

Online Appendix

A Fish auctions around the world

Many fish auctions around the world are characterized by large volumes of highly perishable and highly variable in quality goods that are auctioned off sequentially, by individual units or lots. Speed of sales is of the essence given large volumes; however, competitive bidding on each item is also an essential requirement for price discovery, given the large variability in quality and other characteristics of each item. Graddy (2006) specifically attributes the need for a centralized market to heterogeneity of fish; she further notes that “many... major fish markets, including Tsukiji, Sydney, Portland and Boston are auction markets” (p. 219). Because of the variability, the buyers are typically given a chance to examine each unit of the good before or at the time of bidding, with the bidding process then taking only a few seconds per unit.

These auctions are organized under a variety of formats, including purely ascending, purely descending or a combination of both, with each of these arguably providing for competitive bidding and speed.¹ For example, the Tokyo (formerly Tsukiji) fish market, arguably one of the most famous fish auctions around the world, uses an ascending price auction format, where buyers, after having inspected fish before the auction, use sign language to signal their bids to the auctioneer; the auctioneer calls out the highest bid, and bidders then may sign higher bids. Cassady (1967) notes the advantage of allowing many bidders to submit bids at the same time: “The auction system is potentially very fast...It is amazing to realize how quickly the auctioneer can interpret the bids and decide which is the highest... Because speed is essential in the sale of fish, the auctioneer must knock each lot down as quickly as possible” (p. 66).

Many other auctions where large amounts of perishable goods are auctioned have elements of descending, or Dutch, format. Aside from the famous Dutch flower auction, Cassady (1967) gives examples of descending oral auction method used “... in some other Continental, and even British, communities, in certain Middle eastern countries [such as Israel], and elsewhere” (p. 60). He further writes (p. 63): “The oral method of the Dutch auction (but not the clock method) is used mainly for the sale of nonstandardized items where quality differences require flexibility...” It is instructive that Cassady (1967) explicitly refers to the trade-off between the starting price and the speed of auction: “The auctioneer must start the quotation at a sufficiently high level to permit the bidder with the highest demand price to register his maximal bid. On the other hand, *he should not start too high, particularly in market situations where speed is essential* (p. 60; the emphasis is ours).

Honolulu fish auction, run by the United Fishing Agency since 1952, is claimed to be based on the Japanese fish market auction;² however, it is really a combination of descending

¹Plott (2017) emphasizes the role of speed and competition: “...When items are perishable... reserve prices play no role... Many of auction procedures are related to the need to have the auction over quickly... Efficiency both in terms of gains from trade and in terms of “market making” time is a big driver of auction rules and procedures.”

²“The Honolulu Fish Auction is based on the famous Tokyo auction, where large fish are sold individually rather than by the boatload to a wholesaler. The auction provides a marketing service for fisherman and helps them with quality improvement to get the best prices for their catch” (Hawaii-Seafood.org, 2015).

(Dutch) and ascending (English) auctions. Feldman (2006) provides the following description (p. 326, footnote 39): “At the Honolulu Fish Exchange... a modified form of the Dutch auction is used, with the auctioneer starting at a high price and then dropping it until a buyer places the first bid. The auctioneer then calls out a higher price with the hope of getting other buyers to start bidding...”

Such a hybrid descending-ascending auction format is not unique to the fish auction in Honolulu, with variations of it encountered in different parts of the world. Guillotreau and Jiménez-Toribio (2006) document a similar format used in fish sales in two French ports: “ In the ... port [of Lorient], offshore boats have been selling fish in a trading room with descending-ascending auctions... An opening price is proposed by the auctioneer before going down around the clock. When a buyer makes a bid the clock stops... During this signalled delay, other bidders may intervene with a higher bid, until a single buyer remains in the auction.... The second example is given by seven ports of south Brittany... One of these ports – Saint Gue´nole´ – implemented a Dutch system... Six neighboring shout auction systems – including that of Le Guilvinec – were equipped...in April 2002 by mobile ECAS [Electronic clock auction systems], with a descending-ascending bidding process, similar to the offshore fish market in Lorient...” (pp.525-6). Finally, Laksá and Marszalec (2020) provide a description of a very similar descending-then-ascending price clock auction mechanism used at the Faroe Fish market in Denmark.

The above indicates that fish auctions have evolved to meet the essential criteria of combining speed and price efficiency, and that the descending-ascending auction format is a viable institution under these criteria.

B The Case of Linear Time-Adjustment Functions

The analysis for the general time-adjustment functions are too complex to allow for closed-form solutions; they are also not suitable for numerical solutions with the generality of the time-adjustment function. In this section, we focus on a specific type of time-adjustment function for both the bidders and the auctioneer. Assume that for each bidder, the payoff shrinks linearly with time by a factor $1 - bt$, where t represents the total duration of the auction and $b \leq 1/2$ is the bidder unit time cost. Likewise, suppose that for the auctioneer, the payoff shrinks linearly with time by the factor $1 - ct$, with t denoting the total auction duration and $c \leq 1/2$ being the auctioneer unit time cost.³

We begin by examining the Honolulu-Sydney auction.

