Collusion through Communication in Auctions

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Introduction

Our Goal: Study the effects of communication on auction outcomes

- Collusion is important: ~30% of antitrust cases filed by the DoJ since 1994 had to do with bid-rigging.

- Communication happens: e.g., drainage leases (Henricks and Porter, 1988), school milk supplies (Pesendorfer, 2000), cast-iron pipe, collectable stamps, antiques, machinery, and real estate auctions (Marshall and Marx, 2012),…

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- An alternative (potentially complementary) way to collude different from repeated play
- A particular case study for a broader question: When can communication change the set of outcomes in a strategic setting

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Focus on First- and Second-Price Auctions

- Commonly used
- Large body of literature assessing behavior absent communication

Related Literature

Theory

- Collusion in auctions (mostly through repeated play or multi-object auctions)

  Abreu, Pearce, and Stachetti (1986), Athey and Bagwell (2001), Hendricks and Porter (1989), Kwasnica (2002), Marshall and Marx (2007, 2009), McAfee and McMillan (1992), Pesendorfer (2000), Skryzspacz and Hopenhayn (2004),…

- Communication in auctions

  Bergemann, Brooks, and Morris (2013), Matthews and Postlewaite (1989), Lopomo, Marx, and Sun (2011)

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Experiments

- Without communication

  Cox, Roberson, and Smith (1992), Kagel and Levin (1993), Guth, Ivanova-Stenzel, Konigstein and Strobel (2012)

- With communication

  Issac and Walker (1995), Kagel (1995)

Setup

- First and Second price independent private values sealed-bid auctions
- 2 bidders
- Values drawn from U[0,100] (1 token = 1 cent)
- Highest bid wins the object
- Price equals
  - highest bid in first price auctions
  - lowest bid in second price auctions
- All ties are broken randomly

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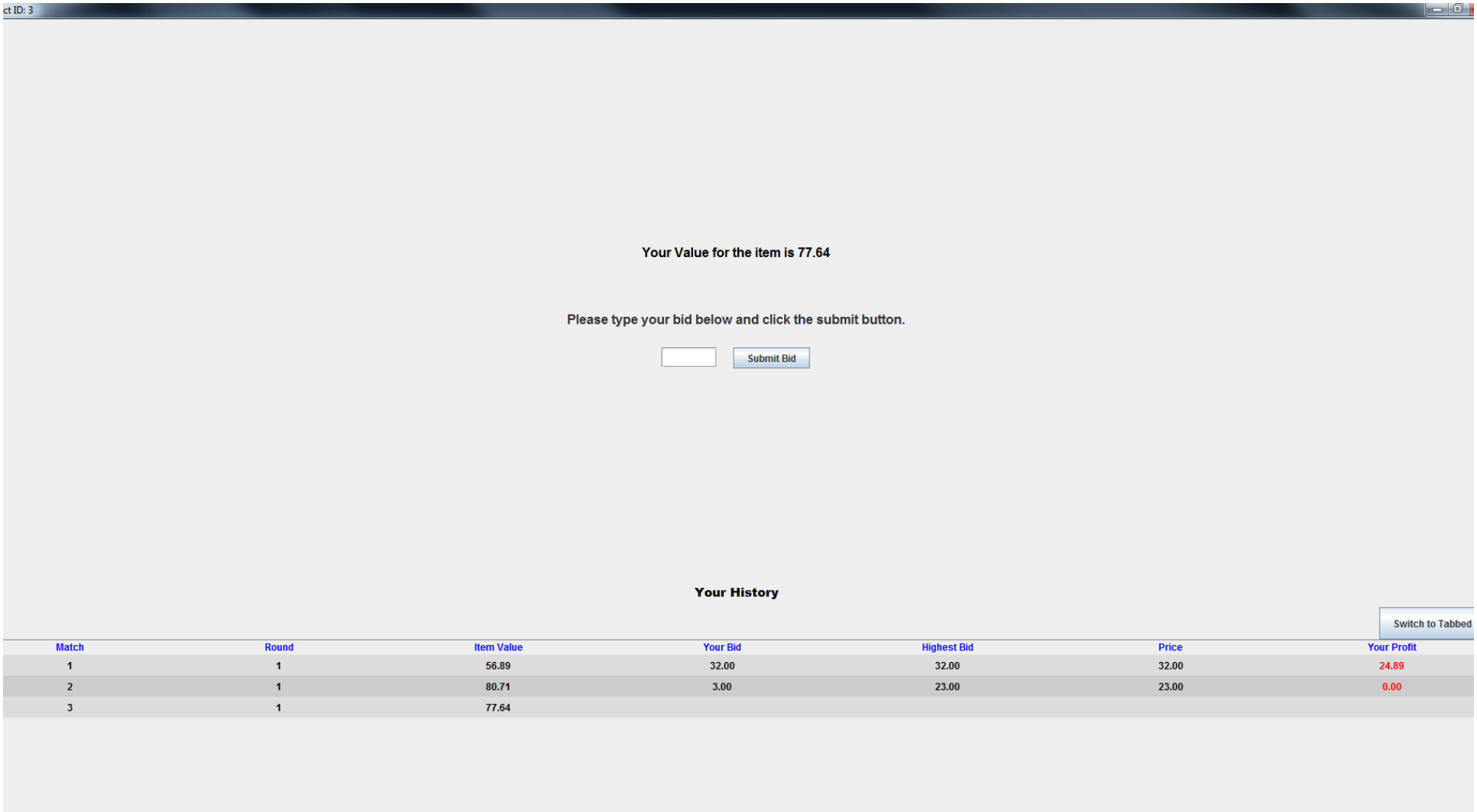
- Available interactions:

No Communication treatment a-la Kagel and Levin (1993)
observe value – bid – results

Pure Communication treatment with free-form chat between bidders
observe value – communication stage – bid – results

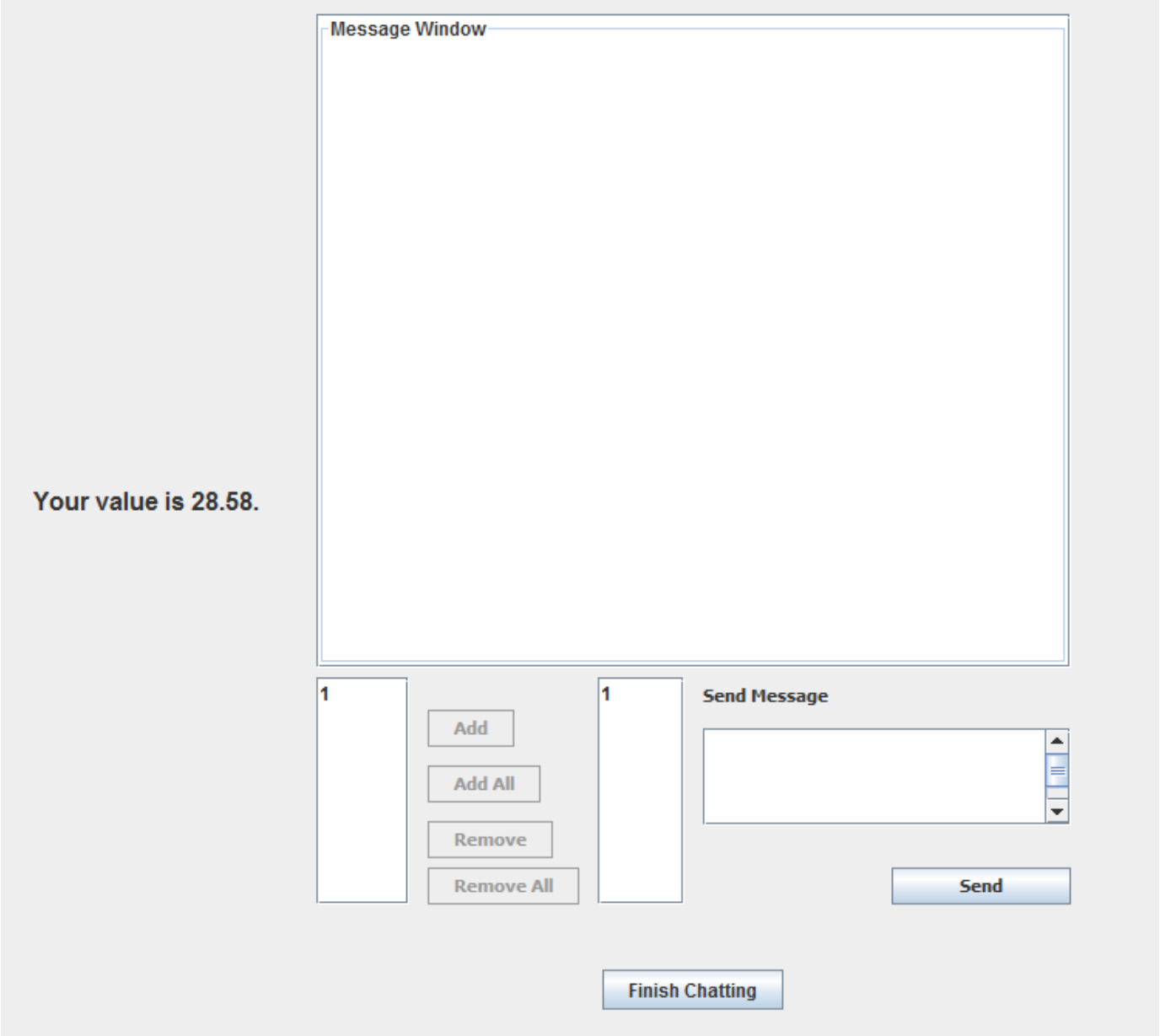
Communication with Transfers treatment with chat + opportunity to transfer points
observe value – communication stage – bid – results – transfers

Screenshot – No Communication



Match	Round	Item Value	Your Bid	Highest Bid	Price	Your Profit
1	1	56.89	32.00	32.00	32.00	24.89
2	1	80.71	3.00	23.00	23.00	0.00
3	1	77.64				

