Collusion through Communication in Auctions

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Abstract

We study the extent to which communication can serve as a collusion device in one-shot first- and second-price sealed-bid auctions. Theoretically, communication between bidders does not change the set of equilibrium outcomes in first-price auctions, but substantially expands the set of equilibrium outcomes in second-price auctions. In an array of laboratory experiments we vary the amount of interactions (communication and/or transfers without commitment) available to bidders. We find that the auctioneer’s revenues decrease significantly when bidders can communicate. When, in addition, bidders can make transfer promises, revenues decline substantially, with 70% of our experimental auctions culminating in the object being sold for approximately the minimal price. Furthermore, the effects of communication and transfers are similar across auction formats.

Keywords: Auctions, Communication, Collusion, Experiments

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1 Introduction

1.1 Overview

Collusion has been a long-standing problem for auction design. Krishna (2002) reported that in the 1980s, collusion and auctions went hand-in-hand: 75% of U.S. cartel cases involving collusion were auction-based. To date, approximately 30% of antitrust cases filed by the Department of Justice since 1994 involved bid-rigging in industries such as construction, antique sales, military supplies, utility procurement, etc.\(^1\) The prevalence of collusion in auctions has led to a substantial body of theoretical work in the Economics literature. By and large, this literature has taken two approaches to explaining the emergence of collusion: through repeated interactions between bidders, and through bidding that occurs over multiple objects (simultaneously or over time). Roughly speaking, both approaches allow bidders to devise joint schemes in which winning bidders alternate over time or over objects. Winning prices are low, because at each period, or for each object, only a select group of bidders is bidding competitively (see our literature review below). We suggest an alternative, possibly complementary, channel through which collusive outcomes may emerge. Namely, we study the effects of communication in one-shot, sealed-bid, first- and second-price auctions. We provide theoretical and experimental results that suggest that communication alone can affect auction outcomes dramatically.

As a motivating example, consider a sealed-bid second-price auction with two bidders, with independent private values drawn from \{0, 1\} with equal probabilities for each value. The unique equilibrium in weakly undominated strategies entails both bidders bidding their values. This would suggest a price of 0 whenever at least one of the bidders values the object at 0, and a price of 1 when both bidders value the object at 1. Suppose now that bidders participate in a pre-play communication phase after learning their values, but prior to bidding, and consider the following protocol. Bidders reveal their values. If either has a value of 0, they both bid their values. However, if both have a value of 1, they toss a fair coin. If it falls on Heads, bidder 1 submits a bid of 0 and bidder 2 submits a bid of 1. If the coin falls on Tails, bidder 1 submits a bid of 1 and bidder 2 submits a bid of 0. This profile constitutes part of an equilibrium: bidders have no incentive to lie nor to submit bids different than those prescribed. Furthermore, the price of the object under such a protocol is always 0. Communication allows bidders to coordinate their bids, contingent on their values.

In our theoretical analysis (Section 3) we consider sealed-bid first- and second-price auctions with two bidders whose values are independently and privately drawn from a uniform

\(^1\)According to the authors’ tabulation, 438 cases out of 1423 antitrust cases involved bid-rigging, see: http://www.justice.gov/atr/cases/
distribution. We show that, as in the example, the set of equilibrium outcomes expands when cheap-talk communication is available in second-price auctions.\footnote{In the example above, the bidders effectively randomize between the symmetric equilibrium, and two asymmetric equilibria (in which one bidder bids 0 and the other 1). In Section 3 we show that the set of equilibrium outcomes strictly contains the convex hull of the equilibrium outcomes without communication.} In contrast, in first-price auctions, a result by Lopomo, Marx, and Sun (2011) illustrates that communication does not impact outcomes. In theory, then, second-price auctions are potentially more fragile to collusion through communication than first-price auctions.

Analyzing the impacts of communication on real-world auction outcomes is difficult to do. Communication is often tacit and unobserved, and private values, available information, etc. are unknown. Laboratory experiments are therefore particularly useful as initial tests of the impacts of communication in auction settings.

We report results from an array of experimental first- and second-price auctions with two bidders. For each auction format, we run three treatments. The first corresponds to auctions without communication, mimicking some of the original designs of experimental auctions (e.g., Cox, Roberson, and Smith, 1982, Dyer, Kagel, and Levin, 1989, Kagel and Levin, 1993, and Harstad, 1991). In our second treatment, subjects freely communicate using an instant messaging screen after observing their private values and prior to bidding. Our third treatment is a modification of the second treatment – subjects freely communicate after observing their values and before bidding and, furthermore, can transfer money to one another (in one simultaneous decision) after seeing the auction results, i.e. the winning bidder and the object’s price. Importantly, in all our sessions we randomly match bidders in each round and in several sessions we employ a complete-strangers protocol in which subjects are never rematched with the same individual. This assured that there are no repeated interaction effects in our design and any collusive behavior is an artifact of the one-shot interaction alone.

The results from our treatments without communication replicate those already noted in the literature. Bidders over-bid in both auction formats and efficiency levels (the probabilities with which the high-value bidder wins the object) are high, hovering around 80%.

Communication by itself leads to significant price drops, reducing the auctioneer’s revenues by up to 33%. From a theoretical perspective, the availability of ex-post transfers should have no effect on outcomes (since there is no incentive to transfer money after the fact). However, the availability of transfers makes a substantial difference in the lab. In particular, the reduction of prices is especially stark in sessions in which both communication and transfers are available. In fact, in about 70% of both first- and second-price auctions in which communication and transfers were available, the object’s price is zero. As
a consequence, the availability of communication and transfers significantly reduces revenues under both auction formats, yielding less than one third of the revenues generated when all communication is banned under either auction format. This is interesting in view of the Department of Justice data – transfers were explicitly mentioned in 148 of the reported 438 antitrust cases involving bid-rigging.

Nonetheless, a sort of Revenue Equivalence Theorem result holds in our data as revenues are not significantly different from one another across auction formats, in all our treatments. Furthermore, the availability of communication and/or transfers does not significantly affect efficiency levels.

When inspecting the communication protocols, we see that subjects tend to discuss two types of strategies. One, which we term flip-a-coin, entails subjects both submitting the same (often low) bid and thereby generating a fifty-fifty chance of each receiving the object; The other, which we term reveal-collude, entails subjects revealing their values and then submitting bids that assure a low price and the high-value bidder winning the object. The flip-a-coin strategy is simpler for subjects to manipulate; One of the bidders need only submit a slightly higher bid than agreed to win the object. Indeed, while that strategy is discussed at fairly high rates, particularly when only communication is available, it is infrequently followed. In contrast, the reveal-collude strategy is often followed when discussed and is the predominant strategy subjects discuss when transfers are available.

In terms of what subjects reveal during communication, the availability of transfers makes a substantial difference. Without transfers, subjects often do not share their private values or their intended bids. When they do, they often understate both their values and the bids they plan to submit. When transfers are available, misrepresentation diminishes significantly and truthful revelation of values and bids is part of the modal communication protocol.

We also see a persistent pattern of behavior at the transfers stage. When the ultimate price is high, indicating the bidders did not successfully collude, transfers are rare. However, when ultimate prices are close to zero, winning bidders submit an average of 44% of their surplus, with a modal transfer of 50%. This suggests a coherent description of how subjects achieve collusive outcomes: they first share their values and then bid in a way that allows the high-value bidder to win the object at a low price (in the first-price auction, this means that both bidders submit a low bid, in the second-price auction, at least the losing bidder submits a low bid). The winning bidder then shares her surplus with the losing bidder, so long as the final price is low. This behavior is in line with several case studies of bid rigging. For instance, Pesendorfer (2000) studied bidding for school milk contracts in Florida and Texas during the 1980s. His data suggest that in Florida, the school milk cartel used side payments to compensate bidders for refraining from bidding competitively, which is effectively what
we see in our experimental data.

The behavior we observe also hints at why collusive outcomes are easier to achieve when transfers are available. Without transfers, losing bidders, who must submit low bids to generate a collusive outcome, do not gain from their behavior. The only beneficiary is the winning bidder. In contrast, transfers allow subjects to align their preferences.

1.2 Related Literature

The empirical literature documents many cases in which bidders in a variety of auction formats colluded (see, for instance, Hendricks and Porter, 1989 and Marshall and Marx, 2012 for reviews).

