) the buyer. This strongly supports Hypothesis 2ALIGN(b). Additionally, consistent with Hypothesis 2ALIGN(c), we find that the suppliers recommend the most valuable location more frequently in

the ex-post mechanism than in the ex-ante mechanism (94.2% vs. 42.1%;  $p < 0.001$ , Mann Whitney U test).

Regarding suppliers' recommending strategies at the individual level, the recommendations in Treatment ALIGN\_ante (Figure 2a) do not exhibit any tendency to follow the most valuable location, which is in line with the predicted babbling equilibrium. This noncorrelation is also supported by a regression (Table 5), suggesting that the recommendations do not contain valuable information at large.

**Figure 2.** Suppliers' Communication Strategies



*Notes:* Scatter plots of suppliers' recommendations (vertical axis) conditional on the most valuable location (horizontal axis) in each treatment. "No rcmd" refers to suppliers who chose "no recommendation". The sizes of the dots are determined by the number of observations taking the respective (most valuable location, recommended location) values.

In Setting MISAL, the suppliers hardly revealed any information, as shown in Figure 1, right panel. In the *ex-ante mechanism*, in 35.6% of the cases, suppliers recommended the most valuable location, in another 49.1% of the cases, suppliers chose to mislead the buyer, with the rest 15.3% of the cases with no recommendation. Although the truthful recommendations are the mode

among all the recommendation choices, much less information is revealed than in the predicted fully informative communication. In the *ex-post* mechanism, only 27.9% of the winning suppliers recommended the most valuable location. The majority (52.5%) of recommendations deviate from the most valuable location, with another 19.6% of the winning suppliers choosing “no recommendation.” The distributions of all the recommendations under both mechanisms are not distinguishable from babbling, i.e. the uniform distribution ( $p=0.167$  for the *ex-ante* mechanism, and  $p=1.000$  for the *ex-post* mechanism, Kolmogorov-Smirnov test). These findings support Hypothesis 2MISAL(b) but not Hypothesis 2MISAL(a).

**Table 5.** Regressions of Supplier’s Recommended Location on the Most Valuable Location

	ALIGN_ante (1)	ALIGN_post (2)	MISAL_ante (3)	MISAL_post (4)
Most valuable location	0.077 (0.096)	0.988*** (0.012)	0.010 (0.057)	-0.017 (0.042)
Constant	-0.012 (0.042)	-0.008 (0.008)	-0.070* (0.032)	0.022 (0.060)
Observations	625	227	610	193
R-squared	0.006	0.975	0.000	0.000

Notes: Standard errors adjusted after clustering data by group in parameters. The observations from the suppliers who chose “no recommendation” are excluded. \*, \*\*, \*\*\* denotes significance at the 10%, 5% and 1% level, respectively.

Regarding the comparison of information transmission between the two communication mechanisms, we notice that the average recommendation’s deviation from the most valuable location in the *ex-ante* mechanism is lower than in the *ex-post* mechanism (1.053 vs. 1.143) and that fewer subjects chose not to make recommendations (15.3% vs. 19.6%) under the ante mechanism. However, both differences are insignificant ( $p=0.201$  by the *t* test for the average deviation comparison, and  $p=0.131$  by the Fisher exact test for the comparison of the fraction of no recommendation), which suggests that in setting MISAL, the *ex-ante* mechanism does not induce significantly more informative recommendations than the *ex-post* mechanism, as in contrast to Hypothesis 2MISAL(c). The observed communication contains very little information under both mechanisms, although full communication is predicted under the *ex-ante* mechanism. Results from a series of regressions (Table 5) also convey the same message, that the recommendations are hardly correlated with the most valuable location in neither MISAL\_ante (column 3) nor MISAL\_post (column 4), as suggested by the nearly zero coefficients of the most valuable location.

#### 4.3 Learning

So far, we have observed that subjects’ behavior supports our theoretical predictions in 3 out of the 4 treatments, with the only exception in MISAL\_ante, in that we observe the babbling, instead

