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Cheap-talk Communication in Procurement Auctions: Theory and Experiment

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Abstract: In procurement auctions, bidders are usually better informed about technical, financial, or legal aspects of the goods and services procured. Therefore, the buyer may include a dialogue in the procurement procedure which enables the suppliers to reveal information that will help the buyer to better specify the terms of the contract. This paper addresses the question of the value added of letting the sourcing process consist of both an auction and a negotiation stage, theoretically and in a laboratory experiment. Our theoretical results suggest that in a setting where the buyer and the suppliers have aligned interests regarding the terms of the contract, allowing the winning supplier to communicate with the buyer after the auction is beneficial to the buyer compared to no communication and ex-ante communication. In a setting where the buyer and the winning supplier have misaligned interests regarding the terms, the buyer benefits from ex-ante communication relative to no communication and ex-post communication. Our experimental data provide strong evidence for the predictions in the aligned-interest setting. In the misaligned-interest setting, we do not observe significant differences between the three mechanisms. Our experimental findings offer several managerial implications for the appropriate design of sourcing processes.

Keywords: Procurement auctions; bidding; cheap-talk communication; negotiations; game theory; experimental economics

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"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

Reverse auctions are commonly used by both public and private organizations to purchase goods and services.[1] An important reason for buyers to use auctions is that 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, pre-auction or post-auction. According to Elmaghraby (2007), in the private sector, the sourcing process often contains several request-of-information rounds.[2] Before the start of the auction, the buyer may invite suppliers to "indicate their capabilities along possibly multiple non-price dimensions" (p. 412) and after the auction, the buyer "may negotiate certain terms of the contract that were strategically left vague before the auction" (p. 417).[3] In the case of complex contracts, public procurement law in the European Union allows for both a 'competitive dialogue,' in which buyers negotiate with suppliers before the latter submit their final tender and a 'negotiated procedure,' where buyers may negotiate with selected suppliers over the contract specifics.[4] Such procedures 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, as such communication boils down to 'cheap talk.' This raises questions like: Under what conditions does non-binding

[1] 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.

[2] Another purpose of request-of-information rounds is to weed out unqualified suppliers (e.g., Elmaghraby, 2007). Boone and Goeree (2009) show that an auctioneer can alleviate winner's curse problems by soliciting non-binding bids before the auction. However, Boone et al. (2009) observe in an experiment that bidders tend to coordinate on a "babbling equilibrium" in which no information is revealed. Another reason for soliciting non-binding bids is to enhance efficient entry into the auction when auction entry is costly. See Ye (2007) and Quint and Hendricks (2018) for a theoretical analysis and Kagel et al. (2008) for a laboratory study.

[3] Other reasons for the buyer to allow for post-auction communication include price renegotiations (e.g., Shachat and Tan, 2014), and contingencies arising which are not specified in the original contract resulting in cost overruns (e.g., Herweg and Schwarz, 2018).

[4] Directive 2014/24/EU on public procurement.

communication reveal useful information for the buyer? Under what conditions does the buyer benefit from non-binding communication from 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 theoretical analysis models the procurement auctions as dynamic Bayesian games. In our framework, a number of suppliers compete to complete a project. The project can be completed in one of three different 'locations,' which can be interpreted as a (horizontal) non-price attribute. Among the suppliers, it is common knowledge which location is the most valuable for the buyer. The buyer is incompletely informed about the most valuable location. We study three mechanisms. In 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* is the no-communication mechanism extended with a communication stage before the auction: The suppliers can send a message to the buyer about what is the most valuable location before the buyer picks the location. The *ex-post mechanism* is the no-communication mechanism extended with a communication stage after the auction: The buyer first auctions an abstract project in a reverse auction; then the winning supplier sends a message to the buyer about the most valuable location after which the buyer chooses the location.

It is well known that cheap-talk games like ours are often plagued by a multitude of equilibria. When restricting our attention to neologism-proof equilibria in which the suppliers reveal the highest possible amount of information to the buyer, we find the following. In a setting where the buyer's and suppliers' preferences regarding the location are aligned (ALIGN), the buyer is better off using the ex-post mechanism than the no-communication mechanism and the ex-ante mechanism. In a setting where the buyer and the suppliers have opposite preferences regarding the location (MISAL), the buyer is better off using the ex-ante mechanism than the no-communication mechanism and the ex-post mechanism.

Which equilibrium of the three mechanisms is most likely to be played remains an open 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, we do not observe significant differences between the three mechanisms. All in all, 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 less limited in that it turns out to be difficult for suppliers to communicate effectively with the buyer.

Laboratory experiments have been successfully used to improve our understanding of market interactions. An extensive body of experimental literature studies bidding behavior in auctions. See Kagel (1995) and Kagel and Levin (2016) for overviews. While most studies involve price-only auctions, the Behavioral Operations Management literature typically studies auction settings in which the buyer cares not only about the price but also about non-price attributes like quality, reliability, and delivery time.[5] In this literature, it is commonly assumed that the buyer is able to evaluate non-price attributes. As far as we know, we are the first to consider a more relaxed assumption that the buyer has incomplete information of the non-price attributes of the goods, and to address the question of whether the buyer may obtain useful information from pre-auction and post-auction cheap-talk communication to resolve information asymmetry about non-price attributes.

Crawford and Sobel's (1982) seminal work on cheap-talk games with asymmetric information has spawned a growing literature on experimental communication games.[6] A common finding in this literature is that among all equilibria, the most informative equilibrium explains the data best, particularly if this equilibrium survives equilibrium selection based on neologism proofness (Farrell, 1993) or the Average Credible Deviation Criterion (ACDC, De Groot Ruiz et al., 2015). A second common observation in the experimental cheap-talk literature is over-communication, i.e., if experimental participants deviate from equilibrium behavior they communicate more than predicted by the most informative neologism-proof equilibrium. 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, the supplier and buyers behave in line with a babbling equilibrium in the ex-ante mechanism, 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.

[5] See, e.g., Chen-Ritzo et al. (2005), Engelbrecht-Wiggans et al. (2007), Haruvy and Katok (2013), Brosig-Koch and Heinrich (2014), and Fugger et al. (2016, 2019). Elmaghraby and Katok (2018) present an excellent overview of this literature.

[6] 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), and Lai and Lim (2018). Blume et al. (2019) is an outstanding survey of this literature.

Our paper also speaks to the auctions vs. negotiations literature. Bulow and Klemperer (1996) emphasize that auctions typically outperform negotiations in the case of standardized transactions. In contrast, Goldberg (1977) argues that in the case of complex transactions, the buyer prefers negotiations over auctions because the former facilitate the exchange of important information that may help the buyer to appropriately establish the terms of the contract. Bajari et al. (2009) find support for this hypothesis using data from private-sector building construction projects in Northern California from 1995 to 2000. In an adverse-selection setting, Manelli and Vincent (1995) derive conditions under which buyers prefer negotiations with a single supplier over auctions with multiple suppliers. Our research adds to this literature by addressing the question of the value added of letting the sourcing process consist of both an auction and a negotiation stage.

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. Section 5 is a conclusion, which includes a summary of our results, management implications regarding the appropriate 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 three different locations, labeled $-1, 0,$ and 1, which can be interpreted as a horizontal non-price attribute in the sense of Hotelling (1929). We focus on horizontal quality because communication about vertical quality is meaningless, at least in theory, as suppliers will always claim to offer the highest possible quality. Each location is equally likely to be the buyer's most valuable location X. 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, 2019). 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). We believe the strategic simplicity of descending auctions 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 the timing 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

$$U_0(X,x,p) = v_0 - t_0|X-x| - p$$

where v_0 is the project's value when built at the most valuable location and $t_0 > 0$ represents the buyer's 'travel costs', i.e., the penalty per distance unit the project is away from the most valuable location. 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 monotone function, with $f(d) > 0$, $d \in \{0,1,2\}$. Before the procurement auction, each supplier is privately informed about his travel costs. We assume that the suppliers' travel costs are i.i.d. drawn from the same smooth distribution function F that has all its mass on the interval $[\underline{t}, \overline{t}]$ where $0 \leq \underline{t} < \overline{t}$. We will let $t^{(k)}$ denote the kth (highest) order statistic from N draws from F. We make the following technical assumptions on the parameters.

Assumption A1 $v_0 \geq \frac{2}{3}t_0 + \frac{1}{3}(f(0) + 2f(1))E\{t^{(N-1)}\}$

Assumption A2 $\frac{1}{3}t_0 + (f(2) - f(1))E\{t^{(N-1)}\} \geq 0$

Assumption A1 ensures that the buyer's expected payoffs are non-negative in equilibrium. Under Assumption A2, without further information about X, the buyer prefers to locate the project 'in the middle', i.e., at $x = 0$.