Screenshot – Pure Communication



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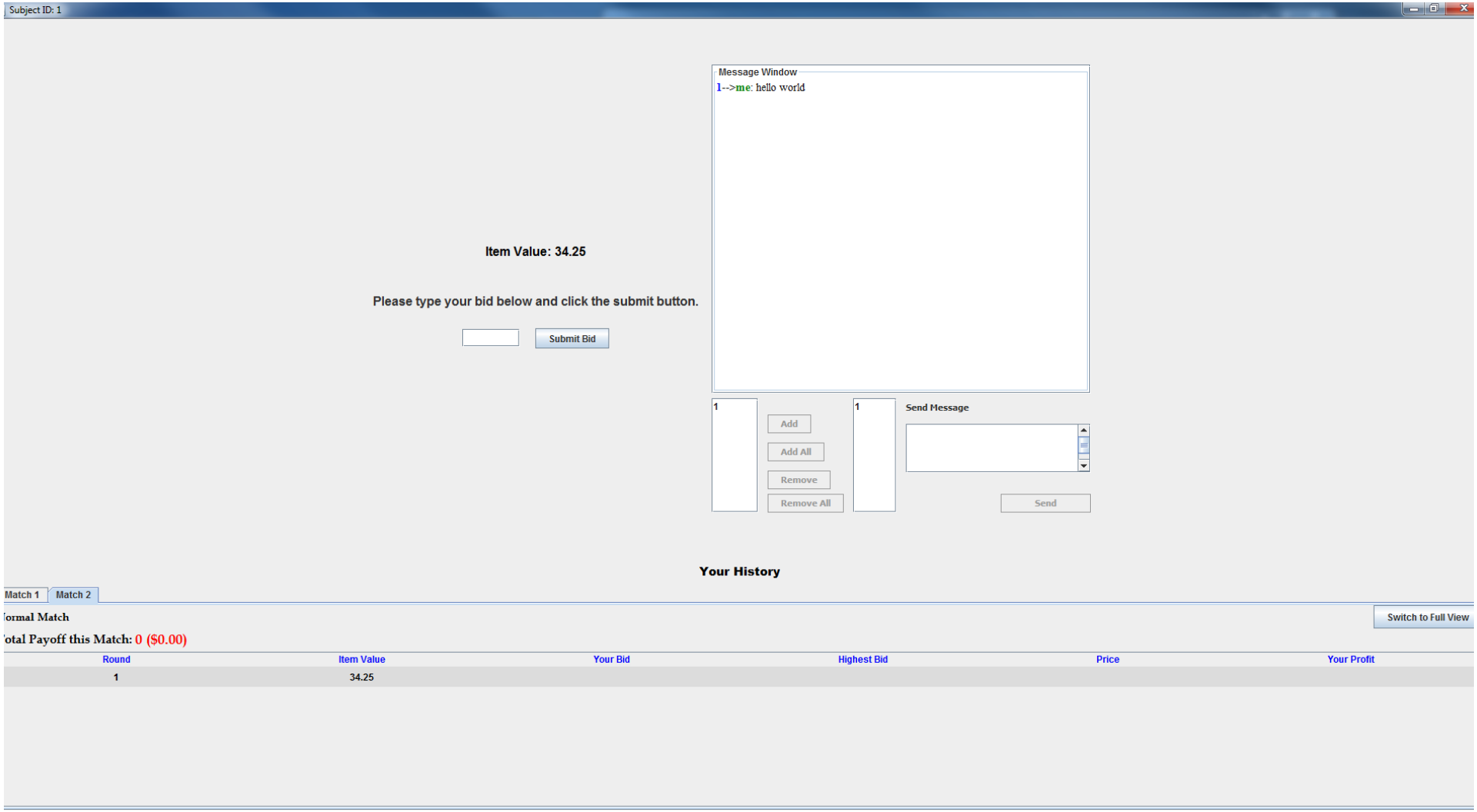
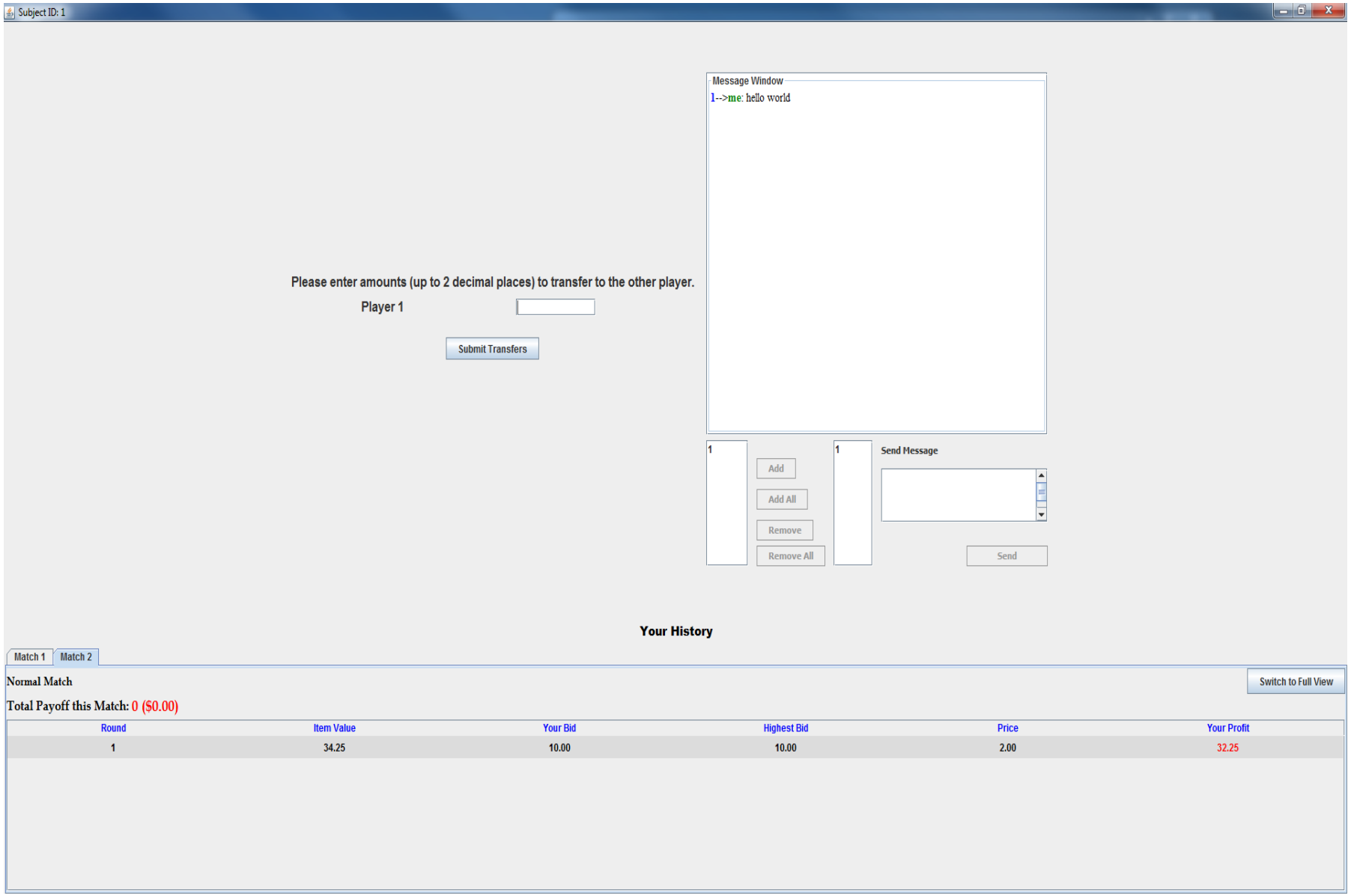


Screenshot – Communication and Transfers



Theoretical Background

Without Communication

- First-price auction:
  - unique equilibrium (Lebrun, 2004; Maskin and Riley, 2003)
  - both bid half their value

- Second-price auction:
  - unique symmetric equilibrium, both bid values
  - but other asymmetric equilibria
    (one bids 100, the other bids 0, regardless of values)
  - **Note:** The Revenue Equivalence Theorem does not speak to these asymmetric equilibria

Theoretical Background

With Pure Communication

- Allowing bidders to communicate does not enlarge the set of equilibrium outcomes in the first-price auction (Lopomo, Marx, and Sun, 2010)

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  – Can emulate first-price auction outcome without communication in the second-price auction with communication: Take bids (b_1,b_2) submitted in a first price auction.

    - If $b_1 = b_2 = b$ then submit (b,100) or (100,b) with equal probability.

    - If $b_i > b_j$ then i submits 100, j submits b_i

  – The outcome produced by bids (100,0) in the second-price auction cannot be produced in a first-price auction

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- Without restricting communication protocols, the set of equilibrium outcomes corresponding to the second-price auction strictly contains the equilibrium outcome corresponding to the first-price auction

- The set of equilibrium outcomes in the second-price auction strictly contains the convex hull of the set of equilibrium outcomes without communication (**Intuition:** Can emulate the equilibrium outcome emerging in a first-price auction without communication)

Theoretical Background

With Pure Communication and Transfers

- SPE outcomes in both auction formats coincide with outcomes corresponding to the case in which only communication is available

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Intuition

- Using backward induction, at the transfer stage, no incentive to pass transfers, so any SPE involves zero transfers

Summary of Treatments

Auction Format	Available Interaction	# of Subjects	# of Sessions	# of Rounds
First Price	No Communication	30	3	(10,10,10)
	Pure Communication	72	6	(15,15,10,10,10,15)
	Communication with Transfers	48	4	(10,11,12,10)
Second Price	No Communication	36	3	(10,10,10)
	Pure Communication	64	5	(10,10,10,10,15)
	Communication with Transfers	46	4	(10,10,10,10)

- All experiments were conducted at UC Irvine (ESSL) in 2013 - 2014
- 296 subjects participated
- Subjects were paid for all rounds + show-up fee (average payment $19)
- Sessions lasted on average 1 hour and 15 minutes
- Random or complete strangers protocol for matching between rounds

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Risk Elicitation – Use Gneezy and Potters (1997), Charness and Gneezy (2010):

- Subjects are endowed with 100 points, worth $2
- Asked to allocate points between a safe investment, and one that pays 2.5 time the amount invested with 50% probability, 0 otherwise
- Amount invested in the risky asset is a proxy for degree of risk aversion

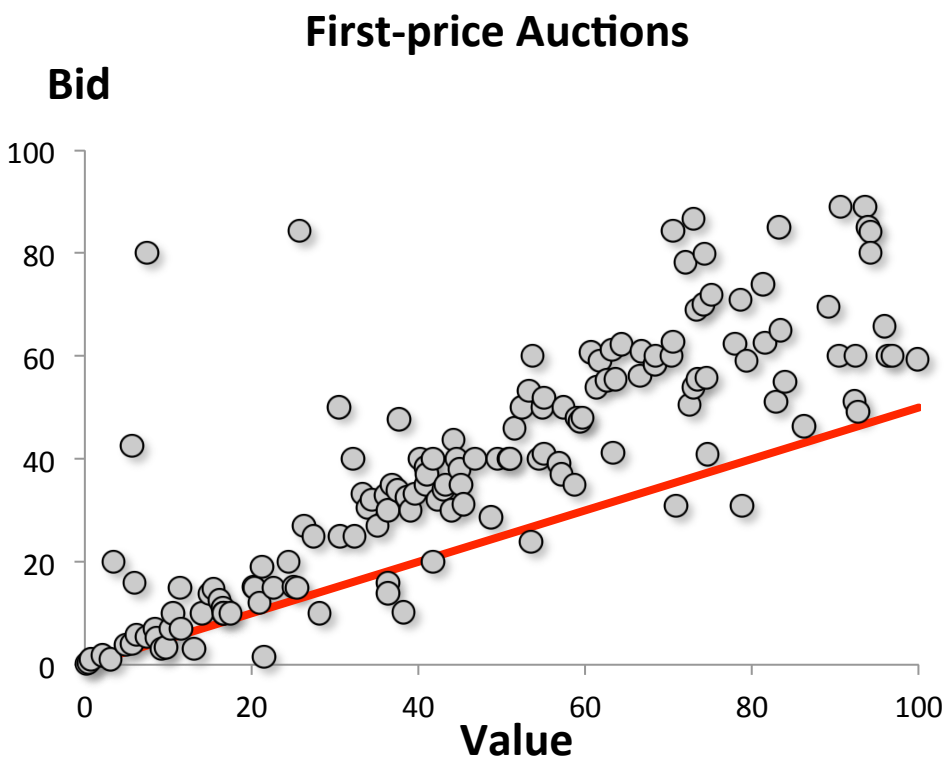
Results - Roadmap

- No Communication treatment
  - Behavior is in line with previous literature
- Aggregate Results: Effects of Cheap-talk and Transfers on
  - Efficiency
  - Revenues and prices
  - Frequency of collusion
- How cheap-talk communication affects bidding strategies
  - Focus on pure communication treatment
- Analysis of conversations and transfers

Results Today – Robustness Note

- Focus on Rounds 6 – 10
  - higher variation in behavior in first 5 rounds presumably due to learning
  - time trends are not significant starting from period 6 onwards
- No difference in behavior in sessions that lasted longer than 10 rounds
- Behavior in the very last round is similar to behavior in rounds 6 – 9
- Results aggregated across sessions
  - qualitatively not much variation between sessions
- Risk has no significant impact on behavior (or results)

No Communication treatment



- Bidding above Nash Equilibrium
  - as in Cox et al. ('82) and Dyer et al. ('89)

- Efficiency = 83%
  - 88% in Cox et al. ('82), 82% in Kagel-Levin ('93)