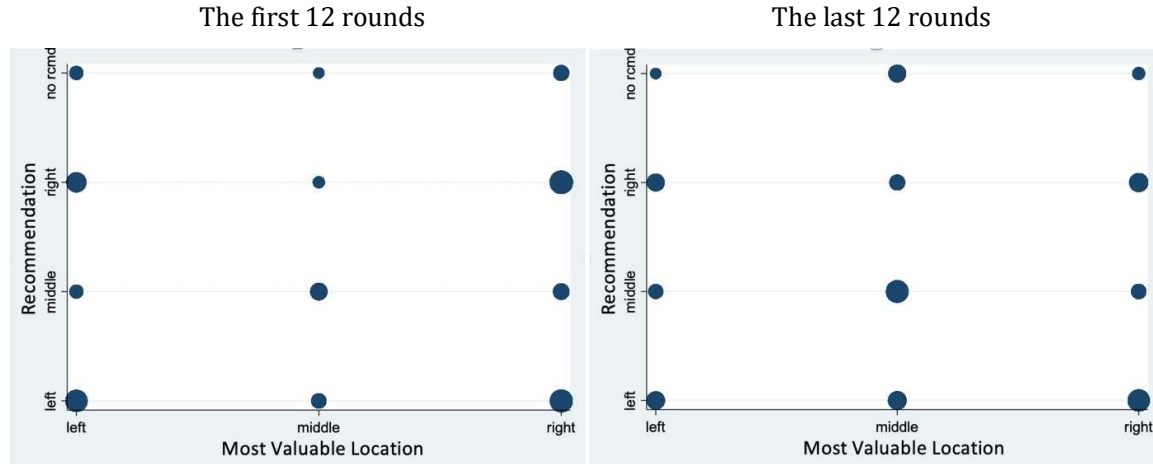
of the predicted fully informative, separating equilibrium. Such finding is in sharp contrast to the afore-mentioned vast existing experimental literature on cheap-talk games: existing literature suggests that deviation from the prediction in cheap-talk games are often characterized by overcommunication, while the deviation in our experiment is undercommunication. In the following, we first try to find out if the undercommunication is persistent in MISAL\_ante. In other words, did the participants learn to move toward a more informative equilibrium over time?

**Table 6.** Regressions of Supplier's Recommended Location in MISAL\_ante

	Recommended Location	Recommended Location
Most Valuable Location	0.0103 (0.0569)	-0.0539 (0.0523)
Most Valuable Location x Last 12 Rounds		0.115* (0.0552)
Constant	-0.0697* (0.032)	-0.0695* (0.033)
Observations	610	610
R-squared	0.000	0.003

Notes: Left, Middle and Right are replaced by -1, 0, and 1 respectively. The observations from the suppliers who chose "no recommendation" are excluded. 'Last 12 Rounds' is a dummy variable which indicates whether the observation is from the last 12 rounds. Values within parentheses below each estimate are the standard errors adjusted after clustering data by group. \*, \*\*, \*\*\* denotes significance at the 10%, 5% and 1% level, respectively.

**Figure 3.** Individual Suppliers' Recommendations in MISAL\_ante over time



Notes: Scatter plots of suppliers' recommendations (vertical axis) conditional on the most valuable location (horizontal axis) in treatment MISAL\_ante. "No rcmd" refers to suppliers who chose "no recommendation". The sizes of the dots are determined by the number of observations taking the respective (most valuable location, recommended location) values.

We first check whether suppliers' recommending strategies differ between the first and the last 12 rounds in MISAL\_ante, and if so, whether the change goes in the direction of the most informative separating equilibrium. Figure 3 does not show a clear difference between the first 12 rounds and the last 12 in terms of correlation between the recommended location and the most valuable location. In fact, not a single group of the suppliers in MISAL\_ante played the most informative neologism-proof equilibrium (see Figure D1 in Appendix D), according to which recommendations should always follow the most valuable location. We further run a regression