Following the prevalence of bid-rigging in auctions, a large body of theoretical work on collusion in auctions has emerged. Much of this work analyzes settings with repeated interactions, in which, roughly speaking, bidders can collude by devising schemes that split the auctions won over time (see Abreu, Pearce, and Stachetti, 1986, Athey and Bagwell, 2001, and Skrzypacz and Hopenhayn, 2004). Another approach considers multi-object auctions, in which collusive outcomes can emerge from bidders “splitting the market”; namely, bidders decide on which objects whom will bid on competitively (see, e.g., Kwasnica, 2002 and Brosco and Lopomo, 2002). Several papers study how communication affects the set of equilibrium outcomes in sealed bid one-shot auctions. McAfee and McMillan (1992) show that cartels can achieve full efficiency in auctions with side transfers and pre-stage communication and commitment. Without transfers, the best payoffs the cartel can achieve are generated by either non-cooperative bidding or bid rotation schemes, in which the winner is decided upon independently of her value. Without commitment, Lopomo, Marx, and Sun (2011) show that in an independent-value setting, a bidding ring operating at a first-price sealed-bid auction cannot achieve any gains relative to non-cooperative bidding, a result we will see is special to first-price auctions.³

In terms of experimental work, our paper relates to the strand of experimental literature that studies behavior in one-shot sealed-bid auctions (see Kagel and Levin, 1993, Cox, Roberson, and Smith, 1992, and the surveys by Kagel, 1995 and Kagel and Levin, 2011). However, to our knowledge, the question of how cheap-talk communication affects behavior in one-shot sealed-bid auctions has not been tackled before – that is our main contribution.⁴

³Matthews and Postlewaite (1989) study k-double auctions with a bidder and a seller who have private values of a good. Communication enlarges the set of equilibrium outcomes and renders the set of equilibrium outcomes identical across all k-double auctions, k ∈ [0, 1]. Bergemann, Brooks, and Morris (2013) study two-bidder first-price auctions with private values and identify the information structures that minimize revenues, which in turn link to the information structures buyers may desire collectively to increase their surplus.

⁴Isaac and Walker (1995) study the effects of face-to-face communication in a repeated first-price, private
Outside the realm of auctions, a growing experimental literature explores the effects of cheap-talk communication on strategic outcomes; see Crawford (1998) for a survey of some early literature, most of which placed strict restrictions on the messages sent. Recently, more studies have focused on free-form unrestricted communication rather than structured restricted communication. Unrestricted communication has been shown to affect strategic behavior of subjects in various environments, including hidden-action games (such as trust games) and hidden-information games as in Charness and Dufwenberg (2006, 2011), weak link games as in Brandts and Cooper (2007), bargaining as in Agranov and Tergiman (2014) and Baranski and Kagel (2015), collective action settings as in Goeree and Yariv (2011), and public good games as in Oprea, Charness, and Friedman (2015). One coherent message emerging from this body of work is that communication promotes coordination on Pareto superior outcomes. In all these settings, however, the outcomes observed with communication tend to benefit all participating individuals. In contrast, in the auction environment, a collusive outcome in which the object is won at a low price entails a huge asymmetry between players: only one bidder (the winner) benefits from driving the final prices down, while others do not gain from colluding. In particular, it is hard to extrapolate existing results to the auction environment.

2 Experimental Design

We use a sequence of first-price and second-price independent private-value auctions involving two bidders.\(^5\) In all of our experimental auctions, each bidder bids for one object, the value of which is drawn independently from a uniform distribution over \([0, 100]\), where each experimental point corresponds to 1 cent. In all of our treatments, both bidders submit a bid. The winner of the object is the highest bidder, generating the value of the object to the winner (and no reward for the loser of the auction). The price, paid only by the winner of the object, is given by the highest bid in the first-price auction and the lowest bid in the second-price auction; ties are broken randomly. Sessions varied in the amount and type of interaction that was available to bidders.

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\(^5\)The full instructions are available at: http://www.hss.caltech.edu/~lyariv/papers/Collusion_Instructions.pdf

value, sealed-bid auction. They restricted the communication protocols by banning discussion of private values or side payments. Kagel (1995) studied collusion in first-price common value auctions with reserve prices, under similar restrictions on communication protocols. There is also some experimental work focusing on repeated auctions and multi-object auctions (see Section 4.1 in Kagel and Levin, 2011).
No Communication. In these treatments, subjects observe their private values and then asked to simultaneously submit their bids. These treatments replicate the classical experimental auctions a-la, e.g., Kagel and Levin (1993).

Pure Communication. In these treatments, subjects observe their private values and are then able to communicate via an instant messenger screen. When at least one bidder decides to stop communication (expressed by a clickable button on the experimental interface), both bidders are asked to simultaneously submit their bids.

Communication with Transfers. In these treatments, subjects observe their private values, are then able to communicate freely, and, after communication comes to a halt, submit bids simultaneously (as in the pure communication treatment). Once bids are entered, the results of the auction are observed by both bidders. Then, each bidder can choose to make a transfer to the other bidder (greater or equal to zero). The ultimate payoff for each bidder is their auction payment plus their net transfers.

To summarize, the experiments employ a $2 \times 3$ design based on the variation in the auction format (first-price and second-price) and the type of interaction available between bidders. Each experimental session implemented one combination of auction format and interaction type. Three to six sessions were run for each treatment. Most sessions entailed one practice round followed by 10 periods of actual play, and subjects were randomly paired in each period. In several of the sessions, we employed a complete strangers protocol, in which subjects were never paired more than once with another subject. While such sessions require more subjects, they allow us to eliminate repeated game effects altogether.

In addition, in several sessions we elicited risk attitudes using the Gneezy and Potters (1997) methodology. Namely, at the end of each of these sessions, we asked subjects to allocate 100 points (translating into $2) between a safe investment, which had a unit return (i.e., returning point for point), and a risky investment, which with probability 50% returned 2.5 points for each point invested and with probability 50% produced no returns for the investment. Any amount earned from this task was added to the overall earnings in the session. Table 1 summarizes our design details.

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6For one treatment, an additional session was run, but due to some slow subjects, the number of rounds was low. This session produced indistinguishable results from our other sessions. However, since for much of our analysis we focus on rounds 6 and on, we excluded this session from our data.

7In several sessions we allowed for subjects to go through up to 15 rounds. However, due to time constraints, most of the sessions were run with 10 rounds only.

8This method is among the more popular ones to elicit risk attitudes of subjects in laboratory experiments (see survey of Charness, Gneezy, and Imas, 2013).
The experiments were conducted at the Experimental Social Sciences Laboratory (ESSL) at University of California at Irvine. Overall, 296 subjects participated. The average payoff per subject was $22, including a $12 show-up fee.

There are a few points to note regarding our design choices. First, we allowed subjects to communicate freely rather than offer them a restricted set of messages, which would have arguably made the analysis simpler. Our decision was due to several reasons: while laboratory auctions certainly have artificial features that do not perfectly match real auctions, we did want to make the communication as organic as possible. In fact, the endogenous communication protocols were something we wanted to inspect. As will be seen, different treatments led to different communication protocols that would have been hard for us to predict (and thereby design an appropriate set of restricted messages). In addition, we were concerned that by restricting communication protocols we would guide subjects toward particular patterns of behavior, thereby introducing a form of experimenter demand.

Second, we study auctions with only two bidders. Many auctions entail a fairly small number of bidders. For instance, the eBay analytics team reported to us that in 2013, 27% of auctions with multiple bidders had only two bidders participating (and 77% had five or fewer bidders). Nevertheless, auctions with more than two bidders are common and would

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\[9\] Hong and Shum (2002) also report a small number of bidders in general highway, construction, and grading and paving procurement auctions and Grether, Porter, and Shum (2014) report a small number of bidders (with averages ranging between 2 – 5) in used automobile auctions.

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### Table 1: Experimental Design

<table>
<thead>
<tr>
<th>Auction Format</th>
<th>Available Interaction</th>
<th>Number of Subjects</th>
<th>Rounds*</th>
</tr>
</thead>
<tbody>
<tr>
<td>First-price</td>
<td>No Communication</td>
<td>30</td>
<td>(10, 10, 10)</td>
</tr>
<tr>
<td></td>
<td>Pure Communication</td>
<td>72</td>
<td>(15, 15, 15, <strong>10</strong>, 10**, 10**)</td>
</tr>
<tr>
<td></td>
<td>Communication with</td>
<td>48</td>
<td>(10, 11, 12, 10**)</td>
</tr>
<tr>
<td></td>
<td>Transfers</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Second-price</td>
<td>No Communication</td>
<td>36</td>
<td>(10, 10, 10)</td>
</tr>
<tr>
<td></td>
<td>Pure Communication</td>
<td>64</td>
<td>(10, 10, 15**, 10**)</td>
</tr>
<tr>
<td></td>
<td>Communication with</td>
<td>46</td>
<td>(10, 10, 10, 10**)</td>
</tr>
<tr>
<td></td>
<td>Transfers</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Each entry corresponds to the number of rounds run in a session.

**Sessions run with a complete strangers protocol.

Numbers in bold correspond to sessions in which risk was elicited.
be interesting for further study. We view the two-bidder auctions as a natural first step to studying collusion through communication: they are simple in that any negotiation is only between two individuals and communication is a two-way interaction. We view the study of auctions with more bidders as an interesting direction for the future.