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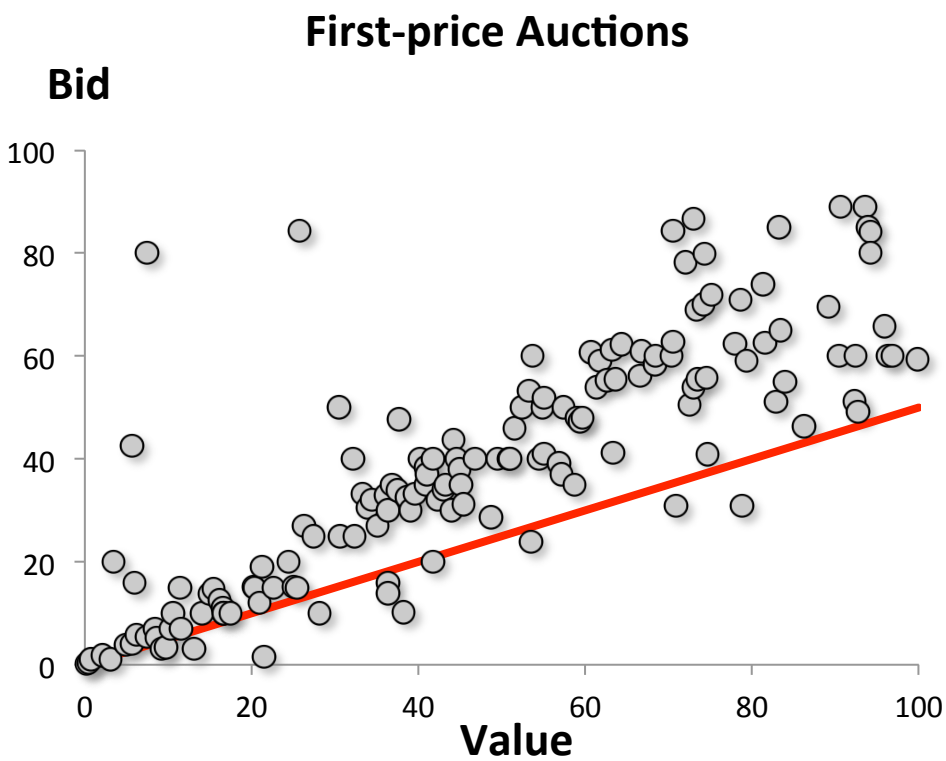

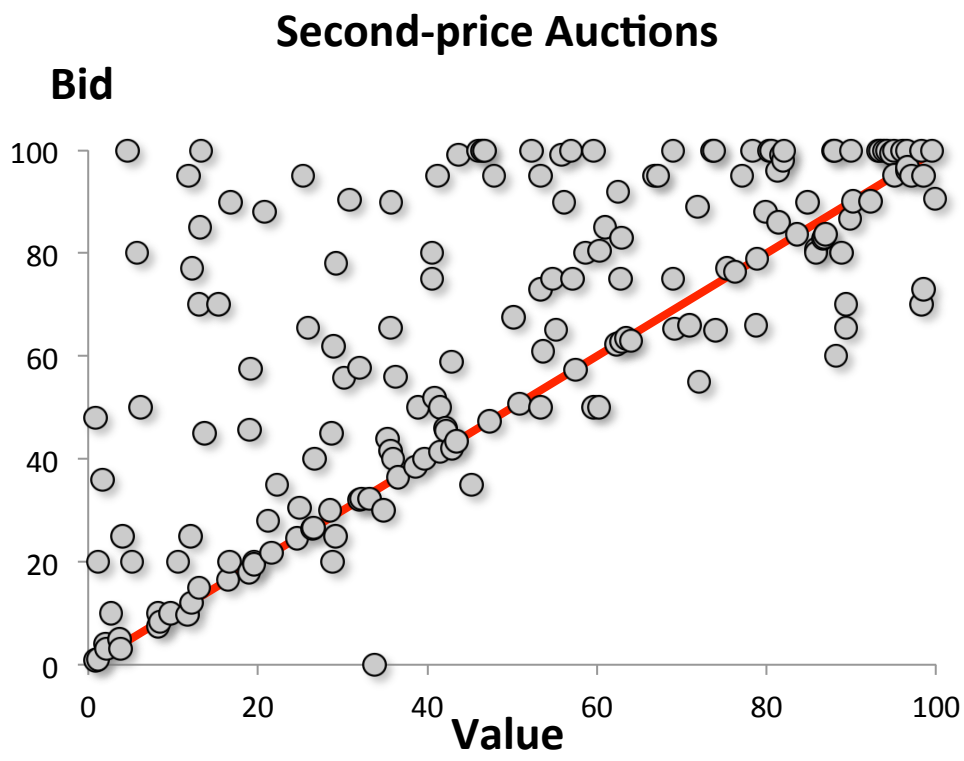

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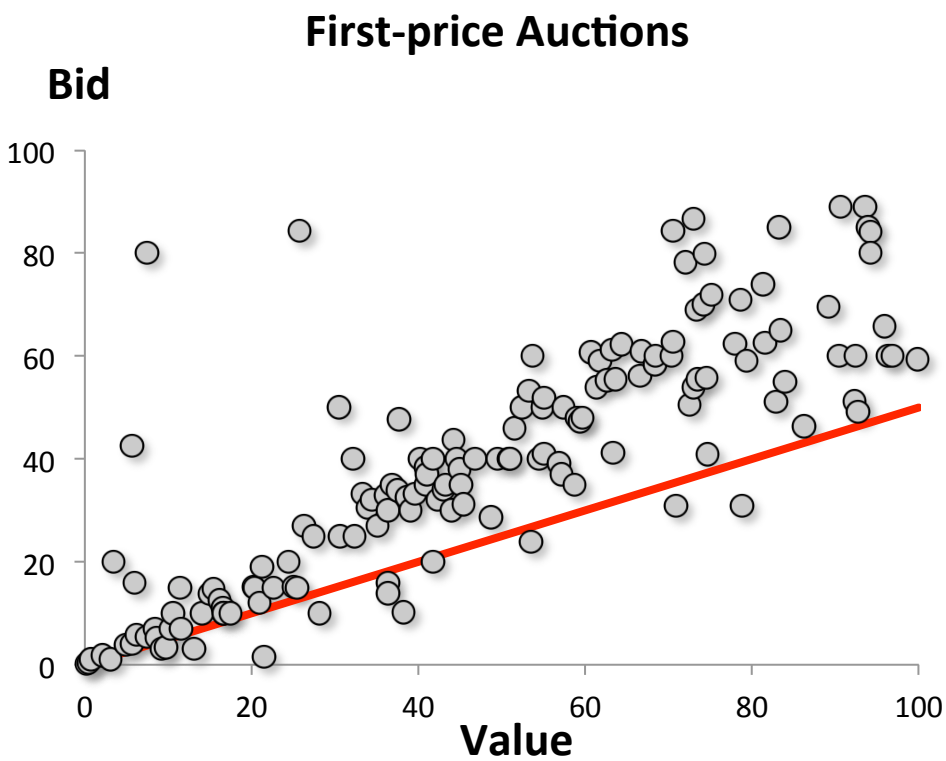

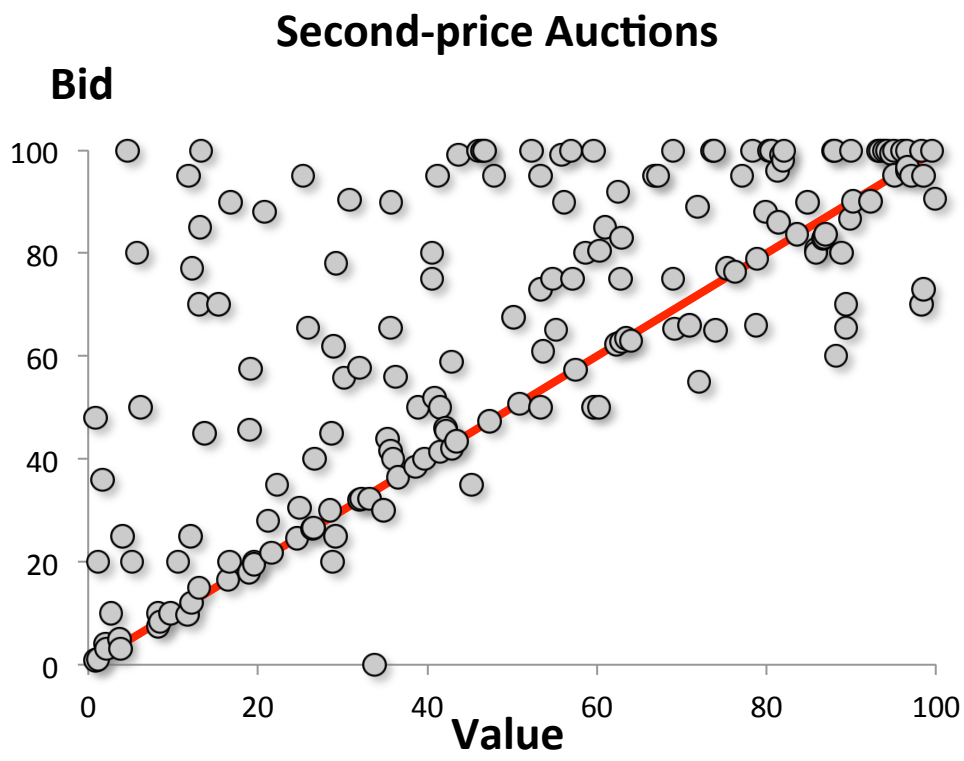

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<u>Result 0:</u>
Behavior in the No Communication treatment is in line with previous work

Aggregate Results - Efficiency

	First Price Auction	Second Price Auction
No Communication	**83%** (5%)	**76%** (3%)
Pure Communication	**79%** (4%)	**72%** (4%)
Communication + Transfers	**86%** (4%)	**76%** (5%)

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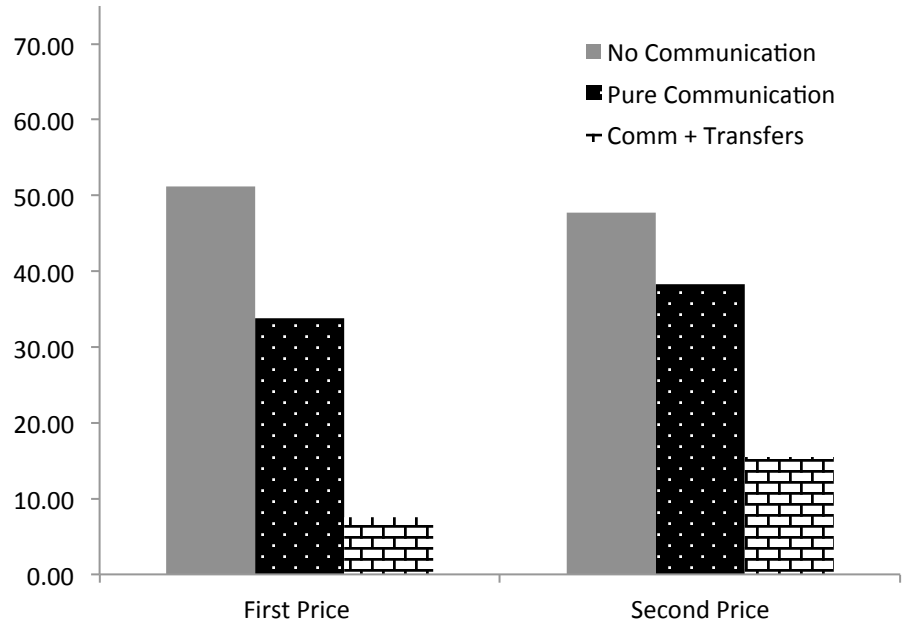
<u>Result 1:</u>
Communication and transfers do not affect efficiency in any auction format