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 $\{-1, 0, 1\}$
2. The buyer auctions the project in a descending reverse 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 $\{-1, 0, 1, \emptyset\}$
2. The buyer picks a project from the set $\{-1, 0, 1\}$
3. The buyer auctions the project in a descending reverse auction

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 $\{-1, 0, 1, \emptyset\}$
3. The buyer picks the project from the set $\{-1, 0, 1\}$

We focus our analysis on the most informative equilibrium, i.e., the equilibrium in which the buyer can deduce the highest amount of information regarding X. 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 $\{-1, 0, 1\}$ 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 neologism proof if and only if no coalition of senders exists that can send a credible neologism.

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.

Proposition 1. *The no-communication mechanism has a unique perfect Bayesian Nash equilibrium in weakly dominant strategies in which the buyer chooses project $x = 0$ and where each supplier i bids $t_i f(|X - x|)$.*

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 -1 or 1 because, according to Assumption A2, this will decrease her expected utility.

Expected equilibrium payoffs for the buyer are

$$\pi_{no} = v_0 - \frac{1}{3} f(0) E\{t^{(N-1)}\} - \frac{2}{3}\left(t_0 + f(1) E\{t^{(N-1)}\}\right).$$

If $f(\cdot)$ is increasing, i.e., if the buyer's and the winning supplier's preferences regarding the location are aligned, it turns out that the buyer will not benefit from the message stage in the ex-ante mechanism.

Proposition 2. *If $f(\cdot)$ is increasing, the Ex-ante mechanism has a perfect Bayesian Nash equilibrium in which all suppliers play a babbling strategy, the buyer chooses location 0 regardless of the messages the suppliers send, and each supplier i bids $t_i f(|X|)$. This equilibrium is neologism proof. No 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. As a result, prior to the auction, 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. For instance, 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.

If $f(\cdot)$ is increasing, the ex-post mechanism has an equilibrium in which the winning supplier reveals information.

Proposition 3. *If $f(\cdot)$ is increasing, 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.*

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.

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 π_{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. *If $f(\cdot)$ is increasing, $\pi_{ex\ post} > \pi_{ex\ ante} = \pi_{no}$.*

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. In such settings, the suppliers have an incentive to reveal the most valuable location ex ante to the buyer in order to maximize the cost differences.

Proposition 5. *If $f(\cdot)$ is decreasing, the ex-ante mechanism has a perfect Bayesian Nash equilibrium in which all suppliers send message X, the buyer chooses project X, and where each supplier i bids $f(0)t_i$. This equilibrium is neologism proof.*

In the case of misaligned interests regarding the location, the winning supplier has no reason to reveal the most valuable location to the buyer. A babbling equilibrium emerges. Notice that if $X = -1$or 1, the buyer may deduce from the bids that $X \neq 0$. However, choosing location 0 is still optimal because $X = -1$ and $X = 1$ are equally likely. As a result, the ex-ante mechanism has the same equilibrium outcome as the no-communication mechanism.

Proposition 6. *If $f(\cdot)$ is decreasing, the ex-post mechanism has a perfect Bayesian Nash equilibrium in which supplier i bids $f(0)t_i$ if $X = 0$ and $f(1)t_i$ if $X = -1$ or $X = 1$, the winning supplier plays a babbling strategy, and the buyer chooses location 0 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. *Suppose $f(\cdot)$ is decreasing and $\frac{1}{3}t_0 + (f(2) - f(1))E\{t^{(N-1)}\} > 0$. Then $\pi_{ex\ ante} > \pi_{ex\ post} = \pi_{no}$ if and only if $t_0 > (f(0) - f(1))E\{t^{(N-1)}\}$.*

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).[7] One member of each group is randomly assigned the role of buyer throughout the whole session. 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 $\{\underline{t}, \underline{t}+1, \ldots, \overline{t}-1, \overline{t}\}$, 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's potential locations, $-1, 0,$ and 1, are relabeled Left, Middle, and Right respectively. Project costs and earnings are in experimental points (pt), with an exchange rate of 30 pt = 1 RMB (about \$0.14 when the experiment was conducted) for the buyer and 1 pt = 1 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., $p_{max} = 3\overline{t}$. The price is decreased successively with discrete steps of 1 point per 1/3 second. 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.

[7] Collusion is a potential risk. However, 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., 2019) or in dynamic non-binding reverse auctions (Fugger et al., 2016). Of course, bidders might find a way to collude tacitly in our experimental setting, which in and of itself will be an interesting experimental result.

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)

To study the effects of the timing of communication, we use a 2x2 between-subjects experimental design in which we vary the timing of the communication stage (ex ante or ex post) and the setting (ALIGN and MISAL). 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.

Table 1. Experimental Design and Parameters

Treatment	#groups	Setting	Communication	v_0	t_0	$\underline{t}$	$\overline{t}$	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

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.[8] 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

Table 2 provides an overview of the equilibrium predictions under each communication mechanism in each setting, based on the most informative neologism-proof perfect Bayesian Nash equilibria derived in Section 3.1.

Table 2. 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	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	Middle	162	5.83

In light of the above theoretical predictions, we present our hypotheses. Regarding information transmission, we derive the following hypothesis for setting ALIGN:

Hypothesis 1ALIGN. *In setting ALIGN, (a) the suppliers do not reveal information about the project's most valuable location in the ex-ante mechanism; (b) the winning supplier reveals information about the project's most valuable location in the ex-post mechanism; (c) the location recommendations are more informative in the ex-post mechanism than in the ex-ante mechanism.*

[8] 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 message "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 over-communication compared to the equilibrium predictions (see Sánchez-Pagés and Vorsatz, 2007, 2009, for evidence from cheap-talk games).

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

Hypothesis 2ALIGN. *In setting ALIGN, (a) the buyer's average profits are greater in the ex-post mechanism than in the no-communication mechanism; (b) the buyer's average profits are the same in the ex-ante mechanism as in the no-communication mechanism; (c) the buyer's average profits are greater in the ex-post mechanism than in the ex-ante mechanism.*

Analogously, we have the following two hypotheses for setting MISAL:

Hypothesis 1MISAL. *In setting MISAL, (a) the suppliers reveal information about the project's most valuable location in the ex-ante mechanism; (b) the winning supplier does not reveal information about the project's most valuable location in the ex-post mechanism; (c) the location recommendations are more informative in the ex-ante mechanism than in the ex-post mechanism.*

Hypothesis 2MISAL. *In setting MISAL, (a) the buyer's average profits are the same in the ex-post mechanism as in the no-communication mechanism; (b) the buyer's average profits are greater in the ex-ante mechanism than in the no-communication mechanism; (c) the buyer's average profits are greater in the ex-ante mechanism than in the ex-post mechanism.*

4. Results

We present our results in three parts. In Section 4.1, we compare the mechanisms in terms of buyer payoffs, addressing the question under what circumstances the buyer benefits from non-binding communication (Hypotheses 2ALIGN and 2MISAL). In Section 4.2 we zoom in to focus on the suppliers' communication strategies testing Hypotheses 1ALIGN and 1MISAL. In Section 4.3, we discuss behavioral patterns in the MISAL_ante treatment in more detail to explore why the data are inconsistent with some of our hypotheses. Throughout this section, 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 the ante and post treatments 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 3 presents the average buyer payoffs in each treatment. We do a within-subjects comparison between parts 2 and 3 in each treatment to test Hypotheses 2ALIGN(a)&(b) and

2MISAL(a)&(b), and a between-subjects comparison of the buyers' average payoff in Part 3 across the ante and post treatments under each setting to test Hypothesis 2ALIGN(c) and 2MISAL(c).

In the ALIGN setting, the data show strong support for Hypothesis 2ALIGN. We observe in Treatment ALIGN_ante that the average buyer payoffs are significantly higher in the ex-post mechanism than in the no-communication mechanism (217.71 vs. 145.73; p<0.001, *t* test). In treatment ALIGN_post, 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, from a between-subjects comparison across treatment ALIGN_ante and ALIGN_post, we find buyers' average payoffs are 217.71 and 157.95 in the ex-post mechanism and the ex-ante mechanism, respectively. The difference is statistically significant (p<0.001, *t* test). All these experimental observations well support Hypotheses 2ALIGN (a)-(c).

Table 3. Buyers' Average Payoffs

		ALIGN		MISAL	
		Ex Ante	Ex Post	Ex Ante	Ex Post
Buyer's Average Payoffs	No Communication (Part 2)	149.96 (6.230)	145.73 (8.566)	160.96 (6.134)	142.67 (7.547)
	Communication (Part 3)	157.95 (4.541)	217.71 (1.595)	151.57 (4.234)	145.02 (4.591)

Hypothesis 2MISAL is not fully supported by the data, however. In Part 3 of Treatments MISAL_ante and MISAL_post, on average, the buyers earn higher payoffs in the ex-ante mechanism (151.57) than in the ex-post mechanism (145.02). While the comparison between the two treatments is in the predicted direction, the difference is insignificant (p=0.295, *t* test). Moreover, according to a within-subjects comparison, under Treatment MISAL_ante, the buyer's average payoffs under the *ex-post mechanism* (in part 3) are not significantly different from that under the no-communication mechanism (in part 2), with the payoffs being 145.02 and 142.67, respectively (p=0.974, *t* test). In line with Hypothesis 2MISAL(a), in Treatment MISAL_ante, average buyer payoffs do not differ significantly between the ex-ante mechanism (151.57) and the ex-post mechanism (151.57 vs. 160.96; p=0.309, *t* test).