Third, our design of the treatment allowing for transfers takes a very special form. In particular, we did not allow subjects more sophisticated contractual mechanisms, namely ones that would allow them to commit to, possibly contingent, transfers. In a way, the transfer instruments we provide are fairly weak (theoretically; they should have no impact at all), and yet, as we will see, they have a dramatic impact on outcomes. In that respect, we suspect that more elaborate transfer instruments may enable even greater levels of collusion. In Section 10.3 we return to this point and report results from auxiliary sessions that allowed for a particular form of commitment to transfers.

Last, we study sealed-bid first- and second-price auctions as opposed to English and Dutch auctions. Sealed-bid auctions are prevalent in applications and are simpler to implement in the lab with communication since there is a natural point in time for communication to occur. Studying the effects of communication on English and Dutch auctions, as well as other auction formats, is also left for the future.

3 Theoretical Background

Our theoretical background is tailored to our experimental design. We assume there are two risk-neutral bidders. Agents’ private valuations are taken from $V = [0, 100]$ according to distribution $F$. That is, at the outset, each individual knows her own value realization, but not the other bidder’s. Bids are restricted to $B = V = [0, 100]$.

We concentrate on first- and second-price auctions in which the highest bidder receives the good for a price corresponding to the highest and second highest bid, respectively. In either auction format, upon a tie, the winner is randomly chosen.

Absent communication, the first-price auction can generally yield multiple equilibria. However, in our setting, there is a unique symmetric equilibrium in which each bidder submits half her valuation (see Lebrun, 2004 and Maskin and Riley, 2003). In the second-price auction, there is a unique symmetric equilibrium, which entails strategies that are not weakly dominated, where each bidder bids precisely her value (see Fudenberg and Tirole, 1991). Nonetheless, there exist multiple asymmetric equilibria (for instance, one bidder bidding 100 and the other 0, regardless of their private values, is an equilibrium).\(^{10}\)

\(^{10}\)For three or more bidders, Blume and Heidhues (2004) characterize the full set of equilibria in second-price auctions without communication.
note that the Revenue Equivalence Theorem applies only to the comparison of first- and second-price auctions when the symmetric equilibrium is played.

In what follows, we consider the case, corresponding to some of our treatments, in which a cheap-talk stage is available after agents learn their private valuations and prior to submitting their bids. Formally, we consider the cheap-talk extensions of the first- and second-price auctions and study the induced set of equilibria.

From the revelation principle, an equilibrium with communication is tantamount to a mapping \( \mu : V^2 \to \Delta(B^2) \) satisfying two types of incentive constraints: truthful revelation and obedience. An equilibrium outcome is a mapping \( \gamma : V^2 \to \Delta(\{1,2\} \times [0,100]) \), which maps any reported value profile into a distribution over the winning bidder and the price paid for the object. Denote by \( \Gamma_k \) the set of equilibrium outcomes corresponding to the \( k \)-price auction with communication, \( k = 1, 2 \).

Lopomo, Marx, and Sun (2011) showed that there is a unique equilibrium with communication in the first-price auction. We now show that the set of equilibrium outcomes generated by the second-price auction strictly contains that generated by the first-price auction. That is:

**Proposition 1** The set of equilibria outcomes generated by second-price auctions with communication strictly contains the (unique) equilibrium outcome generated by the first-price auction, \( \Gamma_1 \subsetneq \Gamma_2 \).

**Proof.** Notice that the outcomes corresponding to equilibria of the second-price auction without communication (and any mixtures of those) remain equilibrium outcomes of the second-price auction with communication. We now show that the outcome corresponding to the unique equilibrium in the first-price auction can be emulated in the second-price auction with communication. Indeed, consider the following mapping:

\[
\mu(v_1, v_2) = \begin{cases} 
(100, \frac{v_1}{2}) & v_1 > v_2 \\
\left(\frac{v_2}{2}, 100\right) & v_1 < v_2 \\
\frac{1}{2} \otimes \left(100, \frac{v_1}{2}\right) + \frac{1}{2} \otimes \left(\frac{v_2}{2}, 100\right) & v_1 = v_2
\end{cases}
\]

where \( \frac{1}{2} \otimes \left(100, \frac{v_1}{2}\right) + \frac{1}{2} \otimes \left(\frac{v_2}{2}, 100\right) \) denotes a 50–50 mixture between the bid profile \( (100, \frac{v_1}{2}) \) and the bid profile \( \left(\frac{v_2}{2}, 100\right) \).

We now show that \( \mu \) constitutes an equilibrium of the second-price auction with communication. Notice first that it is never profitable for a bidder to deviate at the bidding stage when told to bid an amount lower than 100. In this case, the bidder knows the other bidder is bidding 100, and she can only win the object if she bids 100 too, in which case her profit would be at most 0. Now, suppose bidder \( i \) deviates by reporting \( \hat{v}_i \) and bidding \( \hat{b}_i \leq 100 \)
when told to bid 100. If $\hat{b}_i < \frac{\hat{v}_i}{2}$, she never wins the object and her expected payoff is 0. If $\hat{b}_i > \frac{\hat{v}_i}{2}$, her expected payoff is:

$$
\left[ \Pr(v_j < \hat{v}_i) + \frac{1}{2} \Pr(v_j = \hat{v}_i) \right] \left( v_i - \frac{\hat{v}_i}{2} \right) = \frac{2v_i\hat{v}_i - \hat{v}_i^2}{200},
$$

which is maximized at $\hat{v}_i = v_i$, in which case bidding $\hat{b}_i > \frac{\hat{v}_i}{2}$ or 100 generates the same expected payoff. If $\hat{b}_i = \frac{\hat{v}_i}{2}$, then the bidder receives half of the expected payoff she would receive by bidding 100, which is not profitable.

The equilibrium $\mu$ implements the same outcome that would have been achieved in the first-price auction without communication. The highest valuation bidder receives the good and pays a price that is precisely half of her valuation (when valuations coincide, each bidder gets the good with a 50−50 chance). This completes the proof.

Intuitively, an outcome of the first-price auction can be emulated by the second-price auction as follows. Whenever the bidders are to submit different bids, say $b_1 > b_2$ in the first-price auction, bidder 1 submits 100, thereby assuring she will receive the object, and bidder 2 submits $b_1$, thereby assuring the price is $b_1$. When bids coincide in the first-price auction, $b_1 = b_2 = b$, bidders can toss a fair coin in the second-price auction to determine who will bid 100 and who will bid $b$, which guarantees an equal chance of winning at the price $b$. In the proof we also show that this procedure assures truthful revelation.  

The set of equilibrium outcomes in the second-price auction with communication is large. Indeed, bidders can always publicly randomize during the communication phase over which equilibrium they intend to play, assuring that the set of equilibrium outcomes is a convex set. In particular, it contains the convex hull of the outcomes just discussed, those generated by the equilibrium of the first-price auction, as well as the symmetric and asymmetric equilibrium outcomes of the second-price auction (in fact, it strictly contains the convex hull of the set of equilibrium outcomes of second-price auctions without communication). The main message of the proposition is that communication has more of an impact on second-price auctions than it does on first-price auctions. Second-price auctions may then be viewed as more fragile to collusion through communication than first-price auctions.

There are two notes on this theoretical result. First, the cheap-talk extension of the auctions we consider implicitly assumes the availability of an impartial mediator (for the use of the Revelation Principle). The general characterization of games in which unmediated communication generates the same outcomes as mediated communication is a difficult

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11 In fact, the idea of the proof can be extended to auctions with more than two bidders. Furthermore, the inclusion can be extended to general $k$-price auctions. Using the notation in the text, a similar construction can then be used to show that $\Gamma_k \subseteq \Gamma_{k+1}$ for all $k \geq 1$. 

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problem (see Gerardi, 2004 and references therein and note that Gerardi, 2004 suggests that with five or more bidders, a mediator is unnecessary). Nonetheless, even absent a mediator, the set of equilibrium outcomes strictly expands when communication is introduced to second-price auctions (for instance, bidders can randomize between equilibria of the auction without communication). Second, we do not preclude weakly dominated strategies. This certainly simplifies the analysis, but the ultimate validity of this allowance is in the data. As will be seen from our experimental results (as well as extant ones for auctions without communication), subjects do not seem to focus on weakly undominated actions.