Aggregate Results - Revenues



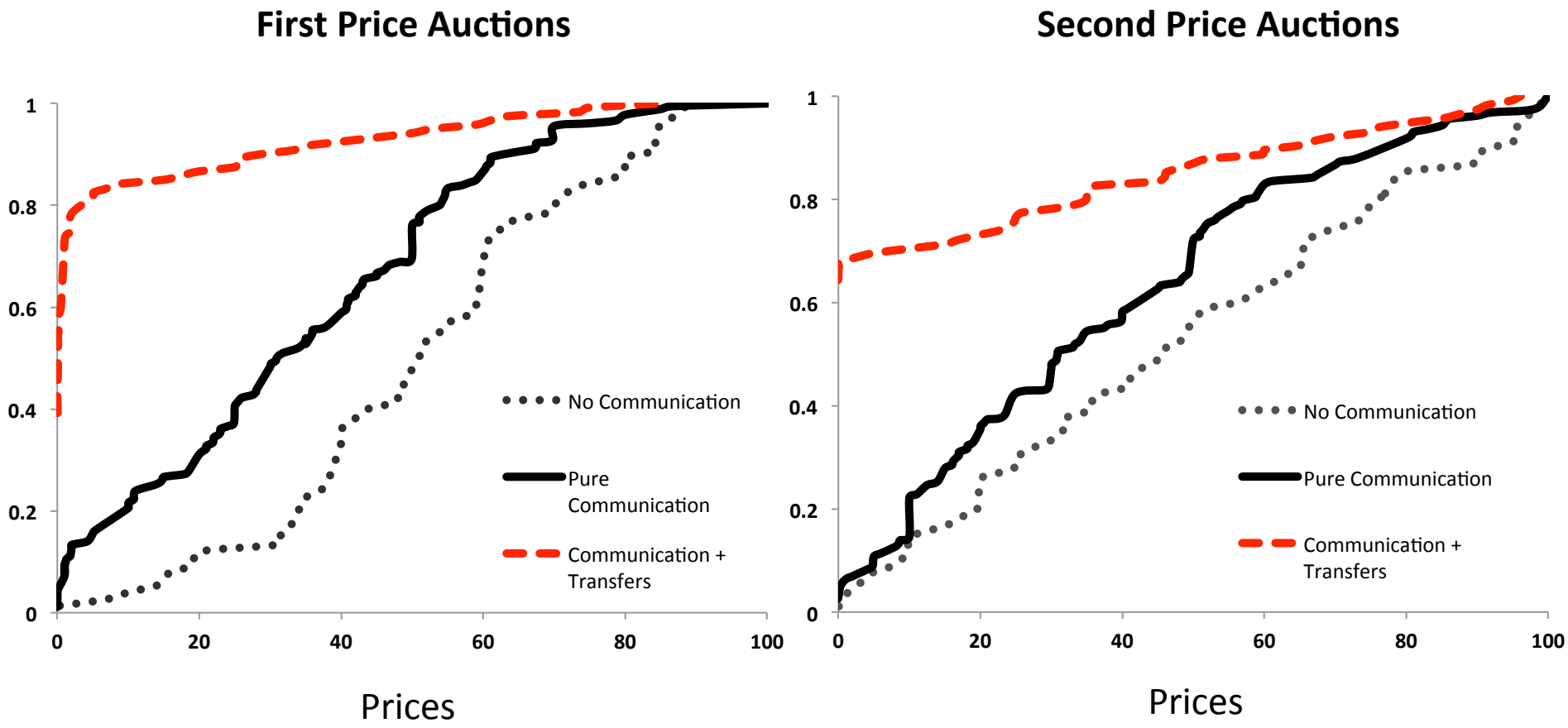
In both auction formats:

- Cheap-talk alone reduces revenues of the auctioneer in both auction formats
- Availability of transfers, in addition to communication, further drives prices down

Conditional on available interaction

- No statistical difference between average prices in the two auction formats

Aggregate Results - Observed Prices



Result 2:

- Communication reduces revenues of the auctioneer in both auctions
- Availability of transfers in addition to communication substantially reduces revenues and leads to zero prices in about 70% of interactions in both auctions

Aggregate Results - Frequency of Collusion

Collusion = price is below equilibrium price without communication

Full Collusion = price is ≈zero (between 0-2)

	No Communication		Pure Communication		Communication + Transfers	
	collusion	full collusion	collusion	full collusion	collusion	full collusion
First Price	5%	0%	36%	13%	88%	78%
Second Price	10%	1%	27%	5%	71%	68%

Result 3
Availability of communication and transfers results in vast majority of successful collusions between bidders in both auction formats (more than 70%)

Effects of Pure Communication

- Without communication, very little learning
  - Random effects GLS regressions of observed bids as a function of one's value, constant and other's bid; clustering errors by subjects
- With communication, substantial learning
  - Random effects GLS regressions of observed bids as a function of one's value, constant and other's bid; clustering errors by subjects
- Communication allows subjects to correlate their bids:
  - A **competition effect:** Subjects increase their bids in response to opponents' bids

Result 4
Availability of communication reduces bids toward equilibrium behavior

Examples of Conversations

First Price Auction

Communication + Transfers treatment

0: hi! do you want to work together to maximize both of our profits? ☺
11: hey
want to work together
haha thinking the same thing
0: ☺ what's your value? mine is 9.87
11: ok so my value is 95.56
11: so I will bid 0.01 and you bid 0
0: so I'll bid 0 and you bid 0.01 then transfer half to me? does that sound good?
11: and I will transfer half
0: ok cool thanks for working with me ☺
11: exactly

Reveal-collude strategy

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Reveal-collude strategy

Second Price Auction

Pure Communication treatment

5: hi!
6: hello
☺
5: how did you want to do this shindig?
6: do you want to bid the same number? 50/50 chance
5: that sounds good!
6: no negative profits

Flip-a-coin strategy

Strategies Discussed and Used

	Pure Communication		Communication with Transfers	
	First-price	Second-price	First-price	Second-price
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%

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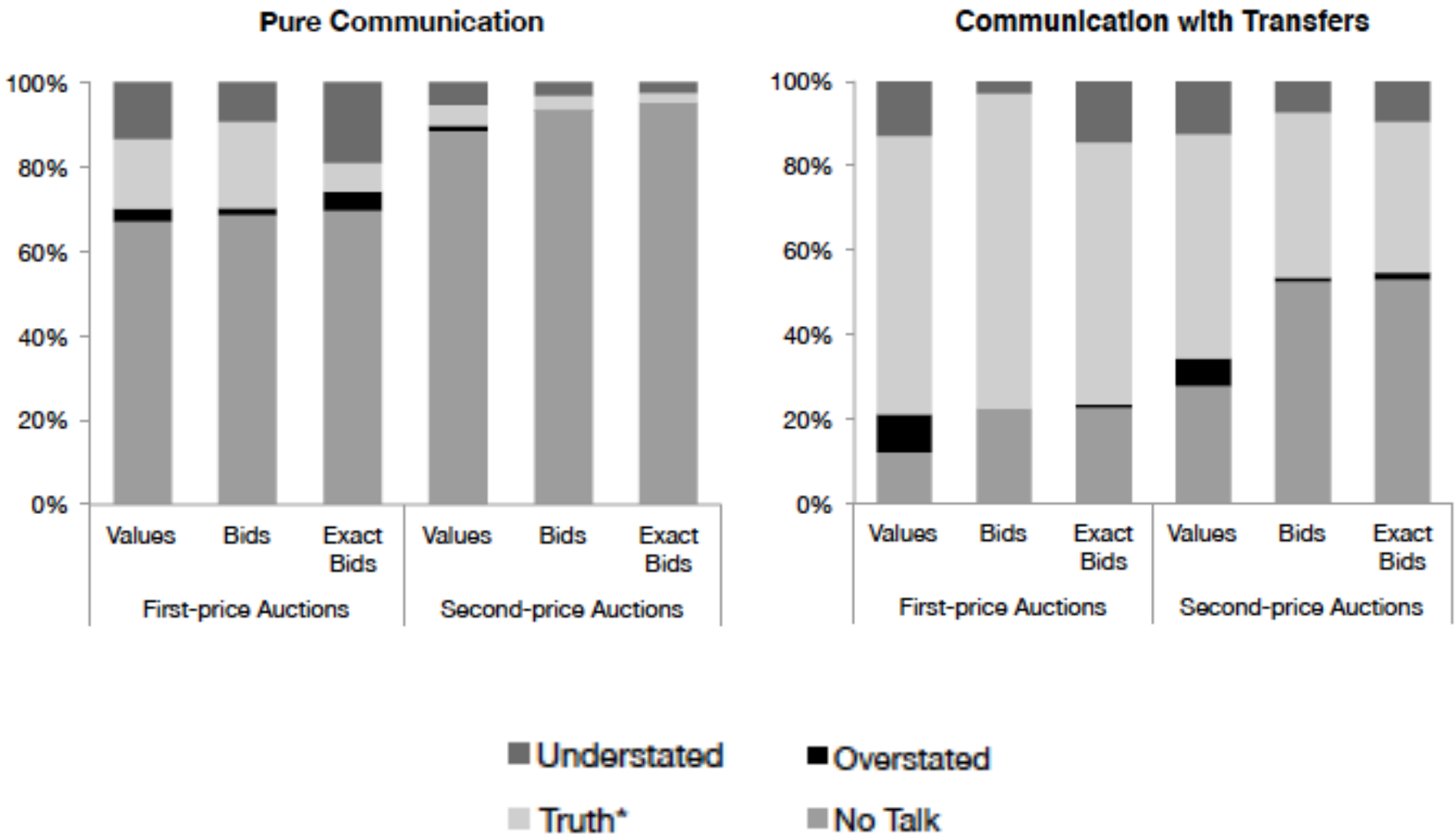
Result 5
Reveal-collude and flip-a-coin strategies often discussed, reveal-collude followed frequently.