B.1 Honolulu-Sydney Auction

The auctioneer starts the auction at price $s \in [0, 1]$. Consider a bidder with value v who bids at the time when the price decreases to p , his/her expected utility can now be written as

$$EU_B^H(p; v, s) = G(p)(v - p)(1 - bs + bp) + \int_p^v (v - x)(1 - bs - bx + 2bp) dG(x)$$

³These constraints are not essential but they guarantee that the cost of time component of the utility remains positive for all possible durations up to the highest $t \leq 2$.

For each v , let us denote the solution to the maximization problem

$$\max_{p \in [0, s]} EU_B^H(p; v, s)$$

by $p(v, s)$. We can easily argue that $p(v, s) \leq v$ and also by definition $p(v, s) \in [0, s]$.

The first-order condition for the maximization problem is to have the partial derivative of $EU_B^H(p; v, s)$ with respect to p is equal to 0 at $p = p(v, s)$. We have:

$$\begin{aligned} \frac{\partial}{\partial p} EU_B^H(p; v, s) &= g(p)(v-p)(1-bs+bp) \\ &\quad -G(p)(1-bs+bp) \\ &\quad +G(p)(v-p)b \\ &\quad - (v-p)(1-bs-bp+2bp)g(p) \\ &\quad +2b \int_p^v (v-x) dG(x) \end{aligned}$$

Since the first and fourth lines cancel each other and by integration by parts in the fifth line, we can rewrite this as

$$\begin{aligned} \frac{\partial}{\partial p} EU_B^H(p; v, s) &= G(p)(vb-2bp-1+bs) + 2b \left(\int_p^v G(x) dx - (v-p)G(p) \right) \\ &= 2b \int_p^v G(x) dx - G(p)(1-bs+bv) \end{aligned}$$

Given that $b \leq 1/2$, we can first argue that the second-order derivative is always negative. This is because

$$\frac{\partial}{\partial p} \left(\frac{\partial}{\partial p} EU_B^H(p; v, s) \right) = -2bG(p) - g(p)(1-bs+bv)$$

and $G(p)$, $g(p)$, $1-bs+bv$ are all positive.

Moreover, let us denote the first-order derivative $\frac{\partial}{\partial p} EU_B^H(p; v, s)$ by

$$K(p; v, s) \equiv 2b \int_p^v G(x) dx - G(p)(1-bs+bv) \quad (1)$$

Then $K(p; v, s)$ is strictly decreasing in p (since second order derivative is negative) and there is a unique solution to $K(p; v, s) = 0$ in $p \in [0, v]$. This is because: (i) at $p = 0$, $K(p; v, s) = 2b \int_0^v G(x) dx > 0$, and (ii) at $p = v$, $K(p; v, s) = -G(v)(1-bs+bv) < 0$.

Let us denote this unique solution p that equates $K(p; v, s)$ to 0 by $k(v, s)$. If $k(v, s) \leq s$, then it would be the price that a bidder with value v would bid. Otherwise, the bidder would bid s . Therefore, we can write the equilibrium bid of a bidder with value v as

$$p(v, s) = \min\{s, k(v, s)\},$$

which can be solved numerically.

Given that we can obtain a numerical solution for equilibrium bid functions, we can write the expected utility of the auctioneer as follows:

$$EU_A^H(s) = \int_0^1 \int_0^{p(v,s)} p(v,s)(1 - c(s - p(v,s)))h(v,x)dxdv \\ + \int_0^1 \int_{p(v,s)}^v x(1 - c(s + x - 2p(v,s)))h(v,x)dxdv,$$

The starting price s that maximizes the above equation will be chosen by the auctioneer and this optimal s again can be computed numerically.

Given the optimal starting price, the expected duration of the auction and the expected selling price (the auction revenue) are as follows (where the maximizer is used to perform the calculations):

$$ED^H = \int_0^1 \left(\int_0^{p(v,s)} (s - p(v,s))h(v,x)dx + \int_{p(v,s)}^v (s + x - 2p(v,s))h(v,x)dx \right) dv \\ ER_A^H = \int_0^1 \left(\int_0^{p(v,s)} p(v,s)h(v,x)dx + \int_{p(v,s)}^v xh(v,x)dx \right) dv$$

Lastly, interim and ex-ante expected utilities of the bidders are given by

$$EU_B^H(v) = G(p)(v - p(v,s))(1 - bs + bp(v,s)) + \int_{p(v,s)}^v (v - x)(1 - bs - bx + 2bp(v,s))dG(x)$$

and

$$EU_B^H = \int_0^1 EU_B^H(v)dF(v)$$

B.2 Dutch Auction

With regards to the Dutch auction, with linear time-adjustment functions, we can rewrite the necessary condition for the equilibrium bid function β as follows:

$$g(v)(v - \beta(v))(1 - b(1 - \beta(v))) = \beta'(v)G(v)(1 + 2b\beta(v) - b - bv)$$

This is an ordinary differential equation for β with boundary condition $\beta(0) = 0$.