As described, in some of our treatments we allowed agents to communicate freely prior to bidding and exchange (simultaneously) non-negative transfers after bidding and learning the identity of the object’s winner. Formally, the game played is a first- or second-price auction followed by a transfer stage in which agents can simultaneously pick a non-negative number to transfer to the other bidder. Their ultimate payoff is then their payoff in the auction plus the net transfers they have received (the transfers the other bidder passed minus the transfers they had passed to the other bidder). Using backward induction, the availability of such ex-post transfers has no impact on the behavior in the preceding communication and auction phases. Indeed, backward induction would imply zero transfers in any subgame-perfect equilibrium and a behavior consistent with some equilibrium in the cheap-talk extension of our baseline auction before that. Let $\tilde{\Gamma}_k$ denote the set of equilibrium auction outcomes corresponding to the $k$-price auction with communication and transfers, $k = 1, 2$. That is, these are mappings from value profiles to distributions over winning probabilities and prices when both communication and transfers are available. We then have the following:

**Proposition 2** In any subgame-perfect equilibrium of the first- or second-price auctions with communication and transfers, no positive transfers are passed. Therefore, the sets of equilibrium outcomes coincide with those of the first- or second-price auctions with communication. That is, $\tilde{\Gamma}_1 = \Gamma_1 \subseteq \tilde{\Gamma}_2 = \Gamma_2$.

To summarize, there are three main theoretical results that are relevant to our design. First, without communication both auction formats entail unique equilibrium predictions when bidders use weakly undominated strategies, which are symmetric; The second-price auction entails multiple asymmetric equilibria if the domination restriction is dropped. Second, with communication, second-price auctions generate substantially more equilibrium outcomes than first-price auctions. In fact, communication has no impact on equilibrium outcomes of the first-price auction, while it expands the set of equilibrium outcomes of the second-price auction. In particular, the set of equilibrium outcomes of the second-price auction strictly contains the set corresponding to the first-price auction. Third, transfers have
no impact on outcomes in either auction format and outcomes are predicted to be identical to those in auctions with communication, but without transfers. Furthermore, no positive transfers are passed in any subgame-perfect equilibrium.\textsuperscript{12}

### 4 Approach to Data Analysis

In all that follows, we report analyses of our data in particular ways that we now discuss. First, we focus on rounds 6 through 10 in order to avoid noise due to learning. There are no significant round effects starting from round 6 and behavior in rounds later than 10 (that some sessions allowed for) did not look qualitatively different than rounds 6 through 10. We report some of the analysis for rounds 1 – 5 and later rounds in the Online Appendix.

While risk can, in principle, play an important role in bidding behavior, it has no significant effect on neither behavior nor outcomes in our data. We therefore report results without explicitly controlling for elicited risk.

The complete strangers sessions, in which subjects never interacted with the same participant more than once, generated data that is statistically indistinguishable from that generated by sessions in which bidders were randomly matched with one another in each round. We therefore report results aggregated across all sessions (the Online Appendix provides results at the session level – by and large, results look very similar across sessions).

In much of our discussion of collusion, we call an outcome collusive if it corresponds to a price that is lower than that predicted by equilibrium absent communication minus a small perturbation that we fix at 2 experimental units. As we will see, when bidders cannot communicate, prices are actually above those predicted by equilibrium behavior, so we view this notion of a collusive outcome a rather conservative one. The subtraction of 2 experimental points is somewhat arbitrary and intended to account for small errors. Without this subtraction, results remain virtually identical. Furthermore, for some of our discussion we will analyze outcomes that are “fully collusive,” ones in which prices are very low. In order to again allow for small perturbations we define such fully collusive outcomes as ones corresponding to prices that are lower than 2 experimental points. Certainly, there is some arbitrariness here and we could have chosen other thresholds that are “small.” If we change our threshold for a fully collusive outcome to be 0 or 1, results remain qualitatively indistinguishable. Similarly, when analyzing transfers, we allow for small perturbations and

\textsuperscript{12}For simplicity, we assumed a continuous set of values and possible bids. We note, however, that our results do not critically depend on this assumption. Indeed, without communication, Chwe (1989) shows that symmetric equilibria in discrete settings converge to the equilibrium in the continuous setting and our results for the second-price auction remain as they are. Furthermore, the comparison of the two auction formats when communication is available remains intact.
call a transfer *significant* if it corresponds to 2 or more experimental points. The results remain practically the same when we consider a threshold of 0 or 1 instead.

Last, throughout our analysis we use non-parametric tests for distribution comparisons. In particular, we use the Wilcoxon rank-sum test whenever reporting confidence levels pertaining to a comparison of two distributions.

The Online Appendix contains many robustness checks relevant to these assumptions and our econometric techniques. We direct the curious reader to the detailed descriptions appearing there.

## 5 No Communication

Recall that absent communication, in our setting, symmetric equilibrium behavior of risk-neutral bidders corresponds to each bidder bidding half their object value in the first-price auction and bidding precisely their object value in the second-price auction.\(^{13}\) Figure 1 illustrates bidding behavior in our sessions without communication (where, in each panel, the solid line corresponds to the equilibrium bidding strategy). The Figure illustrates that without communication our results are in line with the classic observations regarding bidding behavior in experimental auctions (see Cox, Roberson, and Smith, 1982, Dyer, Kagel, and Levin, 1989, Kagel and Levin, 1993, and Harstad, 1991). In first-price auctions, bidders

![Figure 1: Bidding Patterns in Auctions without Communication](image)

\(^{13}\)For second-price auctions, this prediction of behavior does not rely on risk neutrality, but rather on either symmetry or a restriction to weakly undominated strategies.
over-bid relative to their equilibrium behavior, but by and large submit bids that are lower than their private valuations. Similarly, in the second-price auction, bidders over-bid as well, submitting bids that are higher than their values a significant fraction of the time. These trends are reflected in the correlation between bids and values. Clustering observations by session, we find that this correlation is 0.80 in the first-price auction and 1.13 in the second-price auction with robust standard errors of 0.07 and 0.05, respectively.

In terms of efficiency, we calculate the frequency with which the highest-value bidder wins the object. In our first-price auctions, the mean efficiency is 83% while in our second-price auctions, the mean efficiency is 76%. These figures are not significantly different from each other. They mirror the efficiency levels documented in the extant auction literature (see Cox, Roberson, and Smith, 1982 and Kagel and Levin, 1993). We also note that, in our data, inefficiencies are more likely when bidders have values that are close to one another.

6 The Emergence of Collusion

When considering efficiency levels, communication with or without transfers does not generate significantly different outcomes than those generated in sessions without communication. Indeed, in our first-price auctions, generated efficiencies are 79% and 86% for the Pure Communication and Communication with Transfers treatments, respectively. Similarly, in our second-price auctions, generated efficiencies are 72% and 76% for the Pure Communication and Communication with Transfers treatments, respectively. No pair of values is significantly different using regression analysis, while clustering observations at the session level.

The extent to which our experimental subjects managed to establish successful collusion in our treatments can be seen through the distribution of prices. Figure 2 depicts the cumulative distribution of prices across our treatments. As can be seen, the distribution of prices...
prices in the treatments without communication first order stochastically dominates those corresponding to our Pure Communication and Communication with Transfers treatments. Furthermore, for both auction formats, the availability of communication and transfers dramatically reduces prices – the corresponding price distributions are first-order stochastically dominated by those corresponding to our other treatments. In fact, in both auction formats, price distributions are ranked; the distribution corresponding to our No Communication treatment first-order stochastically dominates that corresponding to our Pure Communication treatment, which first-order stochastically dominates that corresponding to our Communication with Transfers treatments. Statistical analysis reveals that all these comparisons are significant at the 1% level, except for the comparison between distribution of prices in the second-price auction in the No Communication and Pure Communication treatments, which is significant at the 7% level.\footnote{For each pair of treatments, we regressed prices on the dummy variable for the treatment, while clustering observations at the session level. For each pairwise comparison, the coefficient on the treatment dummy is significantly different from zero at 1\% level, except for the second-price auction with and without pure communication, which is significant at 7\% level.}

These differences in price distributions translate directly to the auctioneer’s revenues, as revenues effectively correspond to average prices in our treatments. In our first-price auctions, revenues are 51.2, 33.8, and 7.5 for the No Communication, Pure Communication, and Communication with Transfers treatments, respectively. In our second-price auctions, revenues are 47.8, 38.3, and 15.5 for the No Communication, Pure Communication, and

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{fig2.png}
\caption{Cumulative Distribution of Prices across Treatments}
\end{figure}
Communication with Transfers treatments, respectively.\textsuperscript{18} Across our treatments, there is a revenue equivalence – the revenues under both auction formats are statistically indistinguishable in all treatments. Importantly, the availability of communication and transfers significantly reduces revenues under both auction formats, generating less than one third of the revenues generated when all communication is banned under either auction format.