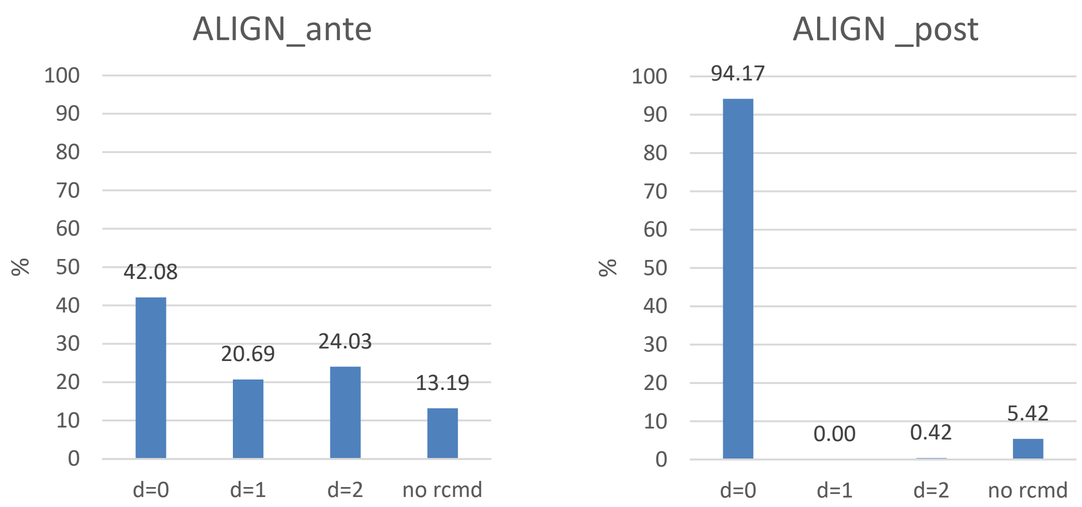
4.2. Suppliers' communication strategies

To study suppliers' communication strategies and to test the related Hypotheses 1ALIGN and 1MISAL, we introduce the variable $d \in \{0, 1, 2\}$, which measures the distance between the recommended location and the most valuable location. $d > 0$ means a supplier misleads 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 provides the suppliers' recommendation deviations in the setting ALIGN. It 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 either by 1 or 2, and the remaining 13.2% chose "no recommendation." Among the suppliers who did choose a recommendation (excluding the "no recommendation" ones), the distribution of all 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 1ALIGN(a).

In ALIGN_post, the dominant majority (94.2%) of the winning suppliers (those who had an opportunity to make a recommendation) truthfully recommended the most valuable location to the buyer, while only 5.4% chose not to give a recommendation and 0.4% misled. This strongly supports Hypothesis 1ALIGN(b). Consistent with Hypothesis 1ALIGN(c), we find that the suppliers make a recommendation of 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).

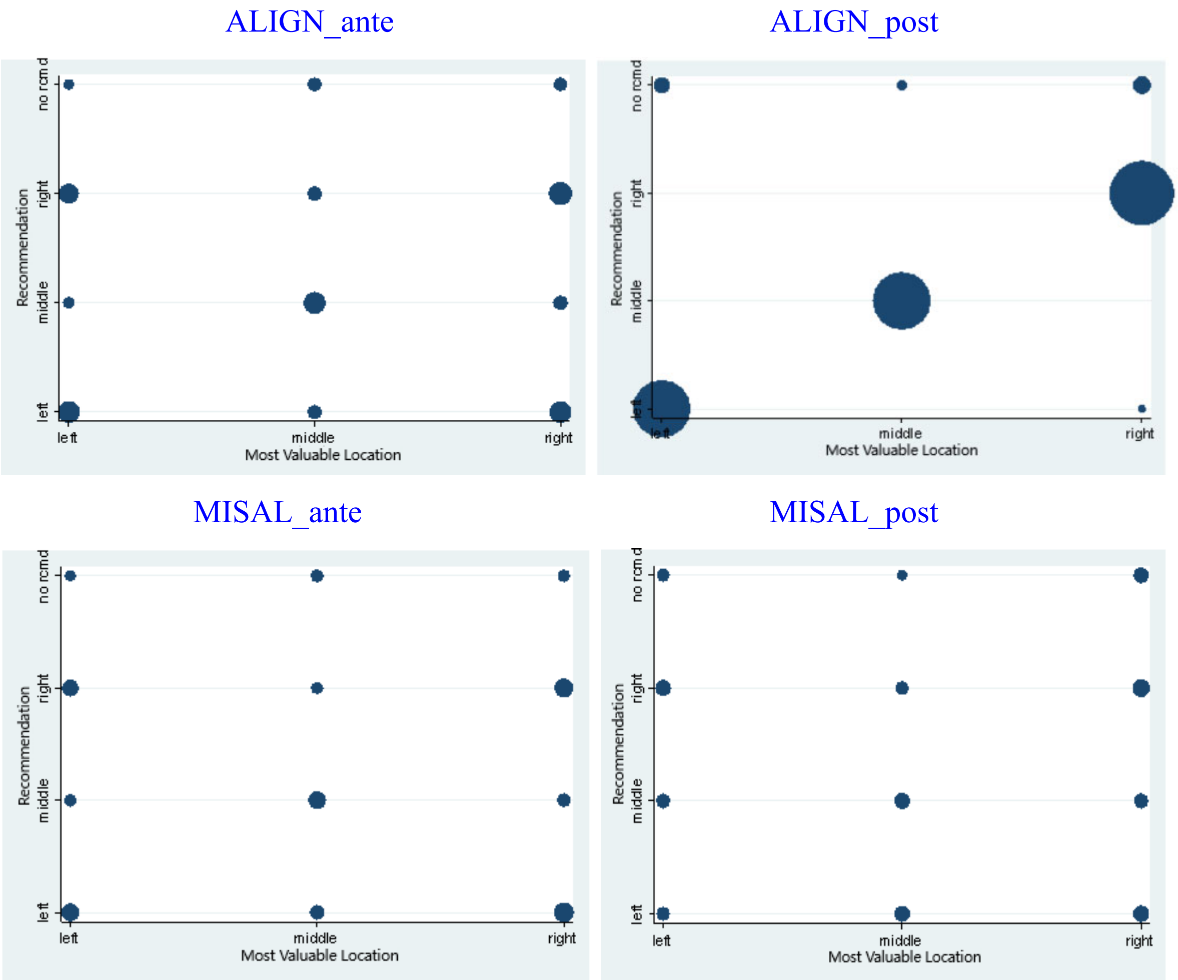
Figure 1. Recommendation Deviation from the Most Valuable Location in the ALIGN Setting



Note: The right-most bar denotes the fraction of suppliers who chose "no recommendation."

Regarding suppliers' communication strategies at the individual level, Figure 2 shows that the recommendations in Treatment ALIGN_ante do not exhibit any tendency to follow the most valuable location, which is in line with the predicted babbling equilibrium. This uncorrelation is also supported by the regression in Table 4, which indicates that the recommendations are insignificantly positively correlated with the most valuable location, suggesting that the recommendations do not contain valuable information at the aggregate level.