Given that we have a solution for equilibrium bids, we can write the expected utility of the auctioneer as follows:

$$EU_A^D = \int_0^1 \beta(x)(1 - c(1 - \beta(x)))dF^n(x).$$

The expected duration of the auction and the expected selling price are as follows:

$$ED^D = \int_0^1 (1 - c(1 - \beta(x)))dF^n(x)$$

$$ER_A^D = \int_0^1 \beta(x)dF^n(x)$$

Lastly, interim and ex-ante expected utilities of the bidders are given by

$$EU_B^D(v) = (v - \beta(v))(1 - b(1 - \beta(v)))G(v)$$

and

$$EU_B^D = \int_0^1 EU_B^D(v)dF(v)$$

C Numerical results and prediction details

Note that the starting price is chosen by the auctioneer to maximize her utility, so for the expected utility for the auctioneer EU_A , the differences between Dutch and Honolulu auctions are always changing smoothly in the 2D parameter space (b, c) . In fact, for given (b, c) , $EU_A(s)$ is a function of the starting price $s \in [0, 1]$ such that it is first increasing, then possibly decreasing, and finally may be increasing again. So, the optimal s can either be some interior value at the peak of the increasing then decreasing inverse U-shaped curve, or simply be at the boundary when the functional value finally increases and exceeds the previous peak (see Figure C.1 for a visual demonstration). Such a jump in the optimal starting price results in discontinuity in the relative performance of the Dutch and Honolulu-Sydney auctions in terms of expected duration, selling prices and bidder expected utility. This is the reason for a sharp change in the relative performances displayed in the top left corner of these plots.

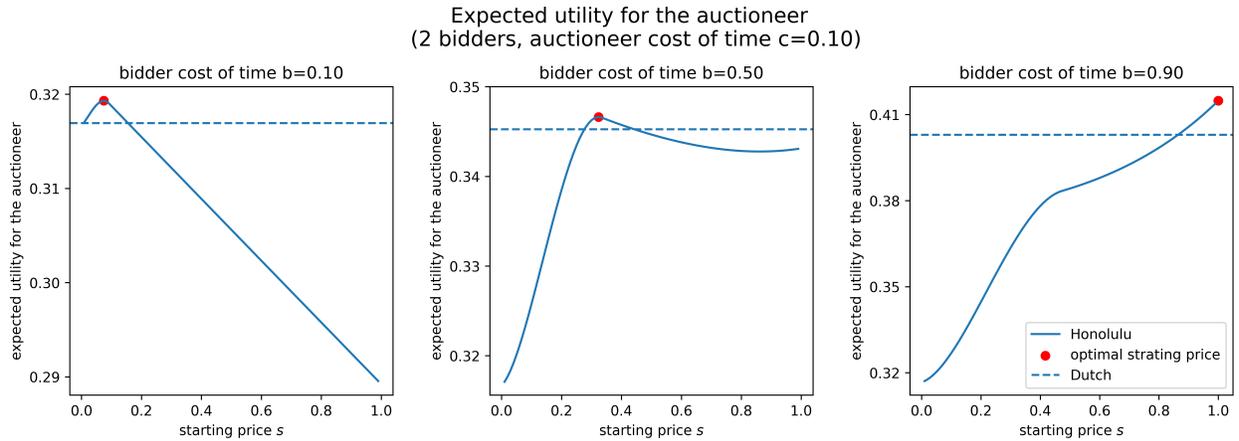


Figure C.1: Auctioneer expected utility as a function of starting price

The performance difference between Dutch and Honolulu-Sydney auctions can take drastic changes when the optimal starting price jumps from an interior point to 1. For example

(Figure C.2), Honolulu-Sydney auctions are always shorter than Dutch under 2-bidder auctions when the optimal starting price is in the interior, while this pattern is completely reversed to Dutch auctions are always shorter when the optimal starting price jumps to 1. We mainly focus on the vast right-hand side area where the optimal starting price is an interior solution. The meaning of the words “under a wide range of parameter values” in the premise of Predictions 1– 4 is to exclude such cases which relate to the aforementioned top-left corner of those plots.

C.1 Theoretical performance comparison

The table below is the theoretical comparison between the two auction formats along the key auction metrics for the parameter values used in the experimental treatments.