As mentioned above, collusion requires one of the participants to submit a low bid so that his or her counterpart will receive the object at a lowered price. Since without communication our results as well as prior literature suggest over-bidding relative to equilibrium behavior, a first glean at collusion can be established by considering the fraction of observations in which the price of the object was below the equilibrium price (namely, half the object’s value of the winner in the first-price auction, and the object’s value for the losing bidder in the second-price auction).\textsuperscript{19} In our baseline No Communication treatments, the frequencies with which such “collusive” outcomes occurred were low: 5\% in our first-price auctions and 10\% in our second-price auctions. When subjects could interact, these frequencies increased substantially. With pure communication, they are 36\% in our first-price auctions and 27\% in our second-price auctions, while with communication and transfers, they are 88\% in our first-price auctions and 71\% in our second-price auctions.\textsuperscript{20} These observations echo those emerging from the price patterns observed in Figure 2: communication and transfers together allow subjects to jointly change prices in a substantial way. In fact, when communication and transfers were available, the fraction of prices lower than 2 was 78\% in our first-price auctions and 68\% in our second-price auctions.

In terms of outcomes, the results are in line with the theoretical predictions for second-price auctions, but not with those pertaining to first-price auctions. In the next sections we will see that subjects do respond to some extent to the incentives imposed by first-price auctions to deviate from a collusive outcome. Nonetheless, these responses are not strong enough to maintain the robustness of first-price auctions to communication assured by theory.

\textsuperscript{18} Clustering by session, robust standard errors for the first price auction revenues are 6.5, 1.9, and 3.0 for the no communication, pure communication, and transfers treatments, respectively. For our second price auction revenues, they are 4.3, 2.7, and 4.6 for the no communication, pure communication, and transfers treatments, respectively.

\textsuperscript{19} As mentioned in Section 4, we define a collusive outcome as one in which the price was lower than the equilibrium price minus 2.

\textsuperscript{20} Statistical analysis reveals that collusion is significantly more frequent in both auction formats when pure communication is available compared to when it is not. Moreover, the availability of transfers in addition to communication increases the instances of collusion even further. Statistical analysis is performed using regressions in which the dependent variable is an indicator of a collusive outcome and the independent variable is the treatment dummy, while observations are clustered at the session level. All pairwise comparisons are statistically significant at the 1\% level.
7 Determinants of Prices

In order to get a sense of the behavior underlying the changes in outcomes generated by the introduction of communication and transfers, we start by analyzing the strategies suggested during the communication stage and followed in the bidding stage of our auctions.

To assure a low price in an auction, at least one of the bidders should submit a low bid (in a first-price auction, both bidders need to submit a low bid for the price to be low). There are indeed two collusive strategies that appear in the analysis of the communication stage.\(^{21}\) One strategy profile, which we term the \textit{reveal-collude} strategy, consists of the bidders revealing their values and submitting bids that assure the object is given to the high-value bidder at a low price, defined as lower than 2. In first-price auctions, this implies both bidders submitting a low bid; In second-price auctions, this implies the losing bidder submitting a low bid and the winning bidder submitting any bid that is higher. The other strategy profile, which we term the \textit{flip-a-coin} strategy, consists of both bidders submitting \textit{the same} bid, yielding an equal probability of winning the object for each of the bidders.

Table 2 describes the rates at which each of the strategies was discussed as well as the rates at which each strategy was used.\(^{22}\) As can be seen, strategies are discussed at much higher rates when transfers are available. Furthermore, the predominance of strategy discussions when transfers are available focuses on the reveal-collude strategy, while a much higher

\begin{table}[h]
\centering
\begin{tabular}{|l|c|c|c|c|}
\hline
 & \multicolumn{2}{c|}{Pure Communication} & \multicolumn{2}{c|}{Communication with Transfers} \\
 & First-price & Second-price & First-price & Second-price \\
\hline
Discuss Reveal-collude & 6.7\% & 1.9\% & 82.5\% & 70.4\% \\
Discuss and Use Reveal-collude & 6.7\% & 1.9\% & 82.5\% & 70.4\% \\
Achieved Efficient Outcome & 5.6\% & 1.9\% & 72.5\% & 57.4\% \\
Achieved Inefficient Outcome & 1.1\% & 0\% & 10.0\% & 13.0\% \\
Discuss Flip-a-coin & 23.9\% & 4.4\% & 3.3\% & 0\% \\
Discuss and Use Flip-a-coin & 3.3\% & 0.6\% & 0\% & 0\% \\
\hline
\end{tabular}
\caption{Strategies Discussed and Used across Treatments}
\end{table}

\(^{21}\)Protocols were analyzed by two research assistants, who were not privy to the research questions posed in this paper.

\(^{22}\)As mentioned, these were the only discussed strategies detected in the communication protocols. Many conversations, particularly in the pure communication treatment, did not involve a discussion of strategy, which we will return to in the next section. We also note that these strategies require a certain level of coordination and were never used unless discussed in the conversation that preceded bidding.
fraction of strategy discussions focus on the flip-a-coin strategy when no transfers are available.

Both of these strategies are sensitive to deviations by the bidder who is to bid the lowest bid. In the flip-a-coin strategy, both bidders serve in that role and can each increase their bids by a small amount in order to out-bid their opponent. This is reflected in the fairly low rates of incidents of bidders discussing and using this strategy across our treatments. The reveal-collude strategy is assessed as a setting in which at least one of the bidders (both bidders in first-price auctions) submit a bid that is very low. Bidders then have an incentive to misreport their values, which determine who is to be winner of the auction. Furthermore, in first-price auctions, a bidder may attempt to out-bid her opponent, while still submitting a low bid to assure the ultimate price is low. Strategic responses as such may both lead to an observed price that is below our threshold of 2. In order to assess when such strategic behavior occurred, we look at the frequency of efficient outcomes when seemingly collusive outcomes were observed. An efficient outcome suggests that the higher-value bidder received the object for a low price; An inefficient outcome suggests that the lower-value bidder received the object at a low price, either due to misreporting of her value or due to out-bidding her opponent. As is evident, we see a substantial fraction of inefficient outcomes when the reveal-collude strategy was carried out. This is suggestive of some strategic manipulation subjects exercised. In the next sections we inspect bidders’ behavior in more detail, both during communication and in the auctions themselves.

Table 3 presents the results of a Tobit regression analysis of how different features of the communication protocols impact prices when bidders interact prior to bidding (errors clustered by session).

At the aggregate level, in either auction format, when agents talk during the communication phase prices drop significantly. The topics discussed during communication matter. When transfers are not available, discussion of values does not seem to have a significant effect on values, discussion of bids does and, in fact, talk of either the flip-a-coin or the reveal-collude strategies has a significant and substantial impact on prices. When transfers are available, discussion of values, bids, or transfers impacts prices significantly and substantially. We note, however, that discussion of bids is highly correlated with discussion of transfers (0.71 in first-price auctions and 0.78 in second-price auctions). Given that their effects on prices are rather similar, it is difficult to isolate which of the two plays a more important role in the determination of the ultimate auction price. We return to a more elaborate analysis of how transfers seem to be set by our subjects in Section 9.

23While the regressions pertain to rounds 6 – 10, the results are practically identical when looking at the full set of rounds. There is some learning occurring in the first few rounds, which becomes insinificant in the last five rounds we report on.
### First-price Auctions (rounds 6-10)

<table>
<thead>
<tr>
<th></th>
<th>Pure Communication Treatment</th>
<th>Communication + Transfers Treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Regression 1</td>
<td>Regression 2</td>
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<tr>
<td><strong>Equilibrium Prediction</strong></td>
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<td>Pairs who Chatted</td>
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<td>0.99** (0.07)</td>
<td>0.82** (0.05)</td>
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<td>Indicator if Bidders Talked about Values</td>
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<td>2.53** (2.78)</td>
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<tr>
<td>Indicator if Bidders Talked about Bids</td>
<td>2.53** (2.78)</td>
<td>2.15 (3.12)</td>
</tr>
<tr>
<td>Indicator if Bidders Discussed Reveal Collude strategy</td>
<td>2.15 (3.12)</td>
<td>2.53** (2.78)</td>
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<tr>
<td>Equilibrium Prediction</td>
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<td>15.97** (2.41)</td>
</tr>
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<td>129</td>
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<tr>
<td># of Sessions</td>
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<tr>
<td>Pseudo R2</td>
<td>0.0468</td>
<td>0.0197</td>
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### Second-price Auctions (rounds 6-10)

<table>
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<th>Communication + Transfers Treatment</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Regression 1</td>
<td>Regression 2</td>
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<tr>
<td><strong>Equilibrium Prediction</strong></td>
<td>All Obs</td>
<td>Pairs who Chatted</td>
</tr>
<tr>
<td></td>
<td>0.88** (0.07)</td>
<td>0.92** (0.21)</td>
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<tr>
<td>Indicator if Bidders Talked about Values</td>
<td>8.96 (6.30)</td>
<td>8.96 (6.30)</td>
</tr>
<tr>
<td>Indicator if Bidders Talked about Bids</td>
<td>8.96 (6.30)</td>
<td>8.96 (6.30)</td>
</tr>
<tr>
<td>Indicator if Bidders Discussed Reveal Collude strategy</td>
<td>8.96 (6.30)</td>
<td>8.96 (6.30)</td>
</tr>
<tr>
<td>Equilibrium Prediction</td>
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<td>10.27* (6.0)</td>
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<tr>
<td># of Observations</td>
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<tr>
<td>Pseudo R2</td>
<td>0.0847</td>
<td>0.0701</td>
</tr>
</tbody>
</table>

Number in parentheses are standard errors, where errors are clustered at the session level.
** indicates significance at the 5%, * indicates significance at the 10% level.