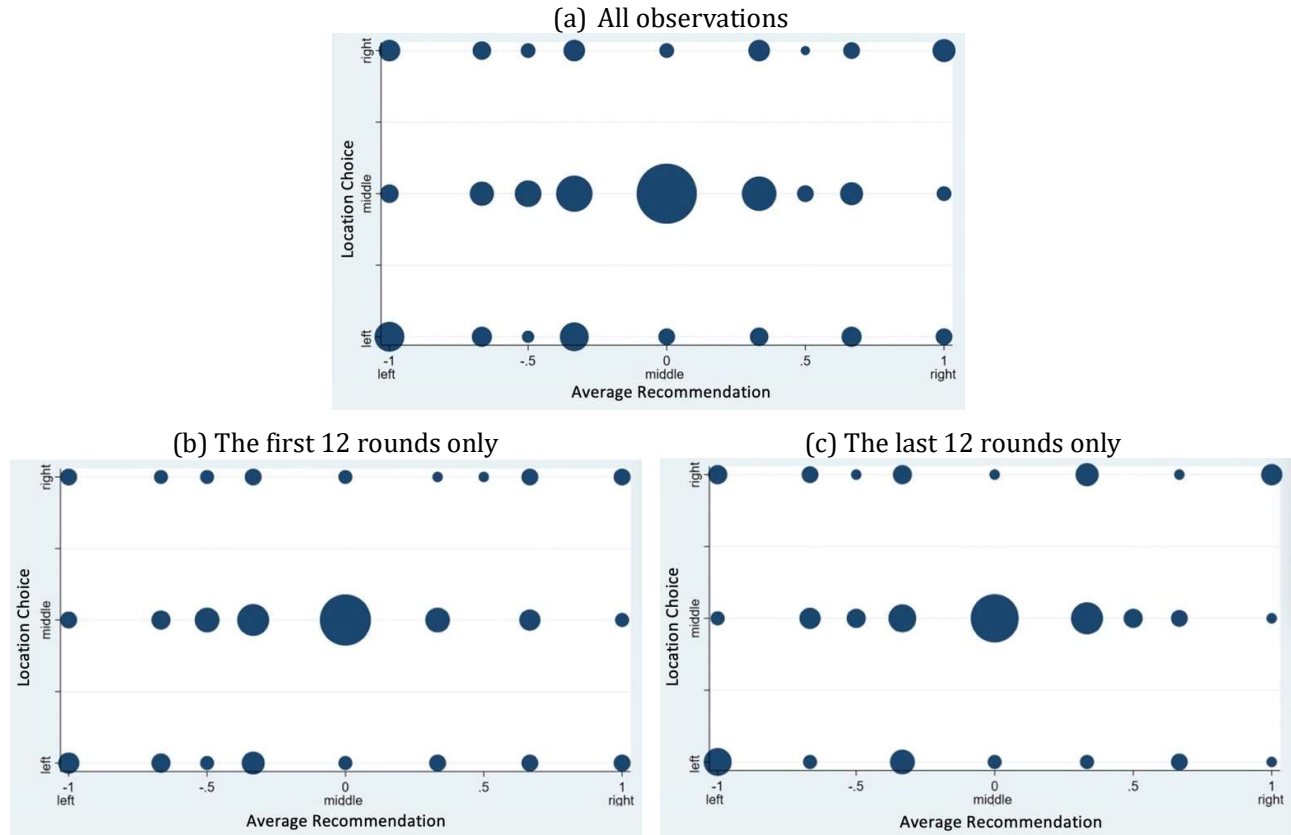
of the individual recommendation on the most valuable location with an interaction term between the most valuable location and a dummy variable indicating whether it is in the last 12 rounds. The results in Table 6 show no correlation between the recommendation and the most valuable location in the first 12 rounds. The interaction term is weakly significantly positive, which suggests a tendency for recommendations to reveal the most valuable location as suppliers gain more experiences. However, the significance and magnitude of the tendency is low, which coincides with the lack of a clear separating pattern throughout the 24 rounds of auctions.

Analysis of individual-level supplier behavior delivers a similar message. We categorize suppliers into three types according to their recommending strategies: Suppliers who recommend the buyer's most valuable location at least 75% of the rounds are labeled as *Mostly Truthful*; Suppliers who recommend another location at least 75% of the rounds are labeled *Mostly Lying*; All remaining suppliers are labeled *Babbling*. In MISAL\_ante, 17 (56.7%) of the 30 suppliers are of the *Babbling* type, 11 (36.7%) are *Mostly Lying*, and 2 (6.67%) are *Mostly Truthful*, which again echoes the babbling equilibrium. By categorizing each supplier twice, once according to their recommendations in the first 12 rounds and again according to their last 12 rounds' recommendations, we find that 18 (60%) of the suppliers' types remain the same across the two phases, 12 of whom are in *Babbling*. Among the rest, 5 (16.7%) suppliers switched from type *Babbling* to *Mostly Truthful*, 4 (13.3%) from *Babbling* to *Mostly Lying*, and 3 (10%) from *Mostly Lying* to *Babbling*. We conclude that there is no clear trend towards more truth telling, let alone towards a separating equilibrium.

Then, why did not participants manage to learn to play a more informative, and more profitable, equilibrium in MISAL\_ante? Theoretically, a babbling equilibrium is not 'stable' in the sense that it is not neologism proof: suppliers have an incentive to deviate and credibly signal the most valuable location to the buyer. Of course, sending out a neologism only works if the buyer understands the signal and acts upon it. So, how does the buyer respond to the various recommendations in MISAL\_ante? Figure 4 shows the scatter plots of each actual location choice and the corresponding average recommendation of the group. Here, we take the mean of each group's recommendations excluding those who choose "no recommendation" by taking values of -1, 0, 1 for Left, Middle, and Right. The majority of the buyers' choices are at Middle, as they should be to best respond to the suppliers' babbling recommendations. The remaining observations are roughly uniformly distributed over Left and Right. The regressions in Table 7 also reveal a very weak dependence of the location choice on recommendations. Specification (2) of the regression suggests that there is no significant change in the correlation between the location choice and the average recommendations after the first 12 rounds. Making analogous plots and regressions as shown in Figure 4 and Table 7, respectively, by replacing the average of recommended locations with the majority of recommendations (if there is one) in each group, we obtain qualitatively the

same results: the buyers do not follow recommendations and still randomize their location choices even when a majority recommendation exists.