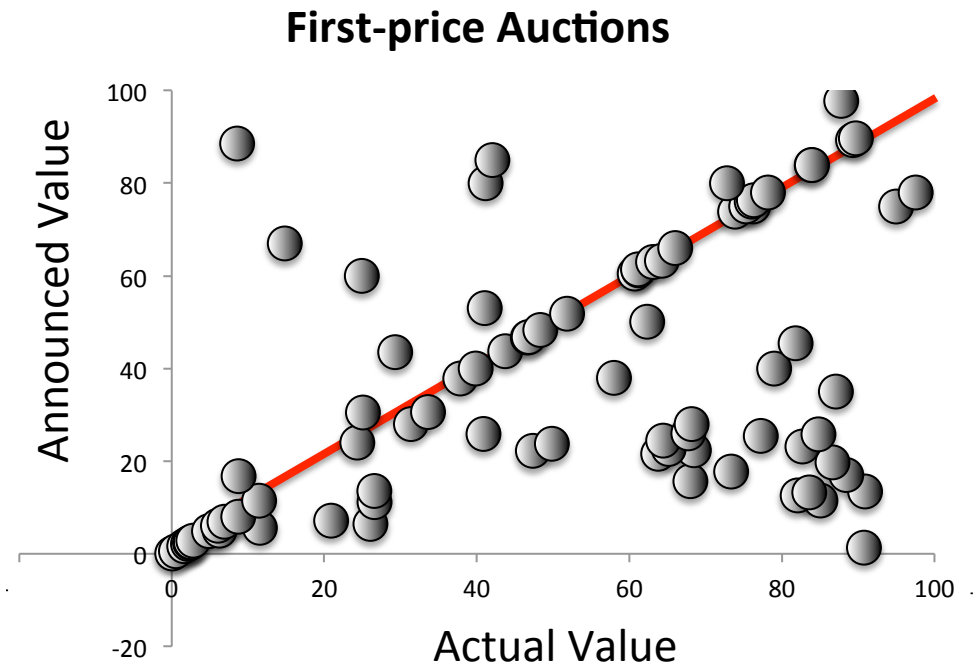
Frequency of Communication

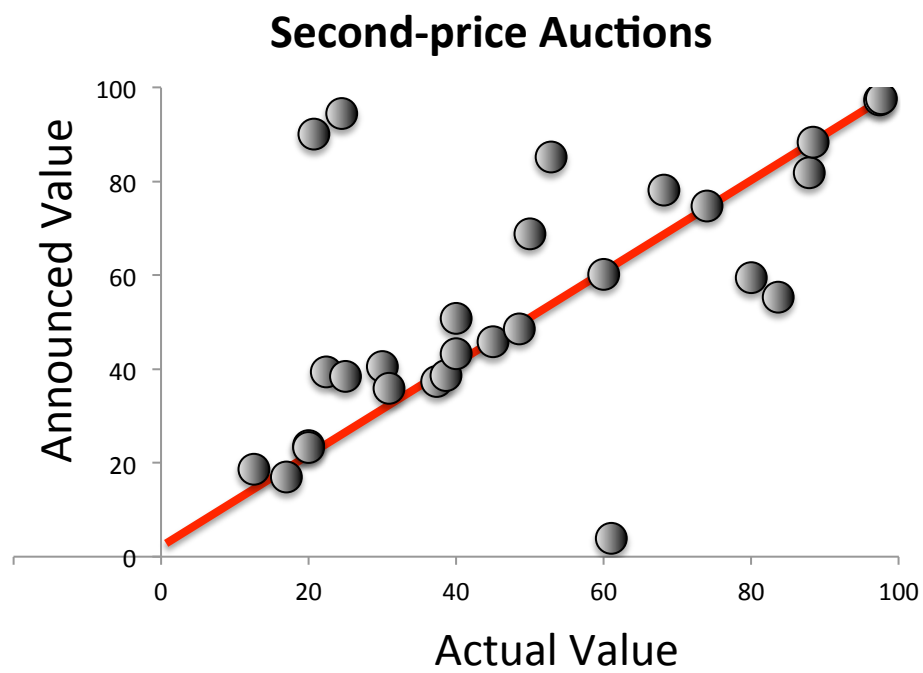


Frequency of Communication

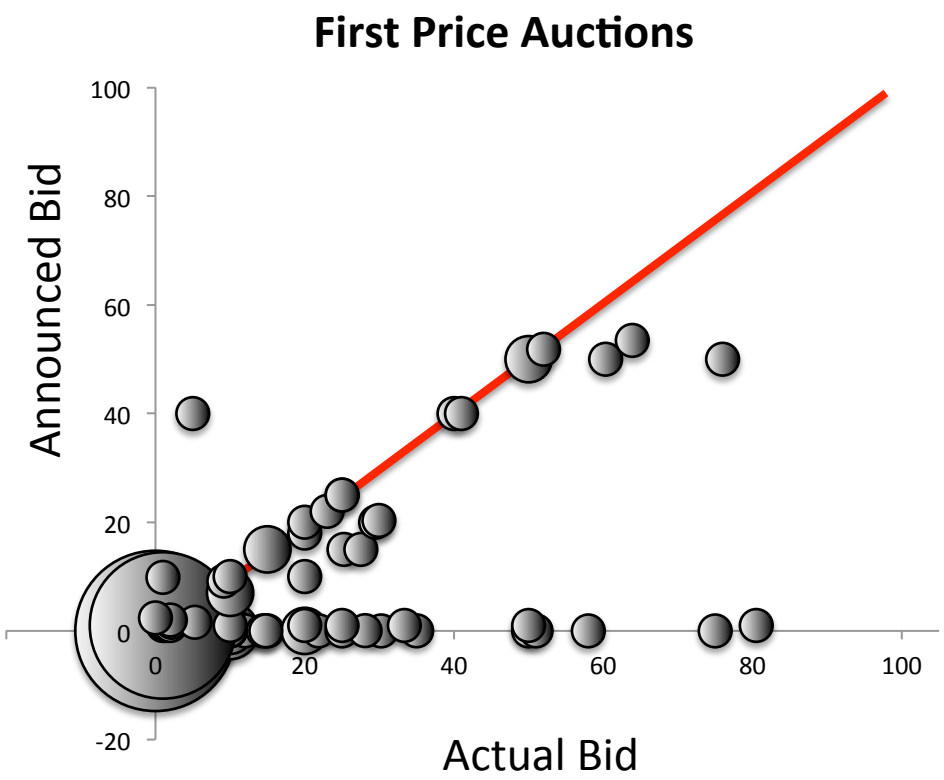
- Far more communication with transfers than without
- Substantially more truthful conversations with transfers than without
- Lying mostly through understatement

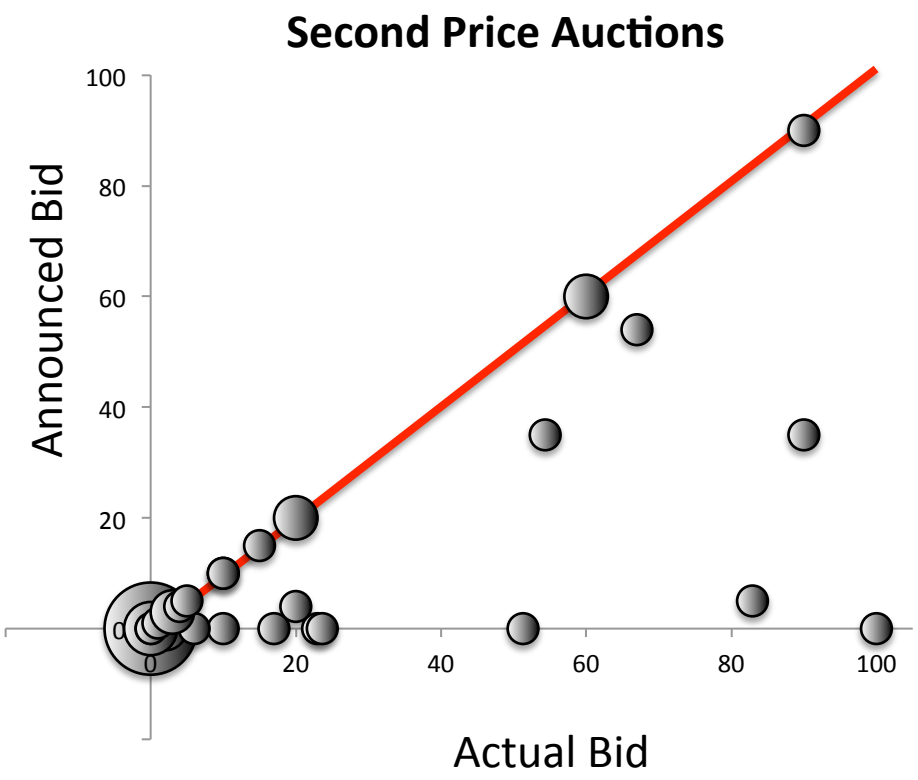
Pure Communication – Lying about Values





Pure Communication – Lying about Bids





Analyzing Transfers

- How often do subjects transfer points to each other?
  - Losers almost never do (less than 5%)
  - Winners do that 69% in first-price and 50% in second-price
  - Winners do so more often if full collusion (83% in first-price and 73% in second-price)

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- **Conditional on making a significant transfer, amount transferred averages 44% of surplus in both auctions**

- **The modal (significant) amount transferred is 50% of surplus** (in 58% of first-price auctions, and 71% of second-price auctions).

General pattern of behavior: subjects share (truthfully) values, bid so that high-value bidder wins at a low price, share surplus roughly equally.

Conclusions

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- Revenues of the auctioneer decrease when bidders can communicate, even more so when transfers are available (over 70% collude)
- The effects of communication and transfers are similar across auction formats
- Communication protocols reveal persistent patterns:
  - Bidders often discuss private values and report values to their opponents
  - Most reports are untruthful when transfers are unavailable and most reports are truthful when transfers are available
  - Bidders frequently discuss “reveal-collude” strategies, especially when transfers are available

The End

The Revenue Equivalence Theorem

For any two Bayesian incentive compatible auctions, if under their respective Bayesian Nash equilibria where all players bid their type,

- a buyer of any type has the same probability of getting the object across auctions, and
- a buyer of lowest type has the same expected utility across auctions,

then the total expected transfers, i.e. the auctioneer's expected revenue, is the same for the two auctions.

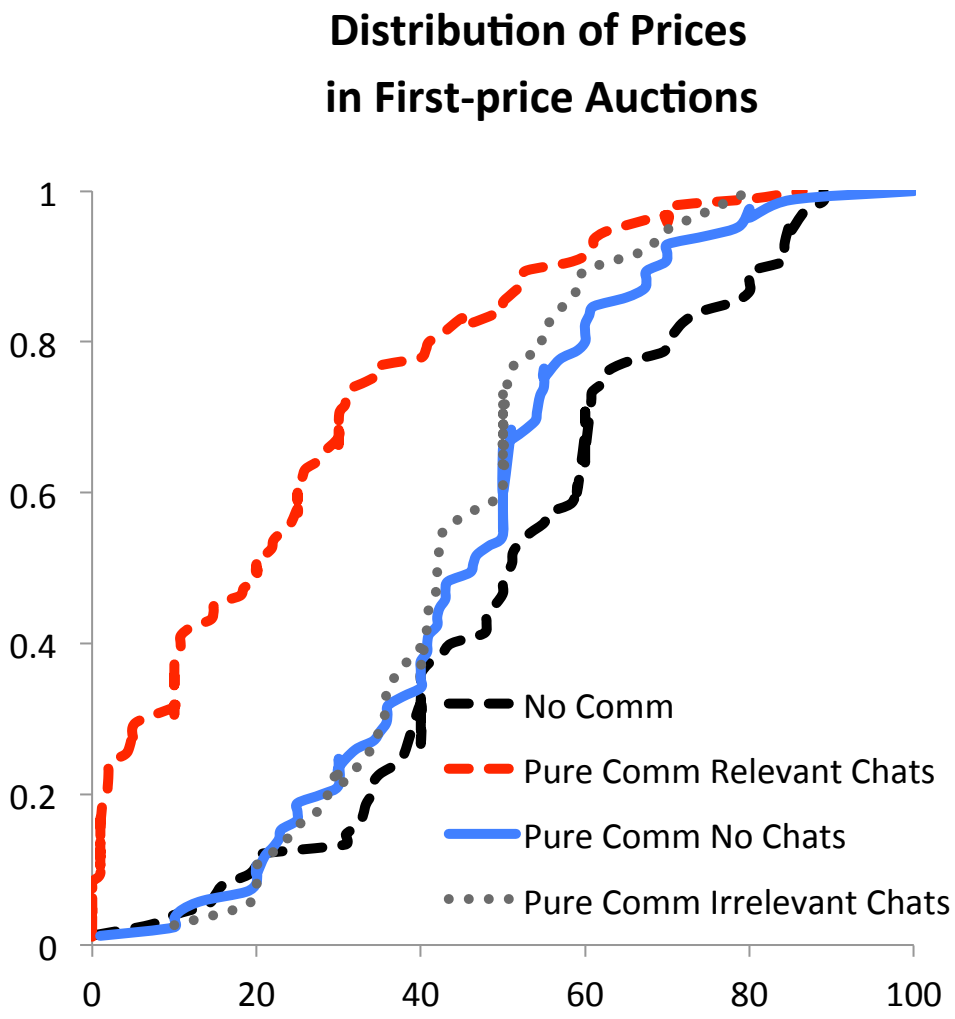
FIRST-PRICE AUCTIONS

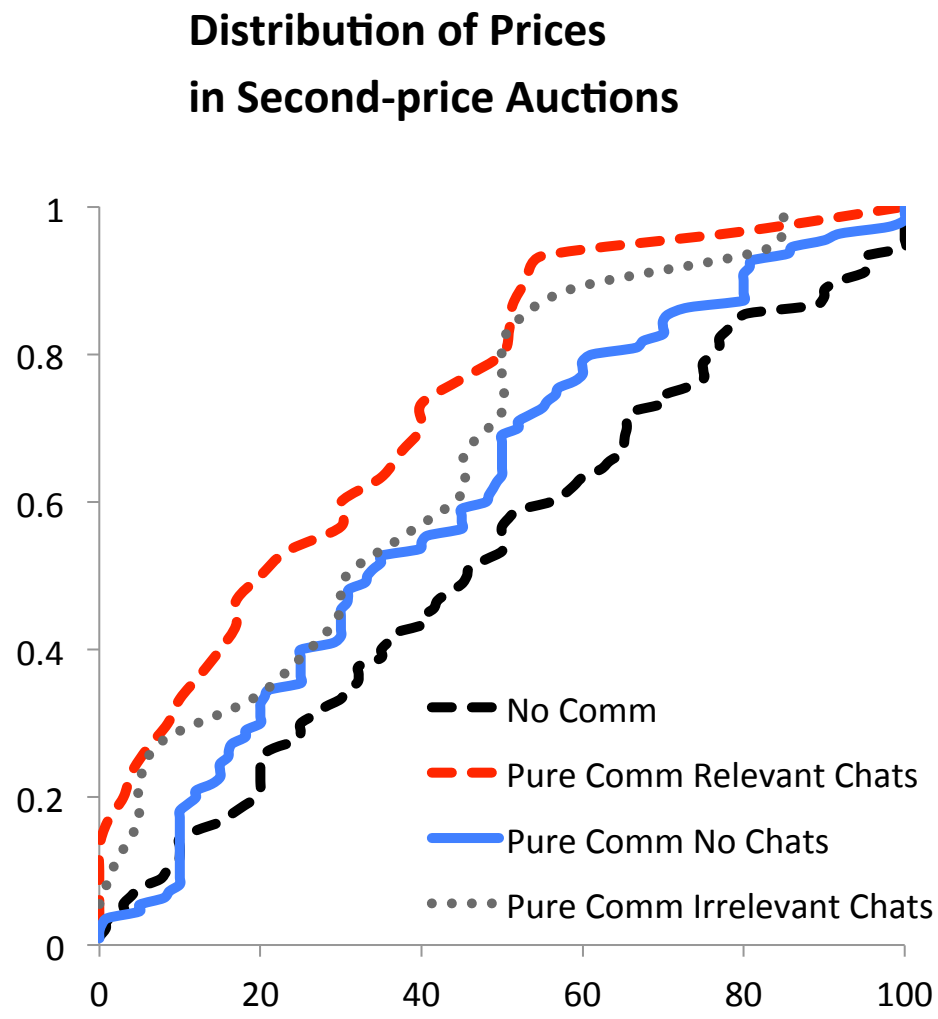
	No Communication		Pure Communication					
			No Chat		Irrelevant Chat		Relevant Chat	
	Rounds 1 - 5	Rounds 6 - 10	Rounds 1 - 5	Rounds 6 - 10	Rounds 1 - 5	Rounds 6 - 10	Rounds 1 - 5	Rounds 6 - 10
Own Value	0.80** (0.03)	0.72** (0.03)	0.76** (0.04)	0.77** (0.03)	0.72** (0.04)	0.61** (0.05)	0.45** (0.06)	0.32** (0.04)
Other's Bid	- 0.01 (0.04)	- 0.01 (0.04)	- 0.01 (0.04)	0.04 (0.04)	- 0.02 (0.05)	0.16** (0.03)	0.45** (0.06)	0.26** (0.06)
Constant	3.63 (3.16)	5.79** (2.71)	0.72 (2.57)	- 4.92** (2.50)	1.46 (3.05)	- 5.51 (3.97)	- 9.38** (3.51)	- 4.46 (2.55)
# obs	150	150	90	92	123	77	147	190
# subjects	30	30	42	48	63	43	62	64