Table C.1: Theoretical performance comparison by experimental treatment

Treatment	2H	2L	5H	5L
n – Number of bidders	2	2	5	5
b – Bidder unit cost of time	0.95	0.45	0.95	0.45
c – Auctioneer unit cost of time	0.95	0.95	0.95	0.95
s^* – Optimal Honolulu-Sydney auction starting price	0.4104	0.2370	0.6317	0.5405
Expected auction duration				
Dutch	0.5654	0.6382	0.3074	0.3232
Honolulu	0.2456	0.2729	0.1991	0.2582
Honolulu/Dutch ratio	43.4%	42.8%	64.8%	79.9%
Expected selling prices				
Dutch	0.4346	0.3618	0.6926	0.6768
Honolulu	0.3922	0.3526	0.6899	0.6773
Honolulu/Dutch ratio	90.2%	97.5%	99.6%	100.1%
Expected utility for the auctioneer				
Dutch	0.2245	0.1593	0.5034	0.4816
Honolulu	0.2964	0.2342	0.5581	0.5039
Honolulu/Dutch ratio	132.0%	147.0%	110.9%	104.6%
Expected utility for the bidder				
Dutch	0.0596	0.1117	0.0205	0.0270
Honolulu	0.1176	0.1452	0.0253	0.0289
Honolulu/Dutch ratio	197.3%	130.0%	123.4%	107.0%

Note: The calculations in this table are based on the value range of $[0, 1]$, as in the theoretical model setting.

C.2 Auction duration

The observations below are made for the wide range of parameters resulting in an interior solution of the optimal starting price, i.e., the top-left corner of the plots is excluded.

The general observation is that Honolulu-Sydney auctions are faster than Dutch auctions in most cases, which is evident from the overwhelming red color on the graphs. In all four

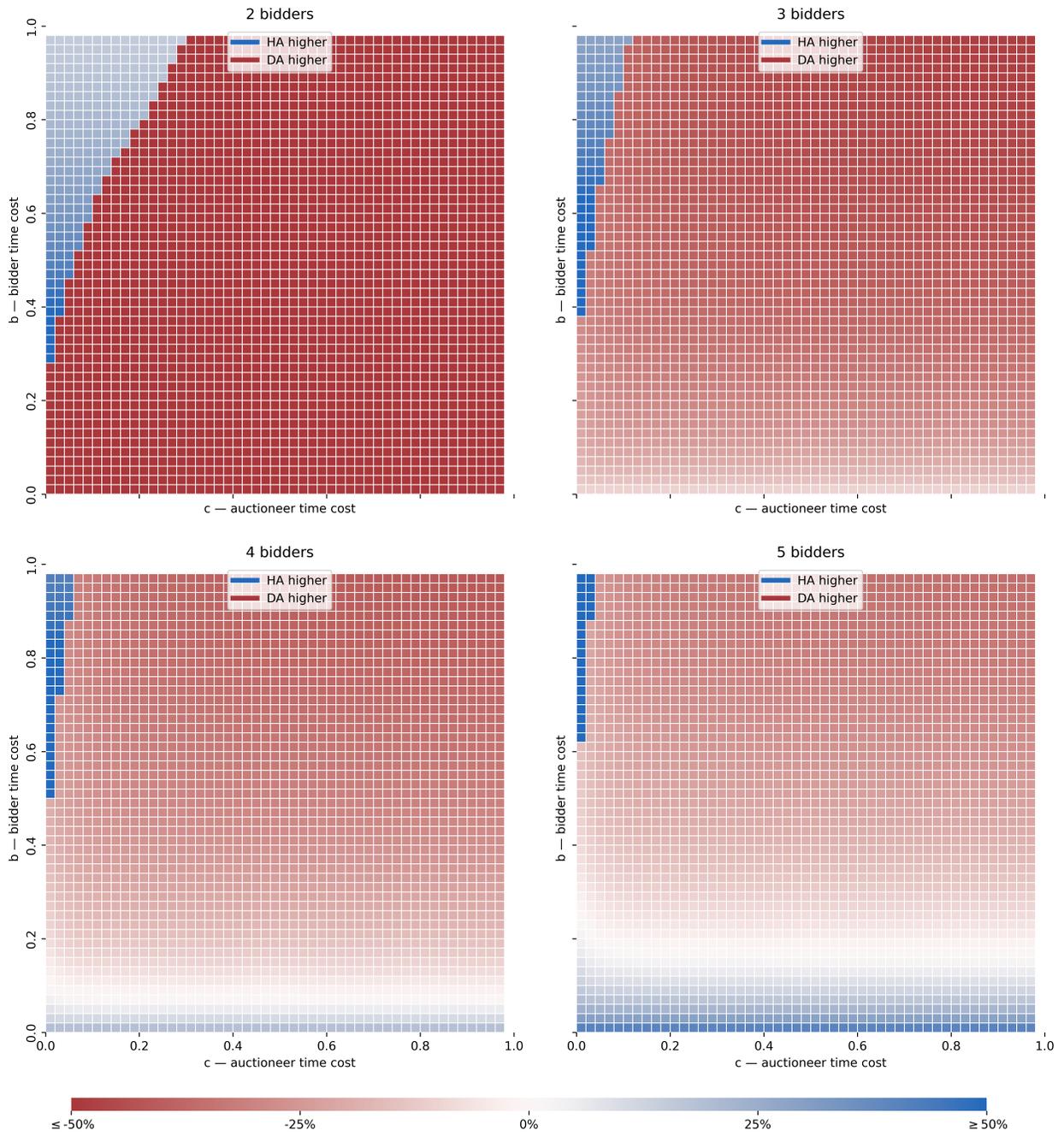


Figure C.2: Auction duration differences, $\frac{H-D}{D}$

treatments we use in the experiment, Honolulu-Sydney auctions are at least 20% faster than Dutch.