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"

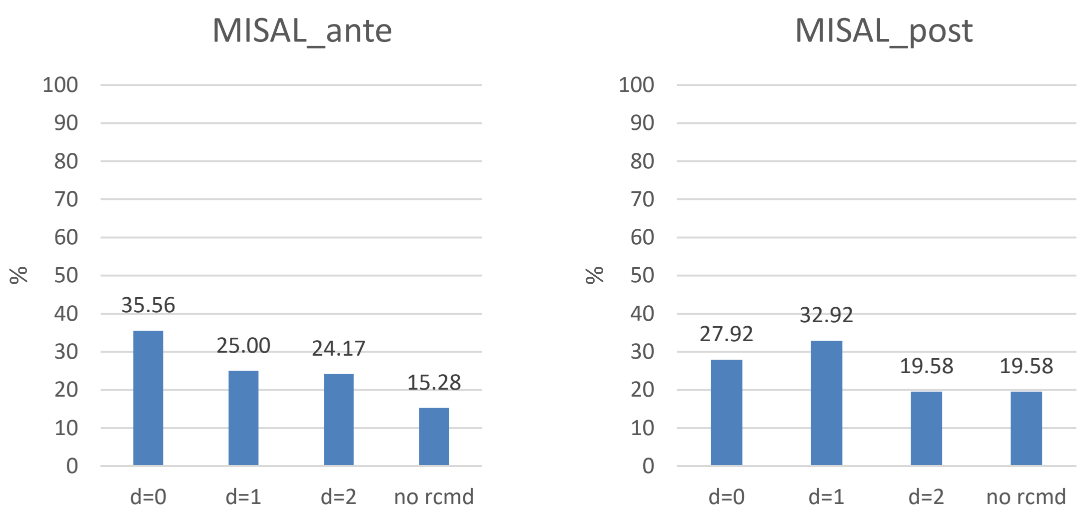
In Setting MISAL, the suppliers reveal hardly any information, as Figure 3 shows. In the *ex-ante mechanism*, in 35.6% of the cases, suppliers recommended the most valuable location, and in 25.0% and 24.1% of the cases, suppliers chose to mislead the buyer to a location that deviates from the most valuable one by 1 and 2 respectively. In the remaining 15.3% of cases, suppliers did not make a recommendation. Although the truth-telling recommendations are the mode among all the recommendation choices, much less information is revealed than in the predicted information-revealing communication. In the *ex-post mechanism*, only 27.9% of the winning suppliers recommended the most valuable location. The majority's (52.5%) recommendations deviate from the most valuable location, and another 19.6% of the winning suppliers chose "no recommendation." The distributions of all the recommendations under both mechanisms are not distinguishable from 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 1MISAL(b) but not Hypothesis 1MISAL(a).

Table 4. Regressions of Supplier's Recommended Location on the Most Valuable Location

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

Notes: Values within parentheses below each estimate are the standard errors adjusted after clustering data by group. The observations from the suppliers who chose "no recommendation" are excluded.
*, **, *** denotes significance at the 10%, 5% and 1% level, respectively.

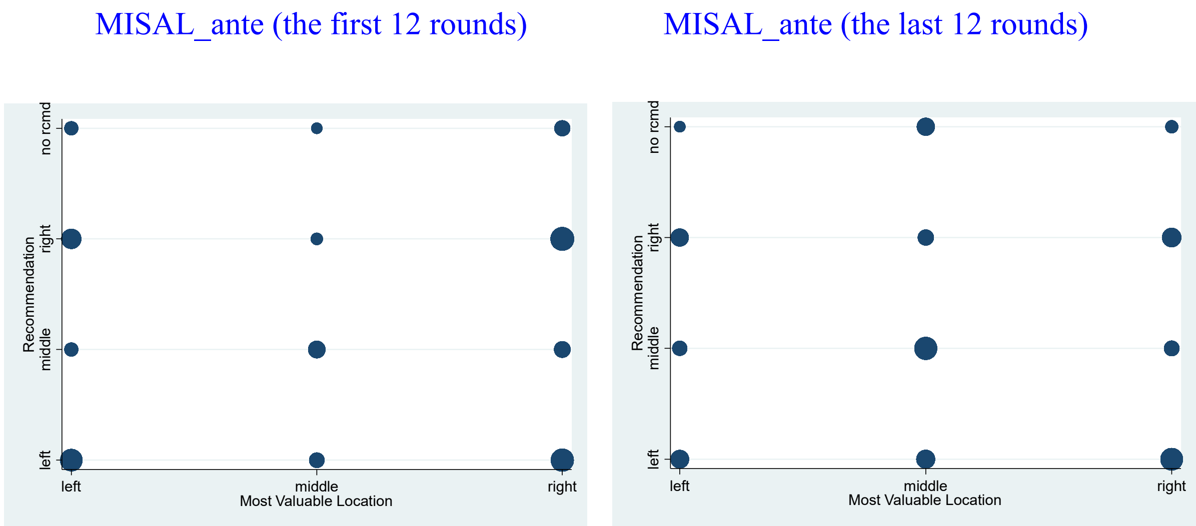
Figure 3. Histogram of Recommendations' Deviation from the Most Valuable Location (MISAL)



To compare the two communication mechanisms in terms of information transmission, we notice that the average recommendation's deviation from the most valuable location is lower in the ex-ante mechanism than in the ex-post mechanism (1.053 vs. 1.143) and that fewer subjects chose to avoid recommendations (15.3% vs. 19.6%) in the former mechanism. However, both differences are insignificant (p=0.201 under the t test for the average deviation comparison, and p=0.131 under the Fisher exact test for the comparison of the fraction of no recommendation.)

These findings suggest that in setting MISAL, the ex-ante mechanism does not induce more informative recommendations than the ex-post mechanism, in contrast to Hypothesis 1MISAL(c). Indeed, Figure 2 indicates that in the ex-ante mechanism, where full communication is predicted, the observed communication contains very little information. The regression results in Table 4, column 3, also show that the recommendations are hardly correlated with the most valuable location in this treatment. In the ex-post mechanism, the recommendations are in line with a babbling equilibrium. The regression in Table 4, column 4, indicates that the correlation between recommendation and most valuable location is close to zero.

Figure 4. Scatter Plots of the Individual Suppliers' Recommendations Conditional on the Most Valuable Location in the First and the Last 12 Rounds



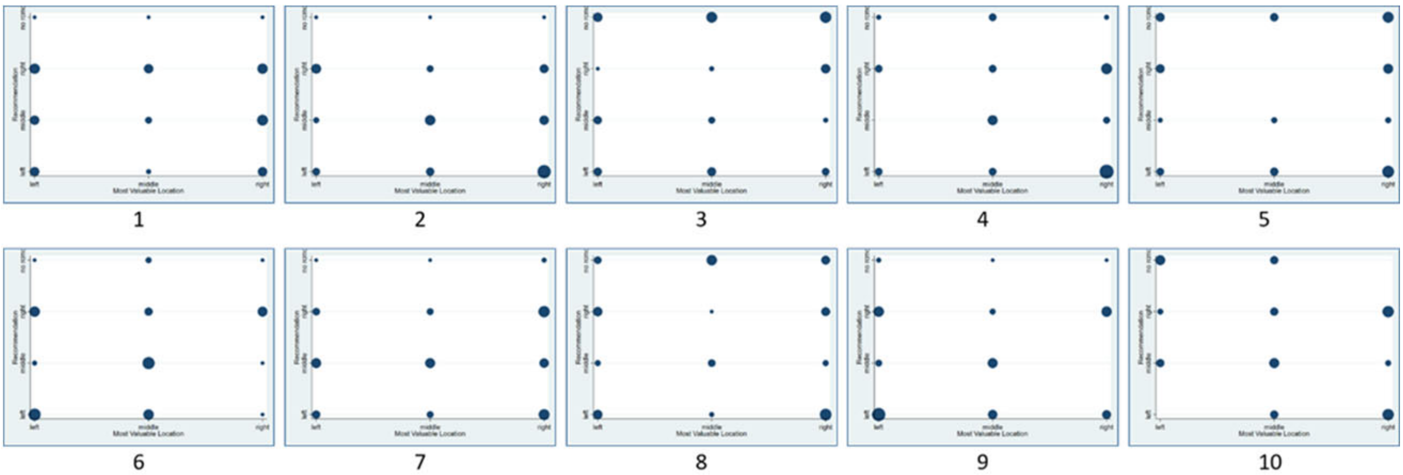
Notes: Scatter plots of suppliers' recommendations (vertical axis) conditional on the most valuable location (horizontal axis) in treatment MISAL_ante. "No rcmd" refers to suppliers who chose "no recommendation"

4.3 Further analysis

So far, we have observed that subjects' behavior supports our theoretical predictions, with the only major exception in setting MISAL under the ex-ante mechanism, in that it is not quite in line with a fully separating equilibrium. The latter finding is in sharp contrast to the vast existing experimental literature on cheap-talk games, which shows that participants' communication strategies are typically in line with the most informative equilibrium and if participants deviate from that, they do so in the direction of overcommunication, not undercommunication. In this section, we further explore undercommunication in MISAL_ante. We first consider learning, i.e., do the participants tend to move toward a more informative equilibrium over time? Then, we consider bidder heterogeneity in terms of sending a credible neologism to the buyer to induce her to play the fully separating equilibrium.

We study learning in MISAL_ante by checking if subjects' behavior differs in the first and the last 12 rounds, and if it does, whether the change goes in the direction of the most informative separating equilibrium. The results in Figure 4 do 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, the scatter plots in Figure 5 indicate that not a single group of the suppliers in MISAL_ante played the equilibrium strategies in the most informative neologism-proof equilibrium, where recommendations should always follow the most valuable location. Table 5 contains a regression of the individual recommendation on the most valuable location, and with the interaction term between the most valuable location and the dummy variable indicating whether it is in the last 12 rounds. The results show no correlation between the recommendation and the most valuable location. The interaction term being weakly significantly positive suggests that there may be a slight tendency that the recommendations better reveal the most valuable location as suppliers gain more experiences, which is in the direction to the most valuable location. However, the significance and magnitude of the tendency is low, which coincides with the fact that we do not see the clear separating pattern throughout the 24 rounds of auctions.