SECOND-PRICE AUCTIONS

	No Communication		Pure Communication					
			No Chat		Irrelevant Chat		Relevant Chat	
	Rounds 1 - 5	Rounds 6 - 10	Rounds 1 - 5	Rounds 6 - 10	Rounds 1 - 5	Rounds 6 - 10	Rounds 1 - 5	Rounds 6 - 10
Own Value	0.75** (0.05)	0.74** (0.05)	0.78** (0.16)	0.76** (0.08)	0.50** (0.09)	1.05** (0.17)	0.53** (0.13)	0.82** (0.12)
Other's Bid	0.02 (0.05)	0.02 (0.05)	0.004 (0.08)	0.007 (0.05)	0.05 (0.07)	- 0.03 (0.12)	0.44** (0.11)	0.14** (0.07)
Constant	15.7** (4.55)	25.5** (4.38)	31.9** (11.4)	26.2** (6.66)	29.4** (6.24)	10.19 (12.91)	- 5.58 (8.68)	- 1.22 (8.57)
# obs	180	180	146	210	94	50	79	60
# subjects	36	36	51	63	42	31	40	35

Pure Communication – Effects on Prices





Norms of Transfers

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- A norm prescribing equal division of surplus? (Andreoni and Bernheim, 2009)

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- The following protocol is an equilibrium under both auction formats:
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  - 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.

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  - 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.
- Nonetheless, it is *not* an equilibrium for any unequal split of the surplus

Other-regarding Preferences and Reciprocity

- Other-regarding preferences often observed in the lab (Fehr and Scmidt, 1999, Bolton and Ockenfels, 2000)

- A simple form: preferences entail two linear terms – one corresponding to one's own monetary outcomes and one corresponding to others' outcomes (Fehr and Schmidt, 1999)

- -> Corner solutions! In treatments where transfers are available, agents should either transfer none of their surplus or all of it

- Perhaps non-linearities will do the trick?

Other-regarding Preferences and Reciprocity

- Many ways to introduce non-linearities

- Suppose:

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

own payoff

other's payoff

where $0 \leq \alpha \leq 1$, *f* twice continuously differentiable, *f(x)=f(-x)*, $f'(x) * \mathrm{sgn}(x) > 0$, and convex, $f''(x) > 0$ for all x.

Other-regarding Preferences and Reciprocity

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

- Consider a winner who has an object value of *v* that she gained for the price of *p*. If she makes a transfer of *t*, she receives a utility of:

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- Maximization with respect to *t* yields:

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

Difference between net profits of winner and loser

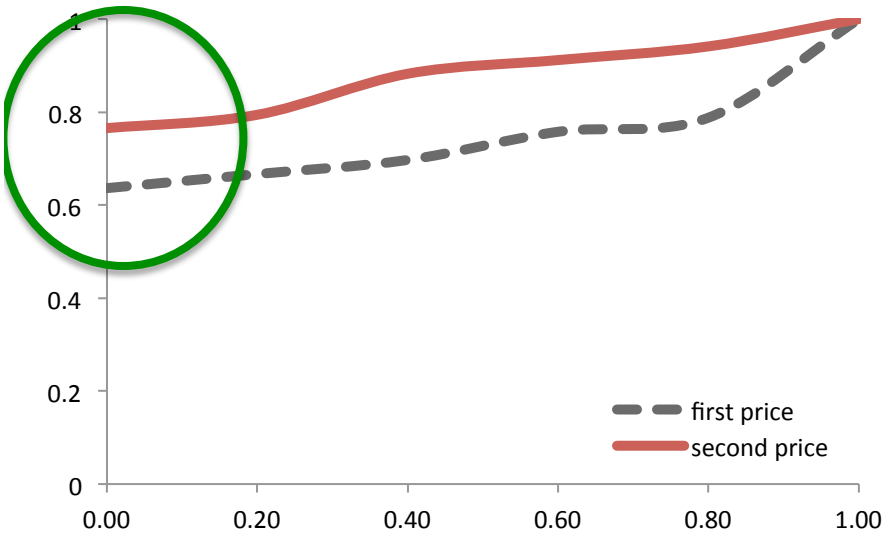
Constant

Other-regarding Preferences and Reciprocity

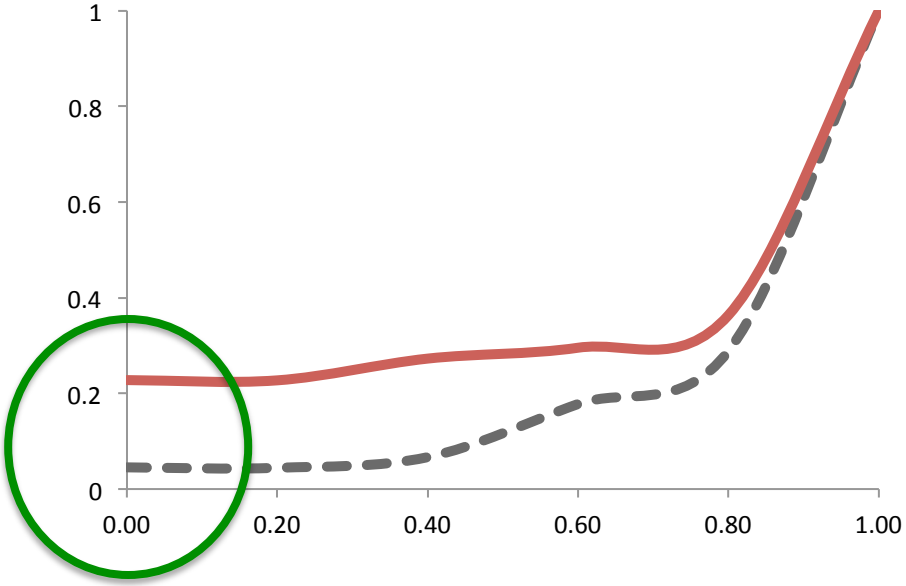
- Such a model would predict constant differences between net profits of winners and losers
- Not what we observe in the data! Not even when conditioning on fully collusive outcomes
- Standard deviation of 26 in both auction formats even when final price is 2 or less

Analyzing Transfers – Conditional Reciprocity

CDF corresponding to individuals' frequency of positive transfers to losers when price is greater than 2



CDF corresponding to individuals' frequency of positive transfers to losers when price is lower than 2



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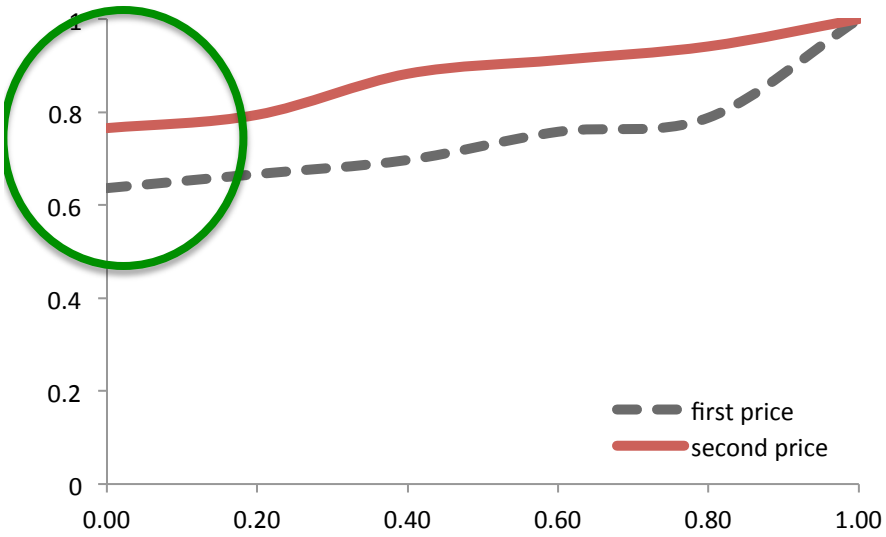
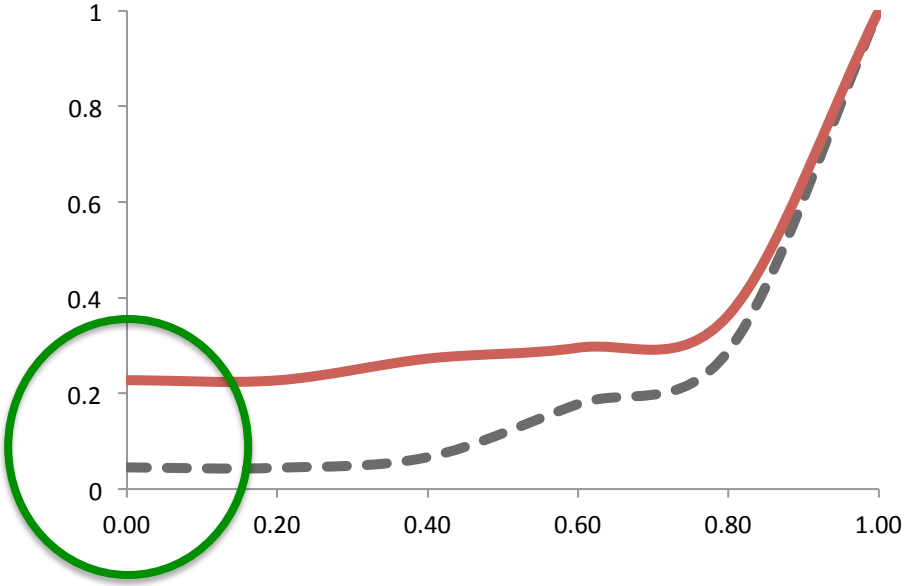


CDF corresponding to individuals' frequency of positive transfers to losers when price is lower than 2



<u>In FP</u>

64% of subjects **never transfer** points if price is greater than 2.

67% of subjects **always transfer** points after full collusion (less than 5% never transfer points after full collusion)

<u>In SP</u>

76% of subjects **never transfer** points if price is greater than 2.