**Figure 4.** Average of Recommended Locations and the Location Chosen by the Buyer



Notes: The sizes of the dots are determined by the number of observations taking the respective (most valuable location, recommended location) values.

**Table 7.** Regression of Location Choice on Average Group Recommendation in MISAL\_ante

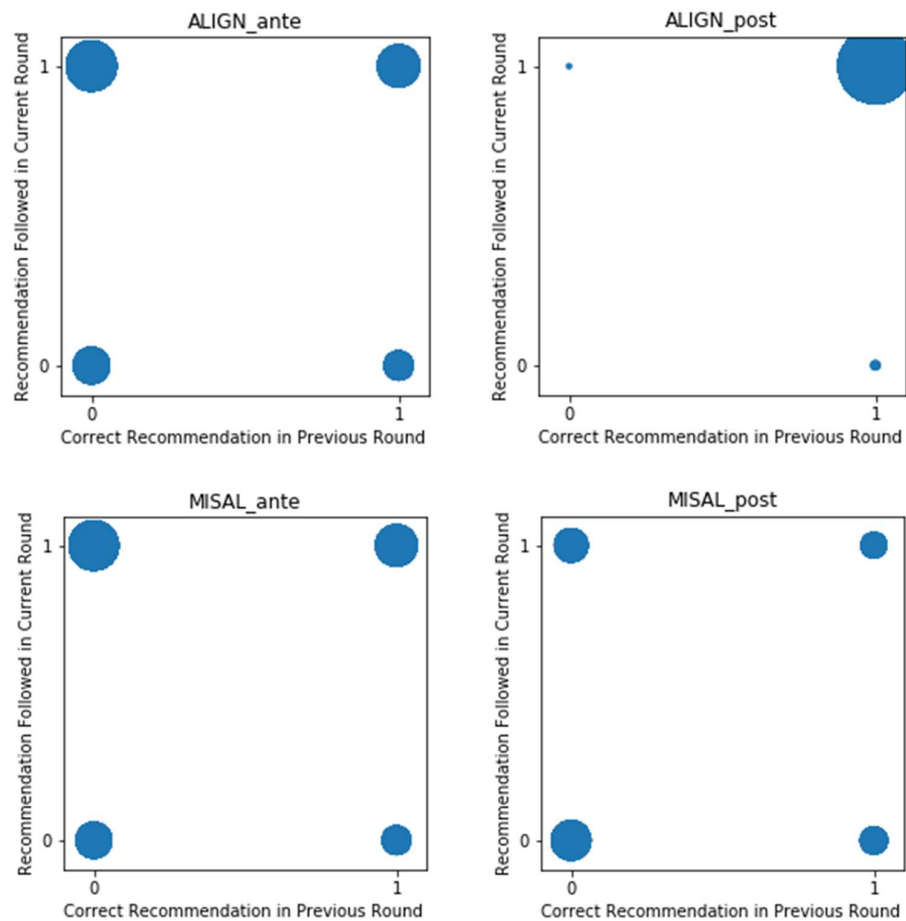
	Location choice (1)	Location choice (2)
Avg Rcnd	0.176 (0.142)	0.113 (0.147)
Avg Rcnd x Last 12 Rounds		0.125 (0.107)
Constant	-0.022 (0.055)	-0.022 (0.055)
Observations	239	239
R-squared	0.022	0.025

Notes: Left, Middle, and Right are replaced by -1, 0, and 1 respectively. 'Avg Rcnd' is the mean of each group's recommendations excluding those who choose "no recommendation." 'Last 12 Rounds' is a dummy variable which indicates whether the observation is from the last 12 rounds. Standard errors adjusted after clustering in parentheses. \*, \*\*, \*\*\* denotes significance at the 10%, 5% and 1% level, respectively.

Figure 5 shows how buyers respond to the suppliers' recommendations. At each round, the buyer is informed with the most preferred location in the feedback and learns whether or not the

suppliers were truthful. Do the learning patterns differ between the ex-ante mechanism, under which a buyer receives three messages from all three suppliers, and the ex-post mechanism, under which a buyer only receives one from the winning supplier? In Figure 5, we see that in ALIGN-post, the winning supplier almost always reveals the most valuable location to the buyer and the buyer almost always follows the supplier's recommendation. In the other treatments, the buyer's location choice tends to be independent of the suppliers' being truthful in the previous round, in line with a babbling equilibrium. In ALIGN, we see clear differences between ex-ante and ex-post mechanism in terms of buyer responses, as in contrast to MISAL.