Figure 5. Scatter Plots of Recommendations and the Most Valuable Locations in MISAL_ante per Matching Group



Notes: Scatter plots of the suppliers' recommendations (vertical axis) conditional on the most valuable location (horizontal axis) per matching group in treatment MISAL_ante. "No rcmd" refers to suppliers who chose "no recommendation"

Table 5. Regressions of Supplier's Recommended Location in MISAL_ante

	Recommended Location	Recommended Location
Most Valuable Location	0.0103	-0.0539
	(0.0569)	(0.0523)
Most Valuable Location x Last 12 Rounds		0.115*
		(0.0552)
Constant	-0.0697*	-0.0695*
	(0.032)	(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.

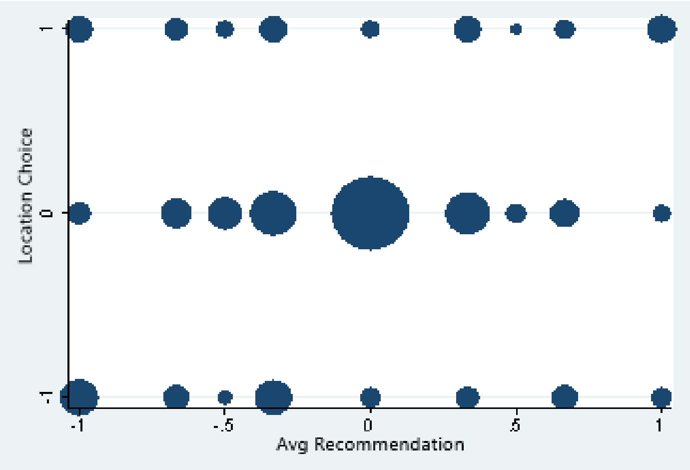
*, **, *** denotes significance at the 10%, 5% and 1% level, respectively.

Why do participants not manage to learn to play a more informative, and more profitable, equilibrium? 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 6 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 babbling recommendations by the suppliers. The remaining observations are roughly uniformly distributed over Left and Right. The regressions in Table 6 reveal a very weak dependence of the location choice on recommendations.[9] 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. Indeed, the lack of information in the suppliers' recommendations and the weak recommendation-following of the buyers seem to suggest that the buyer and the suppliers are best responding to each other's behavior, in that they are 'trapped' in the babbling equilibrium.

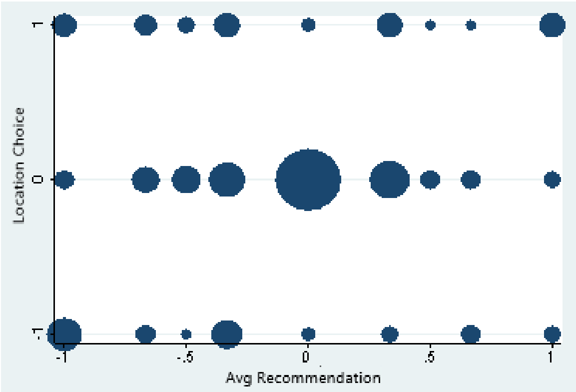
[9] When making the same plots and regressions as shown in Figure 6 and Table 6, respectively, by replacing the average of recommended locations by the majority of recommendations (if there is one) in each group, we obtain qualitatively the same results: the buyers do not follow recommendations and still randomize their location choices even when a majority recommendation exists.

Figure 6. Average of Recommended Locations the Location Chosen by the Buyer

(a) All observations



(a) The first 12 rounds only



(c) The last 12 rounds only

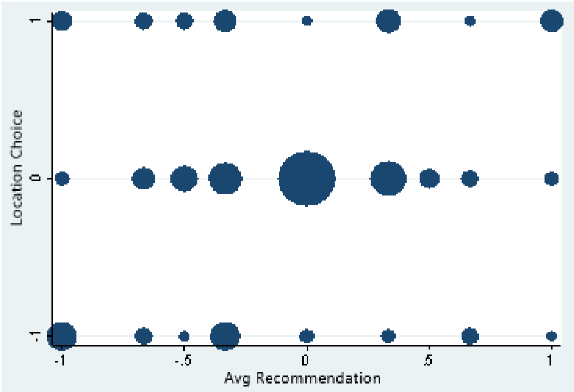


Table 6. Regression of Location Choice on Average Group Recommendation in MISAL_ante

	Location choice (1)	Location choice (2)
Avg Rcmd	0.176	0.113
	(0.142)	(0.147)
Avg Rcmd x Last 12 Rounds		0.125
		(0.107)
Constant	-0.022	-0.022
	(0.055)	(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 Rcmd' 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. 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.

The theoretical predictions for the ex-ante mechanism depend on the assumption that, in equilibrium, all the suppliers follow the weakly dominant strategy to quit at their own costs. Based on this, each supplier anticipates that their profit, conditional on being the winner in the end, equals his cost advantage relative to the runner-up, thus everyone would have an incentive to expand the cost difference between different suppliers by enlarging the common factor $f(|X-x|)$. However, it is also natural to imagine that a less cost-efficient supplier (i.e., with relatively higher travel costs, t) would have less incentive to do so, due to a rare probability of him becoming the winner in the auction. Moreover, if a less cost-efficient supplier also cared about the income difference between other suppliers and himself (i.e., envies the winner), a better strategy may be to choose the opposite communication strategy than predicted by equilibrium in order to shrink the common factor $f(|X-x|)$ and accordingly the cost difference between other cost-efficient suppliers and himself. This means that, for him, a better strategy would be to recommend the most-valuable location when the theory predicts babbling (in ALIGN_ante), and babble when truth-telling is predicted (in MISAL_ante).

To test whether the above argument is valid in our experiment, we first create a variable $mislead$ to indicate each suppliers' recommending strategy in each round (it takes the value of 0, if the supplier recommends the most valuable location, and 1 otherwise), then run a probit regression of $mislead$ on the supplier's own t value in the same round (see Table 7). The estimated results confirm the predicted direction for the ex-ante mechanism in both settings. However, noticing that the effect is much stronger and more significant in ALIGN_ante than in MISAL_ante, this explanation does not seem to be the main reason why the buyer and the suppliers fail to coordinate on the separating equilibrium.

Table 7. Probit Regression of *mislead* on Supplier Type t

	ALIGN_ante	MISAL_ante
Prediction	–	+
Estimated marginal effect	-0.052***	0.004*
Std. err.	(0.001)	(0.002)
Observations	720	720

Notes: Prediction gives the predicted sign of the marginal effect of an increase in the own t value on the probability of trying to mislead the buyer in the recommendation sending step according to the previous argument. 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.

5. Conclusion

The question of the appropriate design of sourcing processes has received much attention in the operations management literature. The purpose of this paper is to better understand communication before or after a reverse auction with the broader aim in mind of helping managers improve their sourcing processes. Much of the literature has focused on the auctions vs. negotiations question. Our research has addressed the question of the value added of letting the sourcing process consist of both an auction and a negotiation stage. We study the ex-ante mechanism, in which potential suppliers negotiate the terms of the contract before the auction, and the ex-post mechanism, which, in a way, auctions the right to negotiate the terms of the contract.

Our theoretical results identify settings in which adding a negotiation stage to a reverse auction combines the best of both worlds, 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 suppliers have aligned interests regarding the terms of the contract, allowing the winning supplier to communicate with the buyer after the auction is beneficial to the buyer compared to no communication and ex-ante communication. In fact, the buyer does not benefit at all from ex-ante communication compared to a setting where the suppliers cannot communicate with the buyer outside the auction. Our experimental results are in line with these theoretical predictions. 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.

Our work offers several managerial implications. A general lesson is that 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 negotiation (before or after the auction). 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 negotiate the terms of the contract before or after the auction. In the settings that we study in our experiment, we find ex-post negotiation to be valuable only in the case of aligned buyer/supplier interests while ex-ante negotiation turns out to be hardly valuable at all.

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…

- … a vertical quality dimension rather than a horizontal one. In such a setting, cheap talk should not matter as all suppliers have a reason to let the buyer believe they can offer the highest possible quality. However, a large experimental literature suggests that cheap talk (in the form of promises) matters even in settings where standard game theory suggests it does not (see Charness and Dufwenberg, 2006, and the extensive literature building on it).
- … repeated interaction. Our experimental framework mimics one-shot interaction by rematching participants across periods. In the case of repeated interaction with the same set of suppliers, suppliers might want to build a reputation for truth-telling so that they are more inclined to inform the buyer truthfully.
- … procurement settings where both the suppliers and the buyer have private information relevant for the transaction. The question of the effect of two-sided cheap talk has been addressed theoretically for bilateral sealed-bid double auctions (see, e.g., Farrell and Gibbons, 1989, and Matthews and Postlewaite, 1989).
- … 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.