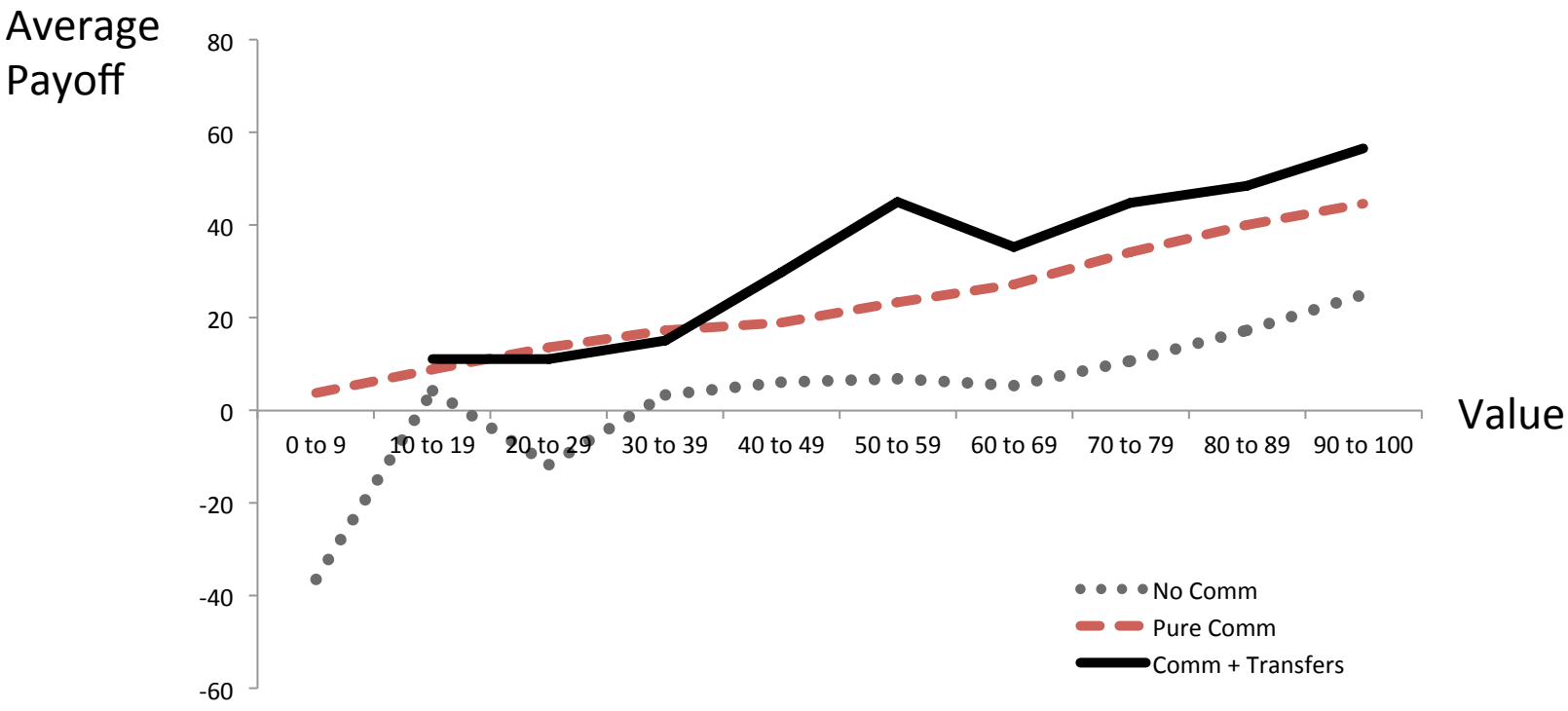
61% of subjects **always transfer** points after full collusion (23% never transfer points after full collusion)

Other Contract Structures

- In our treatments, individuals cannot commit to transfers
- In auxiliary treatments, individuals can commit to transfers after communicating and before bidding
- Similar results. In particular, collusion is detected in 54% of first-price auctions in 78% of second-price auctions

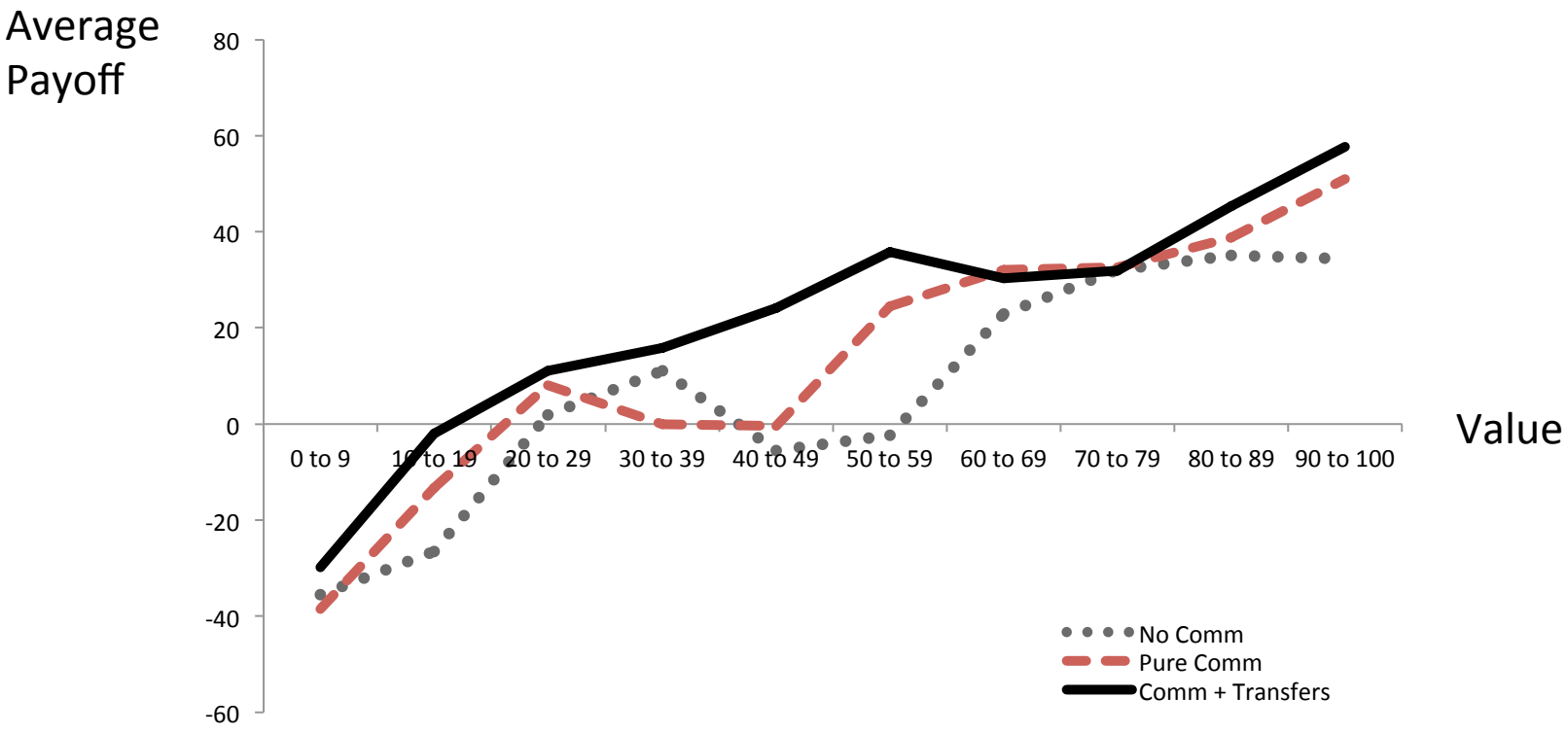
Winners' Payoffs

First Price Auction



Winners' Payoffs

Second Price Auction



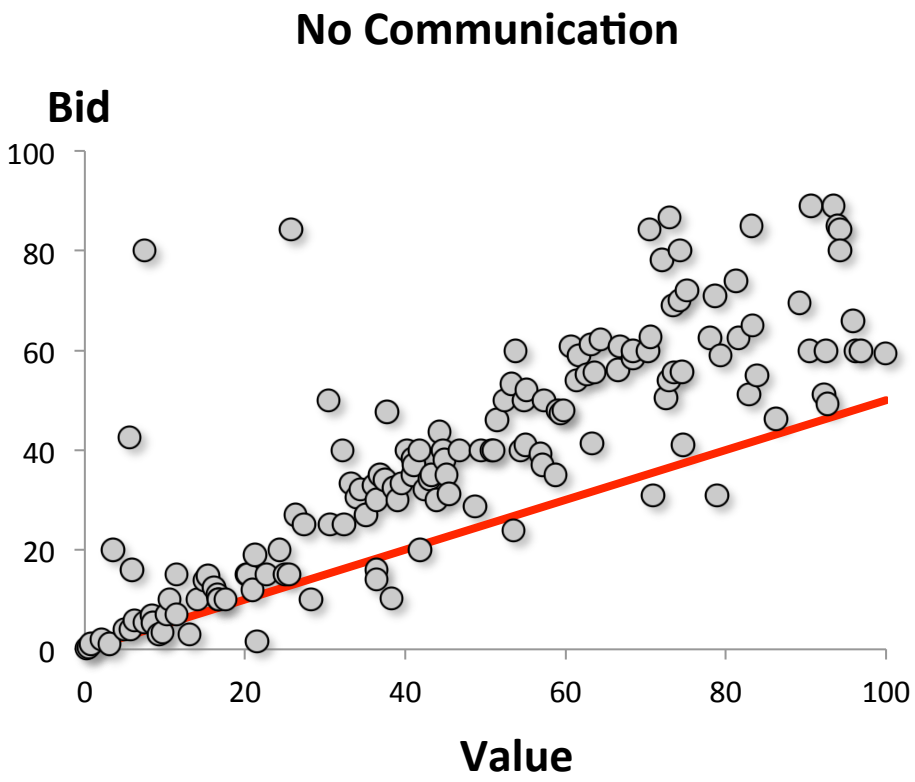
Efficiency in the Communication with Transfers Treatments

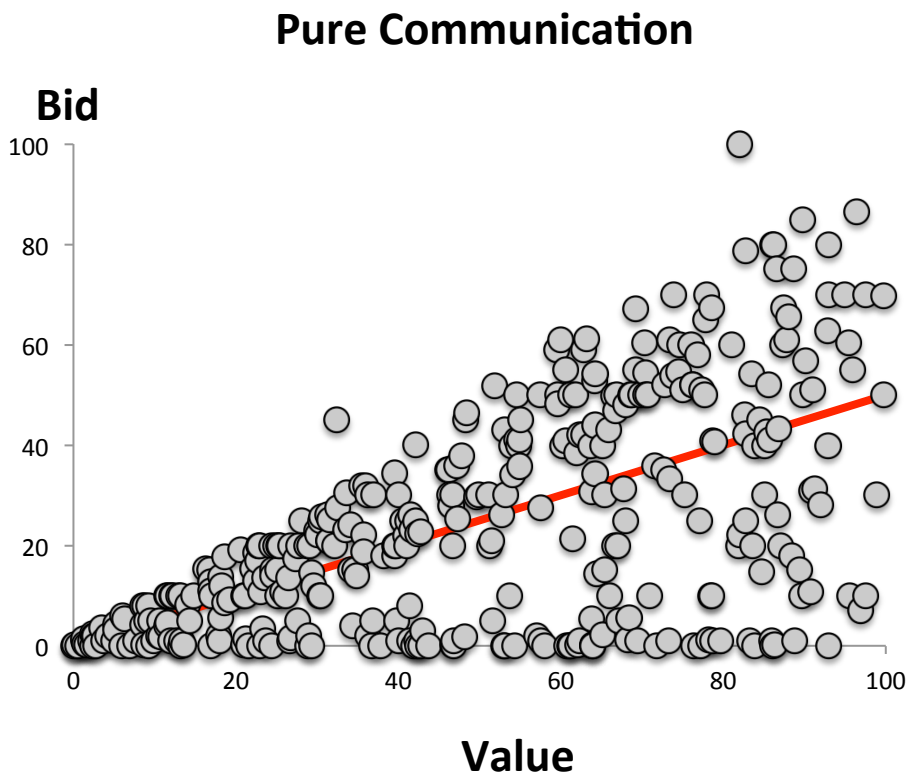
	First Price Auction mean (st error)	Second Price Auction mean (st error)
Winner shares surplus	**0.97** (0.01)	**0.93** (0.036)
Winner doesn't share surplus	**0.64** (0.11)	**0.60** (0.055)

In both formats, auctions in which winners transfer points to the losers are 30% more likely to be efficient than those in which winners transfer nothing.