**Figure 5.** Buyer Responses to Supplier (Average) Recommendations



*Notes:* Scatter plots of the suppliers' (average) recommendations (horizontal axis; truthful=1) in the previous round and whether or not the buyer follows the recommendation in the current round (vertical axis; yes=1).

Overall, the lack of information in the suppliers' recommendations and the weakly informative recommendation following of the buyers, seem to suggest that the buyer and the suppliers are best responding to each other's behavior in MISAL\_ante. As a result, they are indeed stably 'trapped' in the inefficient babbling equilibrium.



#### 4.4 Does It help to Reduce Complexity in Coordination?

In this subsection, we investigate whether the deviation in the MISAL\_ante treatment is due to a coordination problem, rooted in the complexity of the ex-ante mechanism in that, (1) the truthful equilibrium requires all the suppliers to coordinate on recommending the most valuable location and (2) weeding out other equilibria requires all suppliers to coordinate on sending a neologism. This coordination problem is non-existent in the other treatments: In ALIGN\_ante and MISAL\_post, the equilibrium is essentially unique so equilibrium coordination is irrelevant. In the ALIGN\_post treatment, only one (the winning) supplier needs to be truthful to make the information transmission successful. We have designed an additional treatment, MISAL\_ante\_1, to examine if a coordination problem is the reason why, in contrast to the other mechanisms, the suppliers fail to reach the most informative neologism-proof equilibrium in MISAL\_ante.

MISAL\_ante\_1 is the same as MISAL\_ante with the only difference that the recommendation of only one supplier, randomly selected, is communicated to the buyer before the auction stage. After receiving the single recommendation, the buyer makes the location choice and announces the decision publicly before the auction stage starts. We refer to the ex-ante mechanism where the buyer only receives a single recommendation as ‘the single-recommendation ex-ante mechanism’. While we run the additional treatment in an attempt to test if it is the coordination complexity among the suppliers that has caused the deviation of behavior in MISAL\_ante from the theoretical prediction, the single-recommendation ex-ante mechanism is not without practical relevance. This is essentially the mechanism played when it is commonly known that the buyer only gathers advice from a single supplier (e.g., the supplier contracted in the previous period). Moreover, the additional treatment allows us to address the question whether the buyer may benefit from requesting information ex ante from just one supplier rather than from all suppliers.

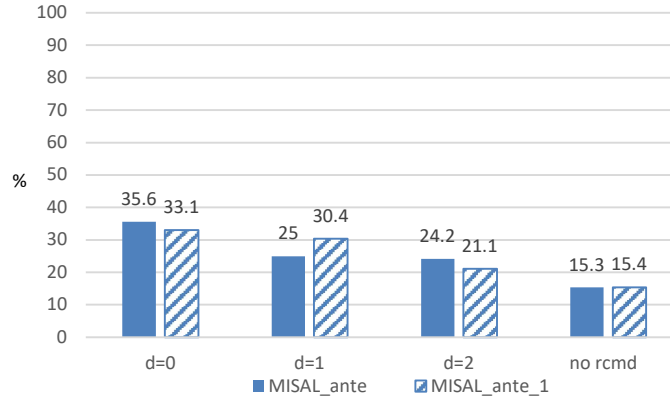
Comparing suppliers’ behavior between MISAL\_ante\_1 and MISAL\_ante enables us to test if the elimination of the strategic interaction among the suppliers in recommendation-making stage may induce more efficient information transmission in the MISAL setting when using pre-auction communication. It is readily verified that the single-recommendation ex-ante mechanism has a neologism-proof equilibrium in which suppliers send message  $X$ , the buyer chooses location  $X$ , and each supplier  $i$  bids  $f(0)t_i$ . Using the data collected for the MISAL\_ante mechanism, the data collected in the MISAL\_ante\_1 treatment allow us to test the following hypotheses:

**Hypothesis 3MISAL.** *In setting MISAL, the location recommendations are more informative in the single-recommendation ex-ante mechanism than in the all-recommendation ex-ante mechanism.*

**Hypothesis 4MISAL.** *In setting MISAL, the buyer’s average profits are greater in the single-recommendation ex-ante mechanism than in the all-recommendation ex-ante mechanism.*

We ran one session of Treatment MISAL\_ante\_1, at Sun Yat-sen University in September 2021, with 40 subjects recruited. The comparison of the new data with those from the MISAL\_ante suggests that the reduced complexity in the strategic interactions among suppliers does not induce a more efficient outcome. In fact, we find little support for hypotheses 3MISAL and 4MISAL. Figure 6. Distribution of the deviation of suppliers' recommendation from the most valuable location ( $d$ ), in MISAL\_ante and MISAL\_ante\_1.