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

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Appendix A: Proofs of propositions

Proof of Proposition 1. Given the buyer's location choice x, it is a weakly dominant strategy for the buyers to bid their costs for completing the project at that location, i.e., $t_i f(|X - x|)$. The buyer prefers $x = 0$ over $x = -1$ or $x = 1$ if and only if

$$v_0 - \frac{2}{3}t_0 - \frac{1}{3}\big(f(0) + 2f(1)\big)E\big\{t^{(N-1)}\big\} \geq v_0 - t_0 - \frac{1}{3}\big(f(0) + f(1) + f(2)\big)E\big\{t^{(N-1)}\big\},$$

which is equivalent to

$$\frac{1}{3}t_0 + (f(2) - f(1))E\big\{t^{(N-1)}\big\} \geq 0,$$

which is Assumption A2. The buyer has no reason to deviate to projects -1 or 1 because this will increase the expected costs for the suppliers and hence the buyer's costs. In a descending reverse auction, it is a weakly dominant strategy for suppliers 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.

Proof of Proposition 2. If the buyer always chooses $x = 0$, babbling is a best response for the suppliers. If the suppliers use a babbling strategy, and if the buyer believes $X = 0$ after receiving an out-of-equilibrium message (if one exists) then, under Assumption A2, $x = 0$ is the buyer's best response. The equilibrium is neologism proof because no credible neologisms exist: if $X \neq 0$, when signaling the most preferred location to the buyer, if believed by the buyer, a supplier i is worse off because, conditional on winning, his payoffs are $f(0)\left(t_i - t_{-i}^{(N)}\right) < f(1)\left(t_i - t_{-i}^{(N)}\right)$, where $t_{-i}^{(N)}$ is the lowest type among supplier i's competitors. Now, consider an equilibrium in which the buyer deduces information from the suppliers' messages. Then it is in the suppliers' joint interest to deviate and send the message "I won't tell you my type" regardless of the actual type X. The buyer best responds by choosing $x = 0$. Each supplier i is at least as well off because, conditional on winning, his payoffs are $f(|X|)\left(t_i - t_{-i}^{(N)}\right) \geq f(|X - y|)\left(t_i - t_{-i}^{(N)}\right)$, where y is the buyer's equilibrium location choice. The inequality holds true because the buyer and the suppliers have opposite preferences regarding the location.

Proof of Proposition 3. The equilibrium is induced by the buyer always choosing the location corresponding to the winning supplier's message, where she chooses $x = 0$ if the winning supplier sends message $\emptyset$. This is the buyer's best response to the winning supplier's message strategy. Supplier i best responds by bidding $t_i f(0)$, which is his costs for completing the project in $x = X$. This equilibrium is neologism proof because the supplier maximizes his payoffs given the buyer's response to his message strategy.

Proof of Proposition 4. As $f(0) < f(1)$, it is readily verified that

$$\pi_{ex\ post} = v_0 - f(0)E\{t^{(N-1)}\} > v_0 - \frac{1}{3}f(0)E\{t^{(N-1)}\} - \frac{2}{3}\left(t_0 + f(1)E\{t^{(N-1)}\}\right)$$

$$= \pi_{ex\ ante} = \pi_{no}.$$

Proof of Proposition 5. The equilibrium is induced by the buyer choosing the location corresponding to the suppliers' messages in case they send the same message, and choosing $x = 0$ if the suppliers are not univocal or if all suppliers send message $\emptyset$. This is the buyer's best response to all suppliers' sending message X. It is not in the interest of supplier i to deviate to sending another message than X because, conditional on winning the auction, his payoffs are $f(X)\left(t_i - t_{-i}^{(N)}\right) \leq f(0)\left(t_i - t_{-i}^{(N)}\right)$, where $t_{-i}^{(N)}$ is the lowest type among supplier i's competitors. In the auction, each supplier i bids $t_i f(0)$, which is his costs for completing the project in $x = X$. This equilibrium is neologism proof because the supplier maximizes his payoffs given the buyer's response to his message strategy.

Proof of Proposition 6. If the buyer always chooses $x = 0$, babbling is a best response for the winning supplier. If the winning supplier uses a babbling strategy, and if the buyer believes $X = 0$ after receiving an out-of-equilibrium message (if one exists), then $x = 0$ is the buyer's best response as her *a priori* expected utility from locations $X = -1,1$ is lower than that from $X = 0$. The equilibrium is neologism proof because no credible neologisms exist: when signaling the most preferred location to the buyer, if believed by the buyer, the winning supplier i is worse off because his costs are $f(0)t_i \geq f(X)t_i$. Similarly, suppose an equilibrium in which the buyer can deduce useful information from the winning supplier's message cannot exist because the buyer and the winning supplier have opposite preferences regarding the location.

Proof of Proposition 7.

$$\pi_{ex\ ante}^{B} = v_0 - f(0)E\{t^{(N-1)}\} > \pi_{ex\ post}^{B} = \pi_{no}^{B} = v_0 - \tfrac{1}{3}f(0)E\{t^{(N-1)}\} - \tfrac{2}{3}\left(t_0 + f(1)E\{t^{(N-1)}\}\right)$$

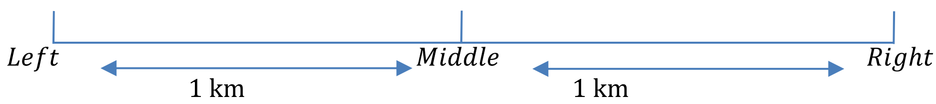
$$\Leftrightarrow t_0 > (f(0) - f(1))E\{t^{(N-1)}\}.$$

Appendix B: English translation of instructions

WELCOME
You are about to participate in an economic experiment. You have already earned 20 RMB for showing up on time. You may make more money in today's experiment. How much more you make depends on your decisions and the decisions of other participants. Your earnings will be paid to you via Wechat Pay in RMB at the end of the experiment. This will be done confidentially. This is an anonymous experiment: your identity will not be revealed to any other participant.
Please read the instructions carefully. During the experiment, you are not allowed to use your mobile phone or any other electronic device. You are also not allowed to talk to other participants or to communicate with them in any way. If you want to ask a question, please raise your hand and someone will come to your desk.
Earnings in the experiment will be denoted by 'points.' At the end of the experiment, the points will be exchanged for RMB.

OVERVIEW OF THE EXPERIMENT
In today's experiment, all participants will be randomly divided into groups of four people. One group member is a buyer and the other three are suppliers. Neither the group composition nor the roles will change during the experiment. You will not know the identity of any group member nor will they know your identity.
You will participate in 40 auctions. In these auctions, the three suppliers bid to complete a project on behalf of the buyer. The buyer cares about the location in which the project is completed. However, the buyer does not know which location would make the project most valuable (we'll call such a location 'the most valuable location' henceforth). The three suppliers know where the most valuable location is. In some auctions, the suppliers get the opportunity to recommend a location to the buyer. At the start of the experiment, the computer will inform you of whether you are a buyer or a supplier.
At the end of the experiment, 15 out of 40 rounds are randomly selected for payment. Please, keep in mind that you may make negative payoffs in an auction.
In the remainder of these instructions, we will explain the way in which the auction is organized.

<u>Setting ALIGN</u>
THE BUYER
The buyer wants to complete a project on one of three potential locations: Left, Middle, and Right. The locations are depicted in the figure below. As you can see, both Left and Right are 1 kilometer away from Middle. Left and Right are located 2 kilometers away from each other.



The buyer does not know the most valuable location for him[10] to complete the project at. Each location is equally likely to be the most valuable location. If the project is completed at the most valuable location, the buyer earns 260 points. The farther away the project is from the most valuable location, the less the buyer earns. More precisely, the buyer earns $260 - 60d$, where d is the project's distance to the most valuable location.
The table below shows that how much the buyer earns depends on the most valuable location and the actual location of the project.

		Actual location		
		Left	Middle	Right
Most valuable location	Left	260	200	140
	Middle	200	260	200
	Right	140	200	260

In each cell of the table, you can see how many points the buyer earns depending on the most valuable location (in the row) and the actual location (in the column). For example, if the most valuable location is

[10] In Mandarin, it is common to use the male gender for situations in which the gender is unknown.

Left and he chooses to build the project at Right, the buyer earns 140 points, so 120 points less than if he built it at the most valuable location.

THE SUPPLIERS

The buyer selects a supplier to complete the project. For this, he invites three suppliers to bid in an auction. The winning supplier will complete the project. The buyer will pay the winner the price determined in the auction.

Before bidding, the suppliers learn which location is the most valuable.

The winning supplier has to travel to the actual location of the project. His cost of completing the project depends on his travel distance to the actual location. The travel distance D for the suppliers is $D = 1 + d$, where d is the distance between the project's location and the most valuable location (as previously discussed).