Table 3: Tobit Estimates Explaining Ultimate Prices
The fact that discussion of bids, rather than values, seems to be an important force in shaping prices when only communication is available may lead one to wonder about the identity of the winning bidders, whether they are the ones with the highest value or not when prices are low. In other words, are efficiency rates lowered when bidders succeed in colluding? In our Pure Communication treatments, that is indeed the case when considering first-price auctions. Recall that we termed an outcome collusive if the corresponding price was below that prescribed by equilibrium behavior minus 2 points. For first-price auctions in which collusive outcomes were achieved, efficiency levels were at 0.58, while for auctions in which outcomes were not collusive, efficiency levels were at 0.91 (with standard errors of 0.04 and 0.03, respectively). Whether or not a collusive outcome was achieved did not, however, affect efficiency levels in our second-price auctions. One potential explanation for this observation is the following. In first-price auctions, both bidders need to agree to submit a low bid in order for the price to be low. Such a profile is fragile to small deviations. Indeed, suppose two bidders agree that the low-value bidder will submit a bid of 1 and the high-value bidder will submit a bid of 2. The low-value bidder need only submit a bid higher than 2 to gain the object (assuming the other remains faithful to the agreement). The price would then remain low, but the resulting allocation will not be efficient. In fact, this type of deviation is at the root of the theoretical result predicting the robustness of first-price auctions to communication. In contrast, in second-price auctions, achieving a low price can entail the intended winner of the auction submitting a high bid (potentially the maximal possible bid of 100). There are therefore agreements that assure that a deviation of the intended low bidder cannot gain him or her the object at a low price. Our analysis of the communication protocols in the following section echoes this discussion.

8 Analysis of Communication

We now turn to the analysis of the communication protocols themselves in the sessions that allowed for some interaction between bidders. We start by describing the frequencies with which bidders conversed about values and bids and the extent to which they misrepresented their reports. We then analyze the dynamics within the protocols that emerged.

8.1 Topics of Conversation and Misrepresentation

The left panel of Figure 3 illustrates the fraction of subjects who did not talk, talked and overstated their values or bids, revealed truthfully their values or bids, or understated their values or bids. In this figure we treat each subject in each round (of a particular auction
As can be seen, in the majority of auctions subjects do not talk about some aspect of the auction when only communication is available. In our first-price auctions in 69% of cases subjects chose not to talk about their bids and in 76% they chose not to talk about values. The frequency of communication in our second-price auctions with pure communication is even lower: over 90% of auctions proceed without subjects discussing their values or bids (only in 9% of cases subjects discuss their values and only in 5% cases they discuss their future bids). Conditional on talking, subjects misreport quite frequently, in fractions comparable to those corresponding to truth-telling. Furthermore, the most prominent pattern of lying is to understate one’s true value or intended bid.

Figure 4 depicts the distribution of announced values and bids as a function of actual values and bids, respectively (where the size of each point is a proxy for the corresponding number of observations) in our Pure Communication treatments. With respect to values, there is substantial volume of truth-telling, as well as some over-statement of values and more frequent under-statement of values. With respect to bids, much of the truthful revelation is linked with fairly low bids, as is much of the misrepresentation. In fact, as we discussed in Section 7, many of the subjects attempt to collude by suggesting a low bid; for instance, by using the flip-a-coin strategy. Nonetheless, many subjects understand that both subjects bidding low is not incentive compatible – particularly in the first-price auction, where both

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24Values and bids were communicated as numbers or verbally (“low”, “high”, etc.). The two research assistants that analyzed the communication protocols were instructed to interpret “low” and its synonyms as corresponding to $0-33$, “moderate” and its synonyms to $34-66$, and “high” and its synonyms to $67-100$. These categories allow us to classify the lying patterns for subjects using verbal messages as well.
individuals need to announce a low bid for collusion to have a chance, a bidder can bid slightly over the announced bid and still get the object for a fairly low price. This is in line with the theoretical forces that, in principle, should make first-price auctions robust to communication. In our experiments, subjects are fairly successful at generating collusive outcomes even in first-price auctions, but the different strategic incentives may explain the somewhat different patterns we observe in reporting between the two auction formats.

In contrast, the right panel of Figure 3 illustrates that the cheap-talk communication channel is used very differently in the treatments with pure communication than in those with transfers. The first distinction is the frequency with which subjects discuss relevant things prior to the auction: while in pure communication treatments these discussions were rare, they are prevalent in the treatments with transfers in both auction formats. Indeed, subjects talk about their values in 87% of cases and their bids in 77% of cases in first-price

\[25\] In first-price auctions, the two most common reported bid and actual bid pairs are \((0, 0)\) and \((0, \varepsilon)\), where \(\varepsilon = 0.01\) or \(\varepsilon = 1\) (indicated by the two big circles on the bottom-left panel of Figure 4). The \((0, \varepsilon)\) case represents bidders who reported that they will bid 0 but then deviated to a bid of \(\varepsilon > 0\) in an attempt to game the opponent and secure winning the auction. In most of these cases, subjects discussed and agreed to play the flip-a-coin strategy, and usually one of the bidders followed through on his or her promise (which is indicated by the substantial number of observations of \((0, 0)\)).
auctions, while in second-price auctions they discuss values in 66% of cases and intended bids in 47% of cases. Furthermore, while in the Pure Communication treatment, conditional on talking, most of the revealed values and bids were attempts to misrepresent the truth, this is not the case in the Communication with Transfers treatment, in which most of the reports are truthful. Conditional on reporting a value, subjects report truthfully 75% of the time in our first-price auctions and 73% of the time in our second-price auctions. Similarly, conditional on reporting one’s intended bid, subjects follow through with this intention 96% of the time in our first-price auctions and 83% of the time in our second-price auctions.

8.2 Dynamics of Communication Protocols

Protocols were very short – between three and six messages in the Pure Communication treatment and between five and six messages in the Pure Communication with Transfers treatment. Nonetheless, we can identify several consistent patterns in the protocols we observe.

At the aggregate level, individuals are significantly more likely to announce their values or bids when their counter-part has already done so. While in our Pure Communication with Transfers treatments most reports are truthful, the order in which announcements are made affects somewhat the announcements themselves in our Pure Communication treatment in which subjects misreported at significant rates. Bidders who speak first about values announce a lower value than those who speak second about their value, albeit not significantly so. In addition, bidders who speak first about their intended bid announce a higher bid than those who speak second, though these differences are not statistically significant either. We note, however, that in all our sessions the order in which values or bids are communicated does not seem to explain outcomes. For example, the first to reveal his or her value had an approximately 50 – 50 chance of winning the object. Furthermore, the length of conversations, in terms of time or number of messages, does not seem to predict outcomes, including efficiency, either.

Figure 5 depicts the order that protocols followed in our treatments. There are two important dimensions that are discussed during communication – values and strategies, which encompass either bids or transfers. In our Communication with Transfers treatment,

\[26\]

\[27\]
discussions of bids and transfers went hand-in-hand (conditional on discussing bids, in 97% of either type of auction transfers were discussed as well). Therefore, we do not separate instances of bid discussion from those in which transfers were discussed. The figure illustrates when only values or only strategies were discussed, and if both were discussed, what order they followed. As can be seen, in our Pure Communication treatments, no clear pattern emerges, though in second-price auctions the modal protocol entails a discussion of values alone. However, when transfers are introduced, subjects discuss both values and strategies at very high rates and, particularly in our first-price auctions, a discussion of values often precedes that of strategy.