**Figure 6.** Histogram of Recommendation's Deviation from the Most Valuable Location



Note: The right-most bars denote the fraction of suppliers who chose “no recommendation.”

**Table 8.** Regressions of Supplier's Recommended Location on the Most Valuable Location

	MISAL_ante_1	MISAL_ante
Most valuable location	0.064 (0.066)	0.010 (0.057)
Constant	-0.078** (0.027)	-0.070** (0.032)
Observations	609	610
R-squared	0.004	0.000

Notes: Standard errors adjusted after clustering data by group in parentheses. The observations from the suppliers who chose “no recommendation” are excluded. \*\* denotes significance at the 5% level.

Figure 6 displays the distribution of the suppliers' recommendation from the most valuable location (where  $d = |\text{recommended location} - \text{most valuable location}|$ ). In both MISAL\_ante\_1 and MISAL\_ante, in only about 1/3 of the cases do supplier send a truthful recommendation ( $d = 0$ ) and about 15% of the suppliers send the message ‘no recommendation’. The fraction of truthful recommendations in MISAL\_ante\_1 is lower than in MISAL\_ante, not higher. The regression results in Table 8 show that in both treatments, the estimated coefficient of the supplier's recommended location on the most valuable location is statistically insignificant, with a close to zero magnitude. Overall, suppliers do not provide more informative recommendations

in MISAL\_ante\_1 than in MISAL\_ante, so we do not find support for Hypothesis 3MISAL. Inconsistent with Hypothesis 4MISAL, buyers' average profit is lower, not higher, in the single-recommendation ex-ante mechanism than in the all-recommendation ex-ante mechanism (148.77 vs. 151.77).

The observations from MISAL\_ante\_1 imply that reducing the complexity of the communication stage does not help to resolve the failure to achieve informative communication in the ex-ante mechanism, suggesting that the buyers failing to achieve informative communication is not rooted in a coordination problem. More broadly, our observation that the buyer does not benefit from ex-ante communication turns out to be robust to the buyer only gathering advice from a single supplier.

#### *4.5 Quantal response equilibrium*

To what extent can the quantal-response equilibrium (QRE) explain the anomalous behavior that we observe in the ex-ante mechanism in the MISAL setting? The QRE is an equilibrium concept that relaxes the rationality assumption by assuming that players play noisy best responses to each other's strategies (McKelvey and Palfrey, 1995, 1998). In a QRE, the probability that a player chooses a particular strategy is greater the higher the strategy's payoff, assuming correct beliefs about other players' noisy strategies. The QRE has been successfully applied to explain experimental behavior in games related to ours including auctions (Camerer et al., 2016), price-contract design games (Lim and Ho, 2007; Ho and Zhang, 2008) and capacity allocation games (Chen et al., 2012). We will use the logit-agent quantal-response equilibrium (logit-AQRE), which is a parametric specification of QRE tailored to sequential games (McKelvey and Palfrey, 1998). Logit-AQRE has been shown to be able to explain overcommunication in experimental cheap-talk games (Cai and Wang, 2006).

The Level-k model (Stahl and Wilson, 1994, 1995; Nagel, 1995) fails to select among equilibria in MISAL\_ante. In cheap-talk games like ours, for senders, salient Level-0 strategies are naïve behavior (the sender always truthfully reveals her private information) and babbling behavior (the sender randomized uniformly over her information set). For receivers, prominent Level-0 strategies are deaf behavior (the receiver assumes that the sender's message does not contain any useful information) and naïve behavior (the receiver assumes that the sender tells the truth about her private information). Depending on the Level-0 behavior assumed, in MISAL\_ante, both the babbling equilibrium and the truthful equilibrium are consistent with level-k thinking for any  $k=1,2,3,\dots$ . The reason is that the babbling-equilibrium strategies are best responses to babbling/deaf supplier/buyer behavior, while the strategies played according to the

truthful equilibrium are best responses to naïve supplier and buyer behavior. For similar reasons, a dynamic level-k model (Ho and Su, 2013) gives the same predictions. In fact, our data are inconsistent with either equilibrium, and hence inconsistent with the level-k model. In contrast to the truthful equilibrium, suppliers recommend the most valuable location in only 35.6% of the cases (recall Figure 2(c) and the text surrounding it). Inconsistent with the babbling equilibrium, buyers are far away from always choosing Middle (recall Figure 4, the regression in Table 7, and the text surrounding it).