Focusing on the same configuration of parameters (b, c) in each panel of the graph for different numbers of bidders, we find that the relative advantage of Honolulu-Sydney auctions over Dutch decreases as the number of bidders increases. The dark red color on the 2-bidder graph fades, and even turns blue on 4- and 5-bidder graphs for very low bidder cost of time. Specifically, Dutch auctions are faster when the time cost of bidders $b < 0.1$ in the 4-bidder case and $b < 0.2$ in the 5-bidder case. This comparison relates to $2H$ versus $5H$ and $2L$ versus $5L$ in Table C.1, where Honolulu-Sydney auctions are about 50% shorter than Dutch for 2 bidders while they shrink to roughly 30% shorter when the number of bidders increases to 5.

For a given bidder cost of time, which is a fixed horizontal slice of the graph, the relative advantage of Honolulu-Sydney auctions over Dutch slightly increases with higher auctioneer cost of time. The greatest increment when comparing the lowest and highest auctioneer cost of time on the graph does not exceed 10% in all cases.

For a given auctioneer cost of time, which is a fixed vertical slice of the graph, the relative advantage of Honolulu-Sydney auctions over Dutch increases with higher bidder cost of time under 4- and 5-bidder cases — Honolulu-Sydney auctions are 35.2% faster than Dutch under $5H$ but only 20.1% faster under $5L$, while it first increases and then decreases under 2- and 3-bidder cases. Furthermore, this possible decrease is always small — the greatest decrement does not exceed 5% and 1% in 2- and 3-bidder auctions, respectively. Our treatment $2H$ is on the decreasing interval, and the relative time advantage of Honolulu-Sydney auctions over Dutch shrinks very little by 0.6% compared to $2L$.

C.3 Selling prices

The observations below are made for the wide range of parameters resulting in an interior solution of the optimal starting price, i.e., the top-left corner of the plots is excluded.

Since we assume the presence of positive time costs for the bidder and the auctioneer in the model, the revenue equivalence theorem no longer holds. However, the expected unadjusted revenue for the auctioneer, which is equivalent to the expected selling price, differs only slightly between the Dutch and Honolulu-Sydney auction formats.

This difference never exceeds 10% in either positive or negative directions, and is usually shrinks with the number of bidders. This is because the auction becomes faster as competition increases, which offsets the role of time cost.

After excluding the top-left corner of the plots, Dutch selling prices are always higher than Honolulu-Sydney for 2-bidder auctions. This advantage vanishes as the number of bidders increases. For auctions with more than 3 bidders, a light blue area where Honolulu-Sydney selling prices are higher than Dutch emerges in the left middle of the plot and is expanding as the number of bidders increases — our $5L$ treatment lies in this area, where Honolulu-Sydney expected selling prices are 0.1% higher than Dutch.