9 The Impacts of Transfers

Our treatment with both communication and transfers seems to have been the most effective in allowing subjects to collude in both auction formats. This is despite the fact that subjects could not commit to the transfers passed and were randomly matched with one another to prevent effective commitment through repeated play. In the Online Appendix we present additional analysis that indicates this is also true in the very last rounds of our sessions, as well as in the sessions in which a complete-strangers matching protocol was used, in which subjects knew they would never encounter the same partner more than once.
We first note that transfers rarely originate from the loser of the object to its winner; This occurred in fewer than 5% of cases under both auction formats. Winners, on the other hand, transfer more than 2 points to their losing opponents at a frequency of 65% in our first-price auctions and 48% in our second-price auctions. The frequency of transfers depends on how the auction culminates: transfers are very frequent if the ultimate price is lower than 2 (winners transfer more than 2 points to their losing counterparts at a frequency of 79% in our first-price auctions and 71% in our second-price auctions).\textsuperscript{28} However, if the price is above 2, then positive transfers are rare (15% in our first-price auctions and 0% in our second-price auctions).\textsuperscript{29}

Table 4 reports results from a Probit regression in which whether or not significant transfers were passed (ones greater or equal to 2 experimental points) is explained by the winning bidder’s value, the final price of the object, an indicator that takes a value of 1 if

\begin{table}[h]
\centering
\begin{tabular}{lcc}
\hline
 & \textbf{First-price Auctions} & \textbf{Second-price Auctions} \\
\hline
Winner’s Value & 0.005** (0.0008) & 0.004** (0.001) \\
Price & - 0.015** (0.002) & - 0.013** (0.002) \\
Indicator if Efficient Outcome & 0.2812** (0.059) & 0.315** (0.071) \\
Indicator if Winner Lied Before & - 0.172** (0.057) & - 0.261** (0.080) \\
Indicator if Pair Agreed on Transfers & 0.159* (0.087) & 0.324** (0.084) \\
Indicator if Winner Lied about his Bid & - 0.290** (0.075) & - 0.158** (0.033) \\
\hline
\end{tabular}
\end{table}

\textsuperscript{28}Our setting is reminiscent of trust games in that losing bidders need to forgo the chance to win the object and submit a low bid providing their opponents large profits in the hope that money will be passed back to them. As a comparison, Berg, Dickhaut, and McKabe (1995) studied trust games in which the first player had $10 to allocate and any amount passed on to the second player was multiplied by 3. Of 28 pairs in which some money was transferred, in 12 cases (or 43%) money was transferred back, in line with our figures.

\textsuperscript{29}We note that these high frequencies of positive transfers from the winning bidders to the losing bidders remain prevalent even in the very last round of the experiment. Indeed, in 67% of cases, in the last round of our first-price auctions winners transferred amounts above 2 points to their losing counterpart, while this happened in 80% of cases in which the price was below 2 points. Similarly, in the very last round of our second-price auctions, in 48% of the auctions winning bidders transferred more than 2 points to the losing bidders, while this fraction becomes 65% once we condition on the price of the object being below 2 points. These data reinforce the claim that our observations are not driven by wrong perceptions of repeated play, since subjects knew when the last round of the experiment was taking place.
the higher-value bidder won the object, an indicator that takes a value of 1 if the winning bidder had lied before (on either her value or her bid), which is designed to capture a “type” of bidder that is more inclined to try acting in a self-interested manner, an indicator of whether the pair agreed on some transfer profile, and an indicator of whether the winner had lied about his or her bid (in that auction). Reported numbers are marginal coefficients corresponding to each variable.\textsuperscript{30}

As can be seen, the winning bidder’s value has a small but significant effect on whether or not transfers are passed. Both prices and the efficiency indicator serve as proxies for how successful collusive efforts were. Greater collusion (in the form of either lower prices or efficient allocations) is associated with significantly greater propensities to pass transfers.\textsuperscript{31} If the winning bidder had lied before, the probability of passing transfers drops in a substantial and, for our second-price auctions, rather significant manner. That is, this “type” of bidder, as identified by the communication protocols, is associated with “strategic” behavior at the transfer stage as well. The discussion of transfers substantially and significantly increases the likelihood of transfers. In fact, when subjects agreed on an exact amount to be transferred, transfers were higher than when the agreement was on an equal split.\textsuperscript{32} However, when the winner lies about her bid, she is also less likely to make a transfer: being “strategic” at the bidding stage goes hand in hand with being “strategic” at the transfer stage.

Conditional on making a transfer of at least 2, the amount transferred averages at 44% of the surplus for both auction formats.\textsuperscript{33} However, the modal fraction of surplus transferred

\textsuperscript{30}Subjects who discussed the reveal-collude strategy almost always agreed on transfers (in 98 out of 99 and 75 out of 81 in our first- and second-price auctions, respectively). Substituting the indicator variable for whether subjects had agreed on a transfer with an indicator variable for whether subjects discussed the reveal-collude strategy generates nearly identical estimates. We also note that losing bidders lied about their bids in less than 5% of cases in both auction formats. Losing participants’ misrepresentation has insignificant power in explaining the occurrence of transfers.

\textsuperscript{31}In fact, efficiency levels are tied strongly to the presence of significant transfers. In our first-price auctions, 97% of the auctions entail an efficient allocation when significant transfers occurred, while only 64% of the auctions entail an efficient allocation when transfers were insignificant. The corresponding percentages for our second-price auctions are 93% and 60%. Differences are significant at any reasonable level. See the Online Appendix for a full description of efficiency levels across different auction outcomes and transfers.

\textsuperscript{32}For example, in our first-price auctions, bidders discussed exact amounts to be transferred in 61% of the auctions, which generated an additional 5.3 experimental points transferred relative to the 23% of auctions in which there was an agreement on an equal split of the surplus. Similarly, in our second-price auctions, bidders discussed exact amounts to be transferred in 45% of the auctions, which generated an additional 9.9 experimental points relative to the 19% of auctions in which there was an agreement on an equal split of the surplus (significant at the 5% level).

\textsuperscript{33}We used random effects generalized least squares regressions in which the amount transferred is explained by the winning bidder’s surplus (and a constant term). The coefficient of the winning bidder’s surplus is 0.44 for both auction formats and is significant at the 5% level, while the constant term is not significantly different from 0. Furthermore, even when we divide our data into the first and last five rounds, the coefficients remain the same (other than the first five rounds of our first-price auctions, in which case the coefficient is 0.45, and not significantly different from 0.44).
is 50% – in 58% of our first-price auctions and 71% of our second-price auctions half of
the surplus was transferred. In Section 10.1 we discuss how norms prescribing such giving
behavior might make the behavior we observe consistent with equilibrium play.

These observations suggest a frequent pattern of behavior as follows. Subjects share
some (mostly truthful) information regarding their values during communication. They then
submit bids that assure a fairly low price and realize approximately the maximal surplus for
the bidders given their values. Last, they share the surplus at roughly equal proportions.

## 10 Conclusions and Discussion

We show theoretically the impacts of cheap-talk communication on one-shot sealed-bid first-
and second-price auctions. While communication does not impact the set of equilibrium
outcomes generated by first-price auctions, it enlarges the set of equilibrium outcomes gen-
erated by second-price auctions. Furthermore, theoretically, non-binding transfer promises
have no effect on outcomes under either auction format. We report results from a sequence
of experiments testing the impacts of communication and transfers on auction outcomes.
The main message is that communication, especially when transfers are available, allows
for a substantial amount of collusion in and of itself. In the lab, the frequency of collu-
sive outcomes is similar across auction formats, so neither is immune to collusive behavior.
Nonetheless, we see somewhat different patterns of misrepresentation during communication
between the two formats that are in line with strategic incentives suggested by the theory.

In what follows, we discuss several behavioral models that relate to our results and some
natural extensions of our basic experimental design.

### 10.1 Norms of Transfers

Recall our observations from Section 9: a successful collusion frequently led to a positive
transfer, and conditional on a significant transfer being passed, transfers averaged at 44%
of the winning bidder’s surplus. Furthermore, the modal fraction of the surplus transferred
was 50% for both auction formats.

This may raise a suspicion that subjects operate under a norm that prescribes an equal
division of the surplus (in the spirit of Andreoni and Bernheim, 2009). As it turns out, under
both auction formats, were such a norm in place, the behavior patterns we observe in our
data are consistent with equilibrium play.

Suppose players act according to the following protocol. In the communication stage,
both reveal their value. Then, the low-value bidder submits a bid of 0 and the high-value
bidder submits a bid of 0.01 (the smallest possible bid greater than 0). If both state the same value, both submit 0. This protocol is incentive compatible under both auction formats. Indeed, both individuals have an incentive for the highest-value bidder to win the object at the lowest possible price since the surplus divided, and consequently their payoffs, are highest in that case. Furthermore, there is no incentive to out-bid at the bidding stage. This protocol echoes what we see in much of our data – subjects utilizing the communication phase to implement the reveal-collude strategy and then splitting the surplus of the winning bidder.\textsuperscript{34}

This profile of actions is no longer an equilibrium if the prevailing norm was to split the surplus unequally between the winning and losing bidders. Indeed, suppose the winning bidder was to keep a fraction $\alpha > 1/2$ of the surplus and transfer a fraction $1 - \alpha$. In this case, winning the object entails an advantage since a greater fraction of the surplus is then kept. This tilts individual incentives – they may prefer to win the object themselves even if it generates a slightly lower surplus. In fact, the above protocol does not constitute part of an equilibrium any longer. It can be shown that a bidder with a private value of $v$ would benefit from misreporting a value of $\frac{\alpha}{1 - \alpha} v > v$ at the communication stage. In that respect, while norms of transfers are in line with much of our data, these conclusions are fragile to the precise norms in place.