Effects of Pure Communication on Bidding Strategies

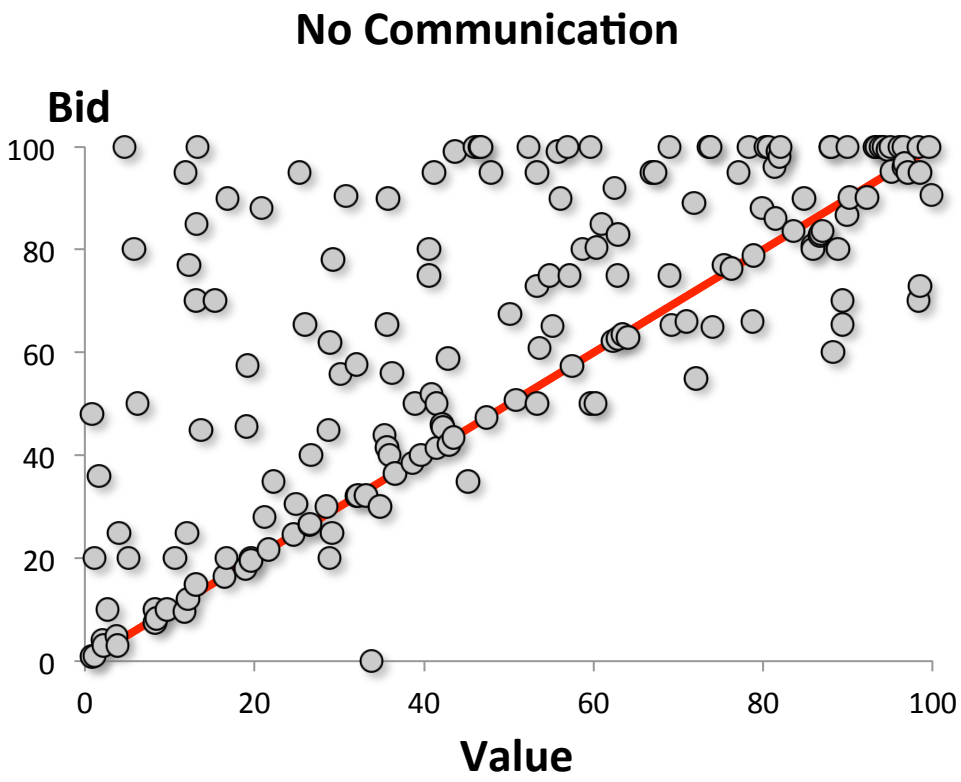
First-price Auctions

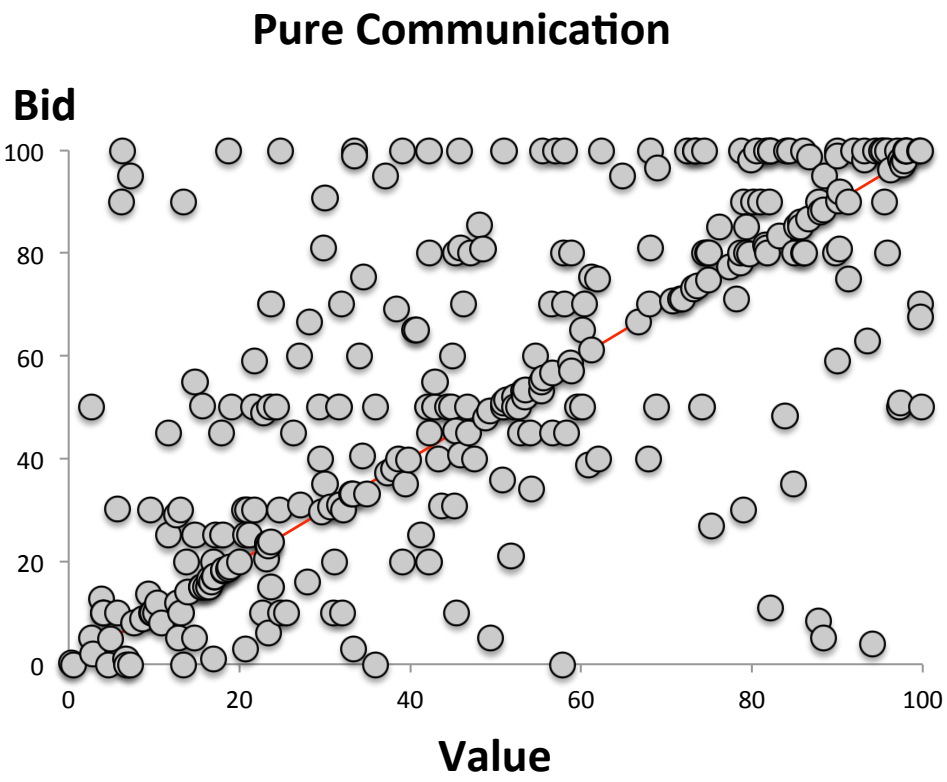




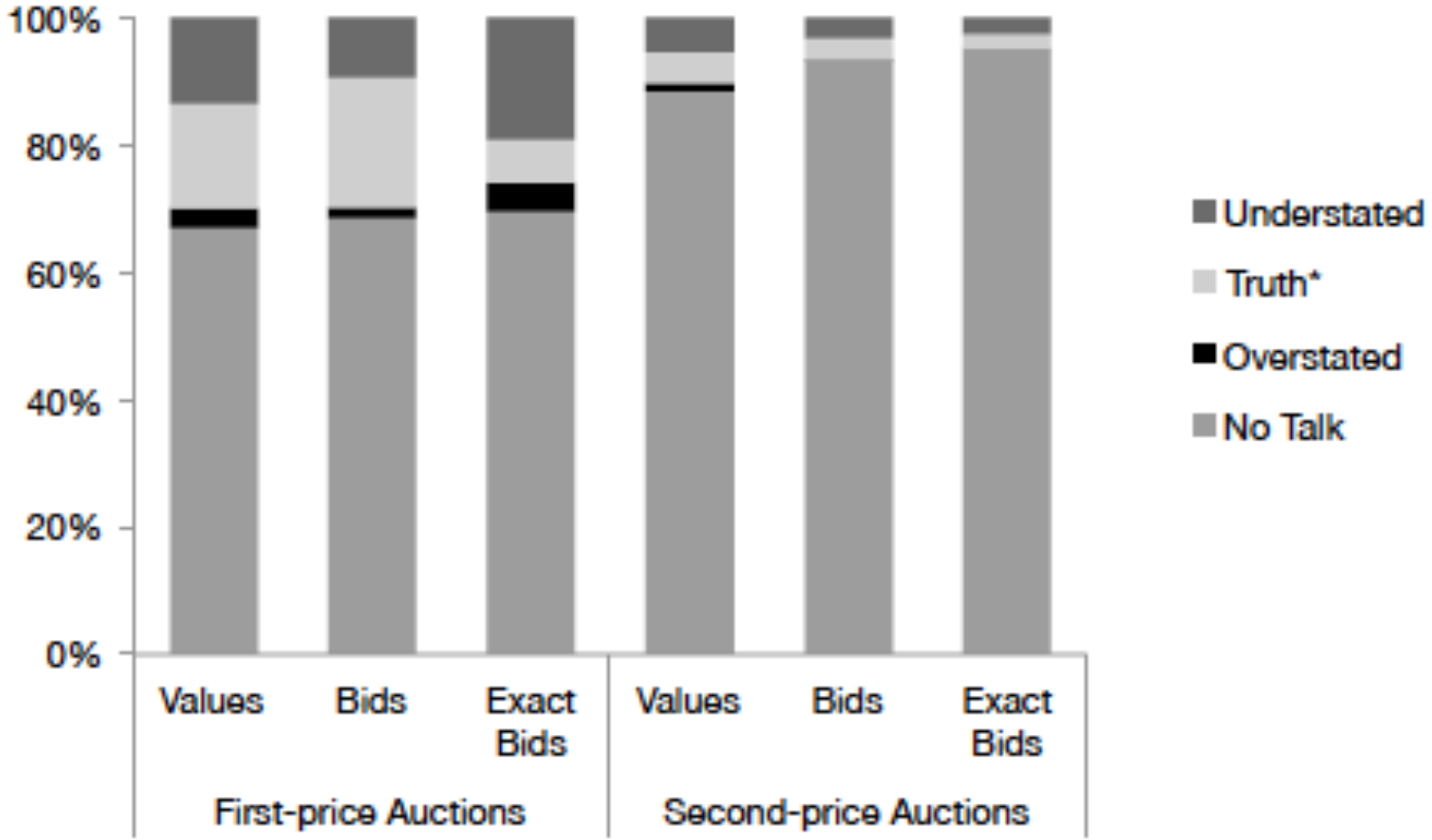
Effects of Pure Communication on Bidding Strategies

Second-price Auctions

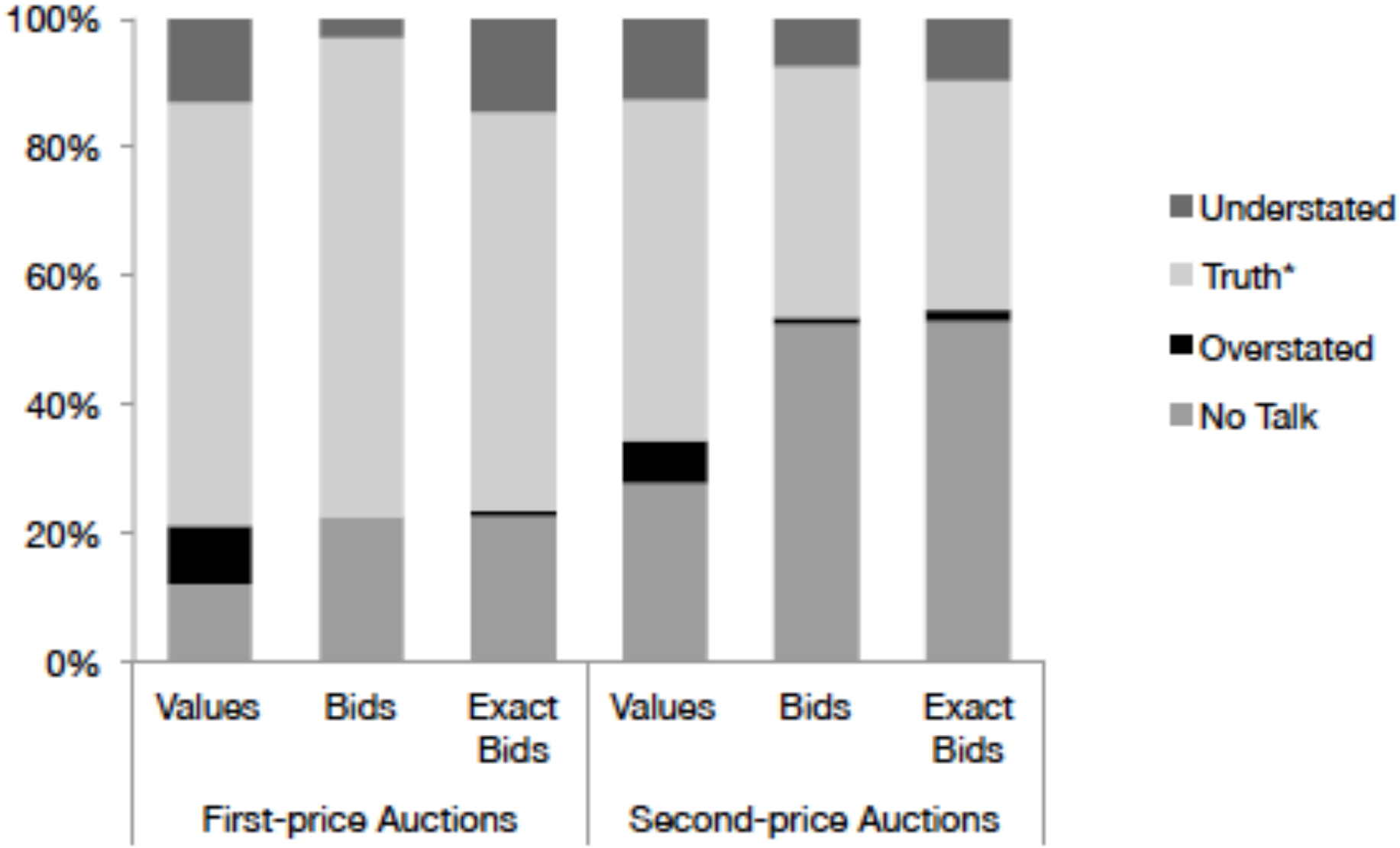




Frequency of Communication – Pure Communication



Frequency of Communication – Communication with Transfers



Explaining when Significant Transfers Occur – Probit results

	First-price Auctions	Second-price Auctions
Winner's Value	0.004** (0.001)	0.005** (0.001)
Indicator if Winner Lied Before	- 0.218 (0.182)	- 0.352** (0.114)
Dummy for Efficient Outcome	0.516** (0.213)	0.296** (0.145)
Indicator if Pair Discussed Reveal-Collude Strategy	0.447** (0.103)	0.681** (0.099)
# of observations	120	115
# of sessions	4	4
Pseudo R2	0.2736	0.4466

Marginal effects are reported (for dummy variables, values correspond to a discrete change from 0 to 1). Errors are clustered at the session level (four sessions for each auction format).