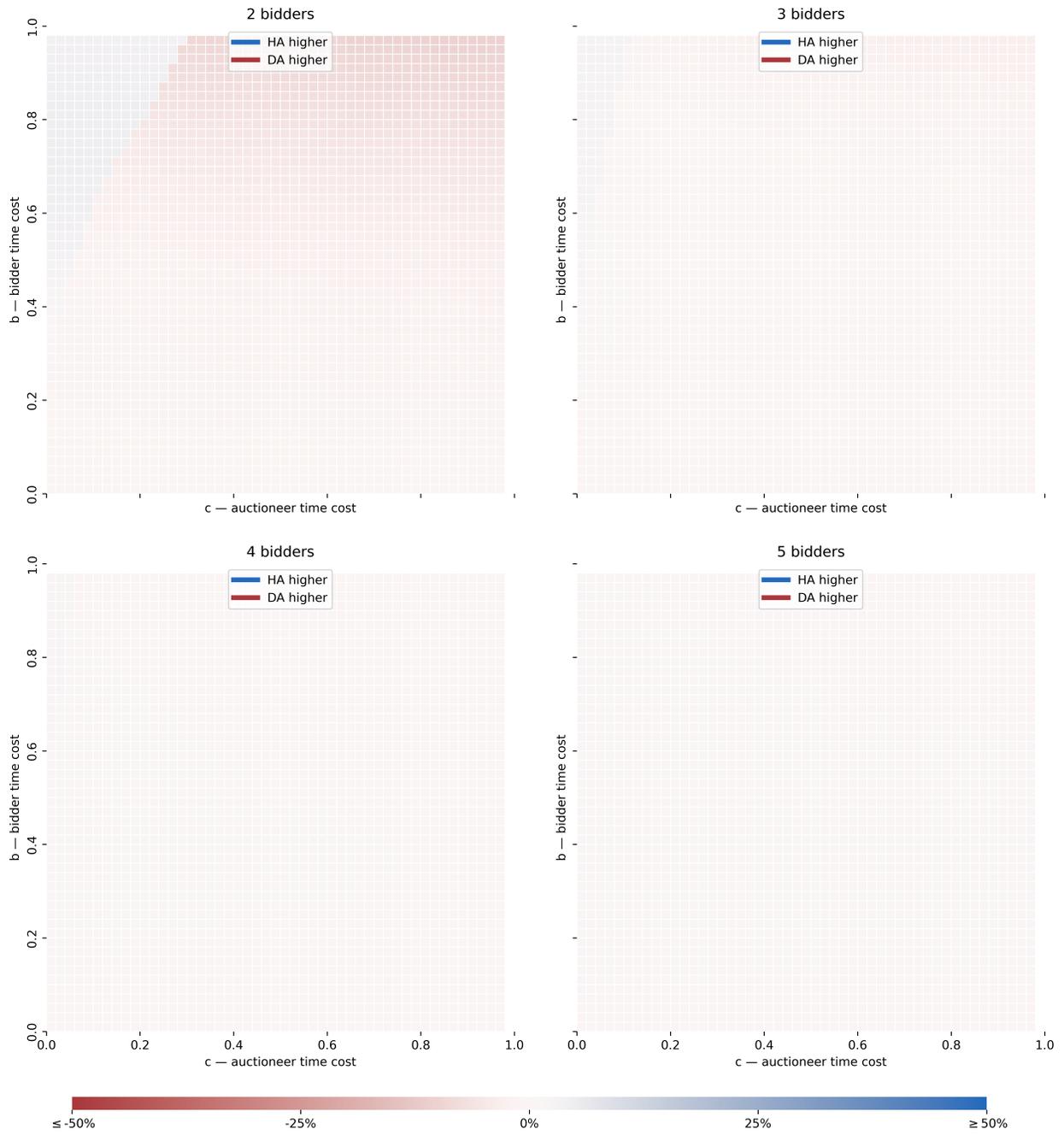


Figure C.3: Selling price differences, $\frac{H-D}{D}$

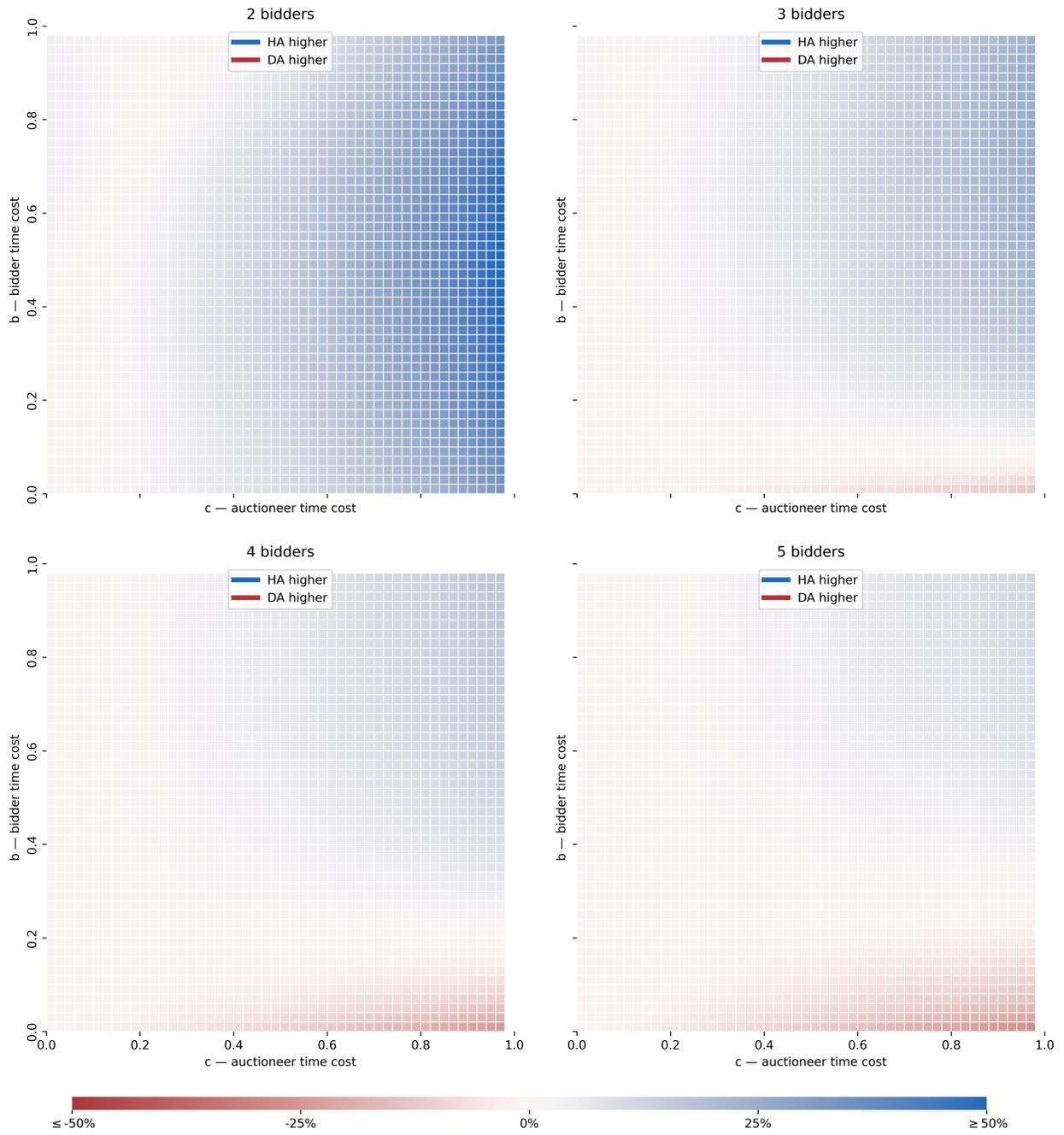


Figure C.4: Auctioneer utility differences, $\frac{H-D}{D}$

C.4 Utility for the auctioneer

The utility for the auctioneer is the only auction performance indicator that changes smoothly in the whole domain of parameters. Thus, we consider the entire graph for our analysis.

We find that the comparison between Dutch and Honolulu-Sydney auctions is overall indistinguishable when the time cost of the auctioneer is relatively low (less than 0.3) — it never exceeds 6%, as represented by the very light red or blue area on the left of each graph.

The remaining observations are made for the auctioneer time cost greater than 0.3.

Honolulu-Sydney auctions are always preferred by the auctioneer in the 2-bidder case, while Dutch auctions become more preferred with low bidder cost of time and when the number of bidders increases. Specifically, Dutch auctions are preferred when the bidder time cost is smaller than 0.1, 0.2 and 0.24 in 3-, 4- and 5-bidder auctions, respectively.

Focusing on the same configuration of parameters (b, c) in each panel of the graph for different numbers of bidders, the relative advantage of Honolulu-Sydney auctions over Dutch usually decreases as the number of bidders increases. Furthermore, related to our experimental parameter choices (Table C.1), this advantage is always decreasing when the auctioneer’s time cost $c > 0.6$. Thus, we have this relative advantage that the Honolulu-Sydney auctions drop from more than 30% under 2-bidder treatments to around 10% under 5-bidder treatments.