TRAVEL COSTS

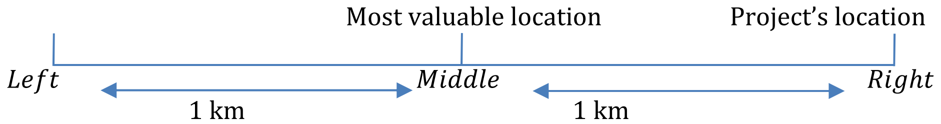
The travel costs per kilometer (t) will typically differ from one supplier to the next. To be more precise, in every round, the computer will draw a new cost for every supplier. Costs are drawn from the set {10, 11, 12, ..., 59, 60}.

Note the following about the travel costs per kilometer:

1. The travel costs per kilometer for a supplier is determined independently of the travel costs per kilometer for the other two suppliers;
2. Any value in the set {10, 11, 12, ..., 59, 60} is equally likely;
3. Each supplier only learns his own travel costs, not the travel costs of the other suppliers;
4. The buyer is not informed about the travel costs of any of the three suppliers.

For a supplier, the total costs are the travel costs per kilometer (t) times the travel distance ($D = 1 + d$, with d being the distance from the actual location to the most valuable location). So, a supplier's total costs are $t \times D = t \times (1 + d)$.

EXAMPLE



Consider the figure above. The most valuable location is Middle, and the winning supplier needs to complete the project at Right, then his travel distance is:

$D = 1 + d = 1 + 1 = 2$,

If his travel cost per kilometer (t) is 30, then his total costs are

$t \times D = t \times (1 + d) = 30 \times (1 + 1) = 60$.

THE AUCTION

Which supplier completes the project and how much the buyer pays him (p) is determined in an auction. The auction works as follows.

The computer gradually decreases the price, starting from 180 points. At each price, each supplier can opt to step out of the auction.

When the first supplier steps out of the auction, the other two suppliers are informed of the price at which he stepped out. The auction ends when the second supplier steps out of the auction. The remaining supplier wins the auction and completes the project. This supplier receives the price at which the second supplier stepped out of the auction.

Suppose that the auction ends when two or three suppliers step out at the same price. Then, the computer will randomly determine which of these suppliers wins. This winning supplier receives the price at which they stepped out.

EARNINGS FOR THE SUPPLIERS

The payoffs for the suppliers depend on both the outcome of the auction and the location of the project.

If a supplier wins the project, his earnings in a round will depend on both the price determined in the auction (p) and the location of the project in the following way:

(Earnings) = (Price) – (Total costs)

= (Price) – (Travel costs per kilometer) × (Travel distance)

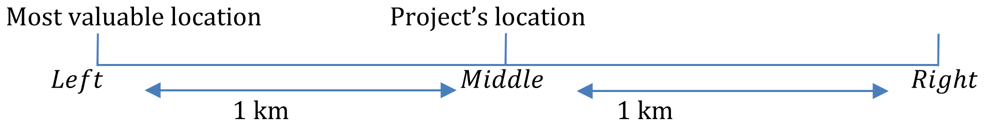
$= p - t \times D$

$= p - t \times (1 + d)$

where d is the distance between the project's location and the most valuable location.
If a supplier does not win the project, his earnings in a round are zero.
At the end of the experiment, the suppliers' earnings will be exchanged to RMB at the exchange rate of 1 point = 1 RMB.

EARNINGS FOR THE BUYER
The earnings for the buyer depend on both the outcome of the auction and the location of the project:
(Earnings) = (Project earnings) – (Price) = $(260 - 60 \times d) - p$
where d is the distance between the project's location and the most valuable location.
At the end of the experiment, the buyer's earnings will be exchanged to RMB at the exchange rate of 30 points = 1 RMB.

EXAMPLE



Consider the figure above. The most valuable location is Left, and the project is built at Middle. If a supplier has a travel cost per kilometer of 20 and wins the auction at price 100, each participant's earnings are as following:
The buyer: $(260 - 60 \times d) - p = (260 - 60 \times 1) - 100 = 100$ points.
The winning supplier: $p - \mathrm{t} \times (1 + d) = 100 - 20 \times (1 + 1) = 60$ points.
The other two suppliers: 0 points.
In the above example, with everything else being the same except that the project is chosen to be built at Left. Then each one's additional net gain are as follows:
The buyer: $(260 - 60 \times \mathrm{d}) - p = (260 - 60 \times 0) - 100 = 110$ points.
The winning supplier: $p - t \times (1 + d) = 100 - 20 \times (1 + 0) = 80$ points.
The other two suppliers: 0 points.

TEST QUESTIONS
Please answer these questions. If you are satisfied with your answers click 'ready,' if you want to go back to the instructions click 'instructions,' if you need help, please raise your hand.
1. Is the following statement correct? In each round, I am always coupled with the same three other people. Yes/No (Yes)
2. Is the following statement correct? 'A supplier will observe the travel costs per kilometer of the other two suppliers before the start of the auction.' Yes/No (No)
3. Suppose that the most valuable location is Middle, and the project is built at Left. A supplier's travel costs per kilometer are 17, and he wins the auction at a price of 78.
What are this supplier's payoffs (in points)?
What are the buyer's payoffs (in points)?
4. Suppose that the most valuable location is Left and the project is built at Right. If a supplier's travel costs per kilometer are 17 and he wins the auction at a price of 125.
What are this supplier's payoffs (in points)?
What are the buyer's payoffs (in points)?

PART 1
Today's experiment consists of three parts. At the beginning of each part, we will give you the corresponding instructions.
In each part, we run several auctions. In total, you will interact in 40 auctions. At the end of the experiment, 15 out of those 40 auctions will be randomly selected for payment.
Part 1 consists of 9 auctions. In each round, the computer determines the location at which the project is completed before the start of the auction.
Please, press the OK button and we will then proceed with the first auction.

PART 2
Part 2 consists of 7 auctions. In each round, the buyer determines the location at which the project is completed before the start of the auction.

Please, press the OK button and we will then proceed with the first auction.

PART 3 [ex ante]
Part 3 consists of 24 rounds. Each round consists of the following three steps:

1. Each supplier can recommend that the buyer build in a particular location. The recommendation can be chosen from the following four alternatives: Left, Middle, Right, and No Recommendation.
2. After receiving all the suppliers' recommendations, the buyer chooses a location to build the project (Left, Middle, or Right). All the suppliers are then informed of the buyer's choice as well as their own costs of building at that location.
3. All suppliers interact in the auction.

TEST QUESTIONS [ex ante]
Please answer these questions. If you are satisfied with your answers click 'ready' to proceed to the auctions, if you want to go back to the instructions click 'previous.' If you need help, please raise your hand.
1. Is the following statement correct? Suppose that all suppliers recommend Left. The buyer is allowed to choose location Middle. Yes/No
2. Is the following statement correct? When bidding in the auction, all suppliers know the location at which the project is completed. Yes/No

PART 3 [ex post]
Part 3 consists of 24 rounds. Each round consists of the following three steps:

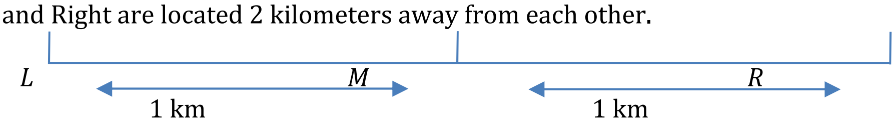
1. All suppliers interact in the auction.
2. The winning supplier can recommend that the buyer build in a particular location. The recommendation can be chosen from the following four alternatives: Left, Middle, Right, and No Recommendation.
3. After receiving the winning supplier's recommendation, the buyer chooses a location to build the project (Left, Middle, or Right).

Notice that when bidding in the auction, the suppliers do not know where the buyer will locate the project.

TEST QUESTIONS [ex post]
Please answer these questions. If you are satisfied with your answers 'ready' to proceed to the auctions, if you want to go back to the instructions click 'Previous,' if you need help, please raise your hand.
1. Is the following statement correct? Suppose that the winning supplier recommend Left. The buyer is allowed to choose location Middle. Yes/No
2. Is the following statement correct? When bidding in the auction, all suppliers know the location at which the project is completed. Yes/No

<u>Setting MISAL</u>

THE BUYER
A buyer wants to complete a project on one of three potential locations: Left, Middle, and Right. The locations are depicted in the figure below. As you can see, both Left and Right are 1 kilometer away from Middle. Left and Right are located 2 kilometers away from each other.



The buyer does not know which location is the most valuable for him to complete the project at. Each location is equally likely to be the most valuable location. If the project is completed at the most valuable location, the buyer earns 300 points. The farther away the project is from the most valuable location, the less the buyer earns. More precisely, the buyer earns $300 - 120d$, where d is the project's distance to the most valuable location.
The table below shows how much the buyer earns depends on the most valuable location and the actual location of the project.