A possible reason why the data are to a large extent consistent with most informative neologism-proof equilibrium for all treatments apart from MISAL\_ante is that the ex-ante mechanism gives rise to an arguably more complex strategic environment than the ex-post mechanism, in particular in terms of the communication decisions. In contrast to the ex-post mechanism, in the communication stage of the ex-ante mechanism, suppliers have to anticipate the communication strategies used by the other suppliers, the way the buyer will respond to the communication, and bidding behavior in the auction. The increased complexity will increase the likelihood of suboptimal behavior in the communication stage.

As the perfect Bayesian Nash equilibrium is a limiting case of the logit-AQRE (where the probability of choosing suboptimal strategies converges to zero), the ex-ante mechanism has potentially multiple logit-AQREs in the MISAL setting, including an informative logit-AQRE and a babbling logit-AQRE. In an informative logit-AQRE, the suppliers are more likely to reveal the true location than the other two locations. In the babbling logit-AQRE, the suppliers randomize uniformly over the message space regardless of the state of the world. For the buyer, the best response to very noisy communication by the suppliers is to ignore the communication and always choose the Middle location. As a result, a babbling logit-AQRE always exists and an informative logit-AQRE may fail to exist.

To verify whether our data are potentially consistent with an informative logit-AQRE, we use Camerer et al.'s (2016) structural estimation approach to determine the suppliers' noise parameter  $\lambda$ . More precisely, we base the logit-AQRE on the assumption that each supplier sends message  $\mu$  with probability

$$q(\mu, X, t) \equiv \frac{\exp(\lambda U(X, t, \mu))}{\sum_{M=-1,0,1,\emptyset} \exp(\lambda U(X, t, M))} \quad (1)$$

if  $X$  is the most preferred location and  $t$  is her type, where  $U(X, t, \mu)$  denotes the supplier's expected utility when sending message  $\mu$  if  $X$  is the most preferred location and  $t$  is her type. The parameter  $\lambda$  is a measure for how closely a supplier's behavior corresponds to her best response. If  $\lambda = 0$ , the supplier randomizes uniformly over the message space, while if  $\lambda = \infty$ , the supplier sends her best-response message with probability 1.

We estimate  $\lambda$  in (1) using maximum likelihood, estimating the supplier's expected utility  $U(X, t, \mu)$  using the suppliers' and buyers' empirical behavior in the experiment (Appendix E contains the details of the estimation procedure). The resulting maximum likelihood estimate for  $\lambda$  equals  $\hat{\lambda} = 0.54$ . This estimate is lower than what is typically found in the literature.<sup>4</sup> In other words, behavior in MISAL\_ante is less in line with rational behavior than what is observed in the literature, which suggests that MISAL\_ante embodies a relatively complex game, consistent with what we have argued above. Next, we observe that for  $\hat{\lambda} = 0.54$ , no logit-AQRE exists in which the buyer chooses Left [Right], even after all three suppliers sending the message 'Left' ['Right'] (see Appendix E). For  $\hat{\lambda} = 0.54$ , the probability that Left/Middle/Right is the most preferred location after three suppliers sending the message 'Left' equals 0.45/0.29/0.26 respectively. When all suppliers send the message 'Left', the expected buyer payoffs equal 158 if she chooses Middle, while choosing Left yields expected payoffs equal to 148. Clearly, Left is not a best response to the suppliers' noisy message strategies. By symmetry, Right is not a best response for the buyer even if all suppliers send the message 'Right'. We conclude that an informative logit-AQRE does not exist. In contrast, the babbling logit-AQRE organizes our data well witnessing the near uniform distribution of messages sent as shown in Figure 3.

Overall, we conclude that QRE organizes the data in the MISAL\_ante treatment well.

## 5. Conclusion

The appropriate design of sourcing processes is not only of academic interest. Beall et al. (2003) report that companies in the US and Europe expected to spend about 11.5% of total expenditure using electronic reverse auctions. OECD (2018) reports that the amount spent in OECD countries on public procurement is about 12% of GDP. The purpose of this paper is to better understand the value-added of cheap-talk communication before or after a procurement auction. We study two mechanisms, the ex-ante mechanism (in which potential suppliers communicate about the terms of the contract before the auction) and the ex-post mechanism (in which communication about the contract terms takes place after the auction). Both mechanisms are modeled after real-world mechanism applications: The ex-ante (ex-post) mechanism models important features of the competitive dialogue (negotiated procedure) frequently used in European public procurement. Equivalent mechanisms are used in private-sector procurement.