10.2 Other-regarding Preferences and Reciprocity

One may worry that some of the generous transfers we observe in our experiments are an artifact of a form of other-regarding preferences that are often observed in laboratory settings (see, e.g., Fehr and Schmidt, 1999, Bolton and Ockenfels, 2000, and work that followed). Certainly, such other-regarding preferences cannot be overwhelmingly strong in our experimental setting. If they were, we would expect, for instance, that subjects submit zero bids in second-price auctions without communication in order to allow their opponent to gain the object at a low cost. Still, subjects may be putting some weight on their opponents’ outcomes, in addition to their own. In their simplest form, models of other-regarding preferences pose utilities that are composed of two linear terms: one corresponding to one’s own monetary outcomes and one corresponding to others’ outcomes (this is the essence of the Fehr and Schmidt, 1999 model). Such a setup would imply corner solutions in our auctions – in treatments where transfers are available, agents should either transfer none of their

\textsuperscript{34}Notice that there could be a multiplicity of equilibria. In particular, in second-price auctions, winning bidders could submit arbitrary positive bids and we indeed see a substantial variance of high bids in our second-price auctions. These equilibria, which are equivalent with respect to outcomes, are welfare maximizing.
surplus or all of it. This is clearly in contrast with what we observe in our data.

There are many ways to introduce non-linearities to the basic model that accounts for both one’s own and others’ outcomes. In order to illustrate the impacts of non-linearities, we consider a class of utilities as follows. The utility for bidder $i$ when her payoff is $\pi_i$ and her counter-part’s payoff is $\pi_j$ is given by:

$$U_i = \alpha \pi_i - (1 - \alpha) f (\pi_i - \pi_j),$$

where $\alpha \in [0, 1]$ is a weight parameter that indicates how much bidder $i$ cares about her own payoff relative to the variation of payoffs within the pair. We assume that the inequality cost function $f$ is symmetric, $f(x) = f(-x)$, twice continuously differentiable, increasing in the distance between payoffs, $f'(x) * sgn(x) > 0$, and convex, $f''(x) > 0$ for all $x$. Now, consider the winner of the object in our treatment with transfers (regardless of the auction format), who has an object value of $v$ that she has gained for the price of $p$. If she makes a transfer of $t$, she receives a utility of:

$$\alpha (v - p - t) - (1 - \alpha) f (v - p - 2t).$$

Maximization with respect to $t$ implies then that:

$$v - p - 2t = (f')^{-1} \left( \frac{\alpha}{2 (1 - \alpha)} \right).$$

In other words, the net profits of the winning and the losing bidders should differ by a constant, the size of which depends on the weight put on one’s own monetary outcomes relative to the egalitarian utility component. We stress that this solution does not depend on the auction format nor on what has transpired in the auction (namely, the ultimate price of the object). However, in our data, the difference between the surpluses of the two bidders exhibit a large variance and does not appear constant, even when conditioning on full collusion, i.e., when conditioning on auctions in which the price of the object was close to zero.\footnote{Indeed, in our first-price auctions, the average difference in surpluses of the two bidders is 19 with a standard deviation of 25 and values varied between 0 and 92. Similarly, in our second-price auctions the average difference is 14 with a standard deviation of 31, while values varied between 0 and 98. Even when one focuses only on the auctions that resulted in the minimal price possible (prices below 2), the difference in surpluses varies significantly from auction to auction with standard deviations of similar size (26 in both auction formats).}

Naturally, one could consider even more general functional forms, incomplete information on the weight $\alpha$ (in which case bids also serve as signals on the private parameter $\alpha$), etc. We leave such elaborations for future work. But simple models of other-regarding
preferences, which are the common ones used in the literature, do not explain our observations.

Our treatments allowing for transfers do point out to some reciprocal behavior. We already saw in Section 9 that the pattern of transfers differed when a collusive outcome was achieved relative to the pattern emerging in auctions in which the ultimate price was not very low. In order to dig deeper into how individuals respond to final prices, we calculate for each individual subject the frequency of auctions in which he or she won the object and transferred a positive amount, when the ultimate prices were low (lower than 2) and when they were high (higher than 2). Figure 6 depicts the corresponding cumulative distributions. The figure illustrates the strong response of subjects to the final price in the auction – subjects transfer substantial amounts at very high frequencies when prices are low, but most subjects transfer positive amounts at much lower frequencies when the price of the object is greater than 2. This suggests that some reciprocity motives might be influencing subjects’ behavior (see Fehr and Gachter, 2000 for an overview of some of the literature on reciprocity).

10.3 Other Contract Structures

In our experimental sessions, individuals could not commit to either actions or transfers. We believe the inspection of contracting structures and their impact on the fragility of different auction formats to collusion is a very interesting direction for future research. For example, one natural alternative contractual agreement would allow participants to commit to the transfers that would be made ex-ante. We ran six such additional sessions (three with first-price auctions and three with second-price auctions, with 36 and 34 subjects, respectively). In these sessions, subjects observed their private values and were then able to communicate
freely as in the Pure Communication Treatment. Once the communication was over, each bidder was asked to submit a transfer to the other bidder (0 or higher). These transfers were then announced simultaneously to the bidders. Following that, bidders submitted their bids. Ultimately, each bidder received their auction payment plus their net transfers (namely, the transfers made to them minus the transfers made by them). That is, subjects could commit to transfers that were paid ex-ante.\textsuperscript{36}

In this auxiliary treatment, observations roughly mirror those we see in our transfers treatment without commitment. Indeed, with commitment to transfers subjects achieve similar levels of efficiency: 82% in first-price and 93% in second-price auctions.\textsuperscript{37} Further, revenues of the auctioneer (as measured by the average and median prices obtained in these auctions) are significantly lower in the sessions with commitment to transfers compared with the ones without transfers and similar to the ones obtained by the auctioneer in the treatment with transfers and no commitment.\textsuperscript{38} This result is also mirrored by the frequencies of collusion: collusion is detected in 54% of first-price auctions with transfers and commitment and in 78% of second-price auctions with transfers and commitment.\textsuperscript{39}

We note that in first-price auctions, collusion as well as the frequency of positive transfers from winning bidders to losing bidders is somewhat lower in sessions with commitment to transfers than in sessions without commitment (in 42% of auctions with commitment winning bidders transfer points to losing bidders, compared with 69% in auctions without commitment). One potential reason is that commitment makes transfers risky as participants pay the transfers regardless of whether they ultimately receive the object or not. However, once we condition on the price being lower than 2 experimental points, the difference between these two contract designs disappears, as the vast majority of winning bidders reward the losing bidders for achieving low prices (this happens in 86% of the auctions with commitment and in 83% of our auctions without commitment). In second-price auctions, the frequency of collusive outcomes and transfers are comparable between sessions with and without commitment. One potential interesting modification of this treatment would entail slightly more complex contracts in which transfers would be contingent on winning the object. This would mitigate the riskiness of transfers prior to the auction.

\textsuperscript{36}This is reminiscent of the theoretical model in Eso and Schummer (2004). They consider second-price auctions in which bidders cannot communicate, but can commit to “bribes” prior to bidding. Unlike our setting, they assume that when a bribe is accepted, the receiver of the bribe is committed not to participate in the auction and illustrate the potential signaling power of bribes as well as the inefficiencies they may induce. See also the experiments reported in Llorente-Saguer and Zultan (2014).

\textsuperscript{37}Robust standard errors are 0.02 and 0.04, respectively, where errors are clustered by session.

\textsuperscript{38}In first-price auctions, the average price is 24 and the median price is 21, while in second-price auctions the corresponding numbers are 11 and 0, respectively.

\textsuperscript{39}There is also a substantial fraction of collusive outcomes in which the price is essentially zero (below 2 experimental points): 40\% in these first-price auctions and 71\% in these second-price auctions.
10.4 Other Auction Formats

Throughout the paper we focus on first- and second-price auctions. This seems like a natural first step, particularly given the prominence of these two auction formats in applications. It would be interesting to inspect the sensitivity of other auction formats to the availability of communication and transfers. For instance, we suspect that all-pay auctions would be rather fragile to communication since preference alignment arises more naturally through the structure of the auction itself: if bidders can successfully share their values, they can both reduce the price experienced by the likely winner and avoid the participation cost of the prospective losing bidders of the auction. On the other hand, general $k$-price auctions (with $k \geq 3$) may exhibit different fragility to communication as coordination between more individuals is required to achieve successful collusion. The differences are subtle and are left as directions for future research.
References