For a given auctioneer cost of time, which is a fixed vertical slice of the graph, the relative advantage of Honolulu-Sydney auctions over Dutch increases with higher bidder cost of time, except for very impatient bidders whose time cost exceeds a threshold ranges from 0.5 to 0.9 depending on the number of bidders. This threshold is increasing with more bidders. Therefore, we have treatment $2L$ close to the end of the increasing interval at 0.5 where Honolulu-Sydney auctions bring 47% higher expected utility for the auctioneer than Dutch, while this advantage shrinks to 32% after moving along the decreasing interval to treatment $2H$. In contrast, treatment $5H$ is close to the threshold around 0.9, such a minor decrease makes the Honolulu-Sydney advantage of 10.9% still higher than that of 4.6% under treatment $5L$.

For a given bidder cost of time, which is a fixed horizontal slice of the graph, as the auctioneer cost of time goes up, the differences between Dutch and Honolulu-Sydney auctions become more pronounced and could go in either direction: Honolulu auctions become relatively more advantageous for sufficiently high bidder cost of time, but Dutch auctions can become relatively more advantageous for auctions with more than two bidders and low bidder cost of time (Figure C.4) ⁴

C.5 Utility for the bidder

The observations below are made for the wide range of parameters that result in an interior solution of the optimal starting price, which means the top left corner of the plots is excluded.

Buyers prefer Honolulu-Sydney auctions to Dutch auctions under a wide range of parameter values. Specifically, after excluding the top-left corner, Honolulu-Sydney auctions are always preferred when there are no more than 4 bidders, and are preferred in the 5-bidder

⁴Thus we chose a high value of auctioneer cost of time for experimental design to obtain a greater expected difference between Dutch and Honolulu auctions.