In different settings, our theoretical results identify which is the effective communication mechanism to be added to a procurement auction, i.e., competition and revealing information in addition to the supplier costs. We have observed that in a setting in which the buyer and the

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<sup>4</sup> Cai and Wang (2006) observe  $\hat{\lambda} = 2.00$  for simple cheap-talk games. Camerer et al. (2016) report  $\hat{\lambda} = 3.59$  for an auction game. Lim and Ho (2007) find  $\hat{\lambda} = 1.96$  [ $\hat{\lambda} = 5.36$ ] for a price-contract game where the seller offers customers two- [three-] block contracts. Ho and Zhang (2008) obtain  $\hat{\lambda} = 0.82$  and  $\hat{\lambda} = 1.27$  in two versions of a price-contract game.

suppliers have aligned interests regarding the terms of the contract, using the ex-post communication mechanism, (i.e. allowing the winning supplier to communicate with the buyer after the auction) is beneficial to the buyer and the ex-ante mechanism does not add any value in such a setting, with both strongly supported by our experimental results. By contrast, in a setting where the buyer and the winning supplier have misaligned interests regarding the terms, in theory, the buyer benefits from ex-ante communication relative to no communication and ex-post communication. Our experimental data provide little support for that prediction, however. The quantal response equilibrium provides a convincing behavioral underpinning.

Our work offers several managerial implications. A general lesson is that procurement managers should be aware of incentives for suppliers to distort the information that they provide in the sourcing process. Our theory shows that the incentive to do so crucially depends on the environment (aligned interests vs. misaligned interests) and the timing of the communication (before or after the auction). Moreover, as Proposition 7 shows, ex-ante communication is only beneficial for the buyer in the case of (1) sufficient buyer competition, (2) the buyer having a strong preference about the product specifications, and (3) suppliers' cost differences across product specifications being relatively modest. Our experimental observations indicate that suppliers find ways to manipulate the information revealed to the buyer. Our experimental findings also point to the limitations of allowing suppliers to communicate about the terms of the contract before or after the auction. In the settings that we study in our experiment, we find ex-post communication to be valuable only in the case of aligned buyer/supplier interests while ex-ante communication turns out to be hardly valuable at all.

The scope of our results is not limited to cases where communication is costless, even though the term 'cheap-talk communication' might suggest otherwise. Indeed, communication may be quite costly for both the buyer and the suppliers: the buyer has to articulate his requirements, the suppliers have to prepare documents, and both the buyer and the suppliers have to attend meetings with each other. For communication to be cheap talk in the sense of Crawford and Sobel (1982), it suffices that the communication costs are independent of the information submitted. As preparation of the communication may be costly for both the suppliers and the buyer, communication before or after the auction should be used with care and only in those cases where it significantly improves the outcome of the sourcing process. Our research points to cases where lack of such benefits is imminent. Indeed, we see our theoretical and experimental results as a warning that buyers should be careful eliciting information before the auction, even if the buyer's and suppliers' preferences are perfectly aligned. The intuition is that suppliers may have an incentive to misrepresent their information as that would soften competition amongst themselves in the auction. The good news is that in the aligned-interest

setting, the ex-post mechanism is an easy-to-implement mechanism that the buyer can use to extract supplier information about both the preferred terms of the contract and the supplier costs. Of course, this begs the question of whether our results can be extrapolated to other settings. Future theoretical and experimental research might shed light on the effect of allowing suppliers to communicate before or after the auction in settings characterized by...

- ... reputation building. Our experimental framework mimics one-shot interaction by not labeling suppliers. If the buyer knew the suppliers' identities, suppliers may want to build a reputation for truth-telling so that they are more inclined to inform the buyer truthfully.
- ... pre-play communication. We observe that the ex-ante mechanism is less effective in terms of information revelation than suggested by theory. Suppliers who can communicate with each other regarding the information they give to the buyer may be able to coordinate on a more informative equilibrium.
- ... selection in the communication stage. In the ex-ante mechanism, the buyer may use the information transmitted in the communication stage to select a subset of suppliers to submit a bid in the auction. For instance, the buyer may only allow those suppliers to participate in the auction whose recommendations coincide with the majority's. This may encourage truthful recommendation and thus induce more frequent emergence of the efficient equilibrium outcome than observed in our experiment.
- ... supplier specialization. We have assumed that all suppliers prefer the same location. In a setting where suppliers' preferences regarding the location differ, e.g., as the result of specialization, ex-ante communication may be expected to be ineffective.

Our experimental framework can be readily extended to explore such settings.

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