		Actual location		
		Left	Middle	Right
Most valuable location	Left	300	180	60
	Middle	180	300	180
	Right	60	180	300

In each cell of the table, you see how many points the buyer earns depending on the most valuable location (in the row) and the actual location (in the column). For example, if the most valuable location is Left and he chooses to build the project at Right, the buyer earns 60 points, so 240 points less than if he built it at the most valuable location.

THE SUPPLIERS

The buyer selects a supplier to complete the project. For this, he invites three suppliers to bid in an auction. The winning supplier will complete the project. The buyer will pay the winner the price determined in the auction.

Before bidding, the suppliers learn where the most valuable location is.

The winning supplier has to travel to the actual location of the project. His cost of completing the project depends on his travel distance to the actual location. The travel distance D for the suppliers is $D = 3 - d$, where d is the distance between the project's location and the most valuable location (as previously discussed).

TRAVEL COSTS

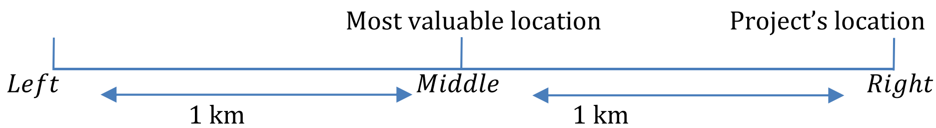
The travel costs per kilometer (t) will typically differ from one supplier to the next. To be more precise, in every round, the computer will draw a new cost for every supplier. Costs are drawn from the set {10, 11, 12, …, 39, 40}.

Note the following about the travel costs per kilometer:

1. The travel costs per kilometer for a supplier is determined independently of the travel costs per kilometer for the other two suppliers;
2. Any value in the set {10, 11, 12, …, 39, 40} is equally likely;
3. Each supplier only learns his own travel costs, not the travel costs of the other suppliers;
4. The buyer is not informed about the travel costs of any of the three suppliers.

For a supplier, the total costs are the travel costs per kilometer (t) times the travel distance ($D = 3 - d$, with d being the distance from the actual location to the most valuable location). More precisely, a supplier's total costs are $t \times D = t \times (3 - d)$.

EXAMPLE



Consider the figure above. The most valuable location is Middle, and a supplier needs to complete the project at Right, then his travel distance is:

$D = 3 - d = 3 - 1 = 2,$

If his travel cost per kilometer (t) is 30, then his total costs are

$t \times D = t \times (3 - d) = 30 \times (3 - 1) = 60.$

THE AUCTION

Which supplier completes the project and how much the buyer pays him (p) is determined in an auction.

The auction works as follows.

The computer gradually decreases the price, starting from 120 points. At each price, each supplier can opt to step out of the auction.

When the first supplier steps out of the auction, the other two suppliers are informed of the price at which he stepped out. The auction ends when the second supplier steps out of the auction. The remaining supplier wins the auction and completes the project. This supplier receives the price at which the second supplier stepped out of the auction.

Suppose that the auction ends when two or three suppliers step out at the same price. The computer will then randomly determine which of these suppliers wins. This winning supplier receives the price at which they stepped out.

EARNINGS FOR THE SUPPLIERS

The payoffs for the suppliers depend on both the outcome of the auction and the location of the project.

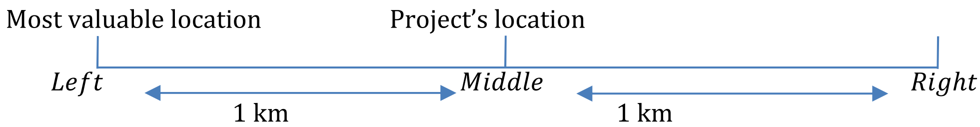
If a supplier wins the project, his earnings in a round will depend on both the price determined in the auction (p) and the location of the project in the following way:

(Earnings) = (Price) – (Total costs)
= (Price) – (Travel costs per kilometer) × (Travel distance)
= $p - t \times D$
= $p - t \times (3 - d)$

where d is the distance between the project's location and the most valuable location.
If a supplier does not win the project, his earnings in a round are zero.
At the end of the experiment, the suppliers' earnings will be exchanged to RMB at the exchange rate of 1 point = 1 RMB.

EARNINGS FOR THE BUYER
The earnings for the buyer depend on both the outcome of the auction and the location of the project:
(Earnings) = (Project earnings) – (Price) = $(260 - 60 \times d) - p$
where d is the distance between the project's location and the most valuable location.
At the end of the experiment, the buyer's earnings will be exchanged to RMB at the exchange rate of 30 points = 1 RMB.

EXAMPLE



Consider the figure above. The most valuable location is Left, and the project is built at Middle. If a supplier has a travel cost per kilometer of 20 and wins the auction at price 100, each participant's earnings are as following:
The buyer: $(300 - 120 \times d) - p = (300 - 120 \times 1) - 100 = 80$ points.
The winning supplier: $p - \mathrm{t} \times (3 - d) = 100 - 20 \times (3 - 1) = 60$ points.
The other two suppliers: 0 points.
In the above example, with everything else being the same except that the project is chosen to be built at Left. Then each one's additional net gain is as follows:
The buyer: $(300 - 120 \times \mathrm{d}) - p = (300 - 120 \times 0) - 100 = 200$ points.
The winning supplier: $p - t \times (3 - d) = 100 - 20 \times (3 - 0) = 40$ points.
The other two suppliers: 0 points.

TEST QUESTIONS
Please answer these questions. If you are satisfied with your answers click 'ready,' if you want to go back to the instructions click 'Previous,' if you need help, please raise your hand.

1. Is the following statement correct? In each round, I am always coupled with the same three other people. Yes/No
2. Is the following statement correct? 'A supplier will observe the travel costs per kilometer of the other two suppliers before the start of the auction.' Yes/No
3. Suppose that the most valuable location is Middle, and the project is built at Left. A supplier's travel costs per kilometer are 17, and he wins the auction at a price of 78.
What are this supplier's payoffs (in points)?
What are the buyer's payoffs (in points)?
4. Suppose that the most valuable location is Left and the project is built at Right. If a supplier's travel costs per kilometer are 17 and he wins the auction at a price of 32.
What are this supplier's payoffs (in points)?
What are the buyer's payoffs (in points)?

PART 1
Today's experiment consists of three parts. At the beginning of each part, we will give you the corresponding instructions.
In each part, we run several auctions. In total, you will interact in 40 auctions. At the end of the experiment, 15 out of those 40 auctions will be randomly selected for payment.

Part 1 consists of 9 auctions. In each round, the computer determines the location at which the project is completed before the start of the auction.
Please, press the OK button and then we will proceed with the first auction.

PART 2
Part 2 consists of 7 auctions. In each round, the buyer determines the location at which the project is completed before the start of the auction.
Please, press the OK button and then we will proceed with the first auction.

PART 3 [ex ante]
Part 2 consists of 24 rounds. Each round consists of the following three steps:

1. Each supplier can recommend that the buyer builds in a particular location. The recommendation can be chosen from the following four alternatives: Left, Middle, Right, and No Recommendation.
2. After receiving all the suppliers' recommendations, the buyer chooses a location to build the project (Left, Middle, or Right). All the suppliers are then informed of the buyer's choice as well as their own costs of building at that location.
3. All suppliers interact in the auction.

Please answer two questions to show that you fully understand the instructions before we proceed with the first auction.

TEST QUESTIONS [ex ante]
Please answer these questions. If you are satisfied with your answers click 'ready' to proceed to the auctions, if you want to go back to the instructions click 'instructions', if you need help, please raise your hand.
1. Is the following statement correct? Suppose that all suppliers recommend Left. The buyer is allowed to choose location Middle. Yes/No (Yes)
2. Is the following statement correct? When bidding in the auction, all suppliers know the location at which the project is completed. Yes/No (Yes)

PART 3 [ex post]
Part 2 consists of 24 rounds. Each round consists of the following three steps:

1. All suppliers interact in the auction.
2. The winning supplier can recommend that the buyer build in a particular location. The recommendation can be chosen from the following four alternatives: Left, Middle, Right, and No Recommendation.
3. After receiving the winning supplier's recommendation, the buyer chooses a location to build the project (Left, Middle, or Right).

Notice that when bidding in the auction, the suppliers do not know where the buyer will locate the project.
Please answer two questions to show that you fully understand the instructions before we start the auctions.

TEST QUESTIONS [ex post]
Please answer these questions. If you are satisfied with your answers click 'ready' to proceed to the first auction, if you want to go back to the instructions click 'instructions,' if you need help, please raise your hand.
1. Is the following statement correct? Suppose that the winning supplier recommend Left. The buyer is allowed to choose location Middle. Yes/No
2. Is the following statement correct? When bidding in the auction, all suppliers know the location at which the project will be completed. Yes/No