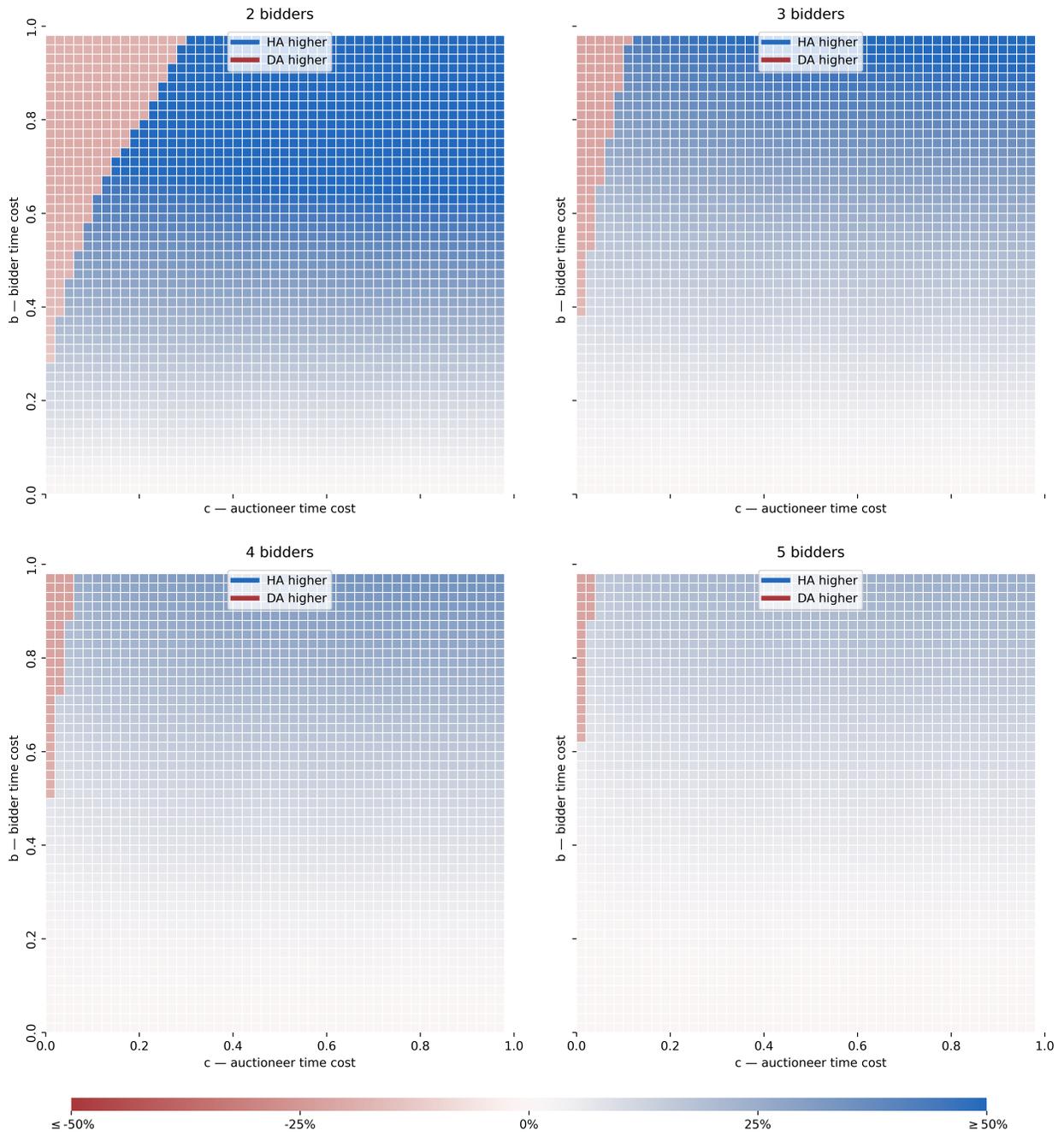


Figure C.5: Bidder utility differences, $\frac{H-D}{D}$

case when the bidder cost of time is not too small (greater than 0.02). In our experimental settings (Table C.1), the expected utility for the bidder is up to 100% higher in Honolulu-Sydney auctions than in Dutch auctions under different treatments.

For a given auctioneer cost of time, which is a fixed vertical slice of the graph, the darker blue color from bottom to top indicates that the advantage of Honolulu-Sydney auctions over Dutch in terms of buyer utility increases with bidder cost of time, especially for small number of bidders. The expected relative benefit for buyers in Honolulu-Sydney auctions increases from about 30% under treatment $2L$ to almost 100% under treatment $2H$.

Using the same configuration of the parameters (b, c) in each panel of the graph, the blue color fades as the number of bidders increases, which means that the relative advantage of Honolulu-Sydney auctions over Dutch decreases with the number of bidders. This relative advantage experiences a rapid drop from almost 100% to around 20% when increasing the number of bidders from 2 to 5 in high-cost treatments, but only a slight drop of no more than 20% in low-cost treatments.

C.6 Social welfare

The social welfare of an auction U_{AB} is defined as the sum of auctioneer and bidders utilities, $U_{AB} = U_A + \sum_i U_{B_i}$, and the expected social welfare EU_{AB} is given by $EU_{AB} = EU_A + \sum EU_{B_i}$. Equivalently, we may use the buyer utility to replace the sum of all bidder utilities. The numerical predictions based on our theoretical model are displayed in Figure C.6 below, where we plot the relative difference between the two auction formats $\frac{EU_{AB}^H - EU_{AB}^D}{EU_{AB}^D}$.

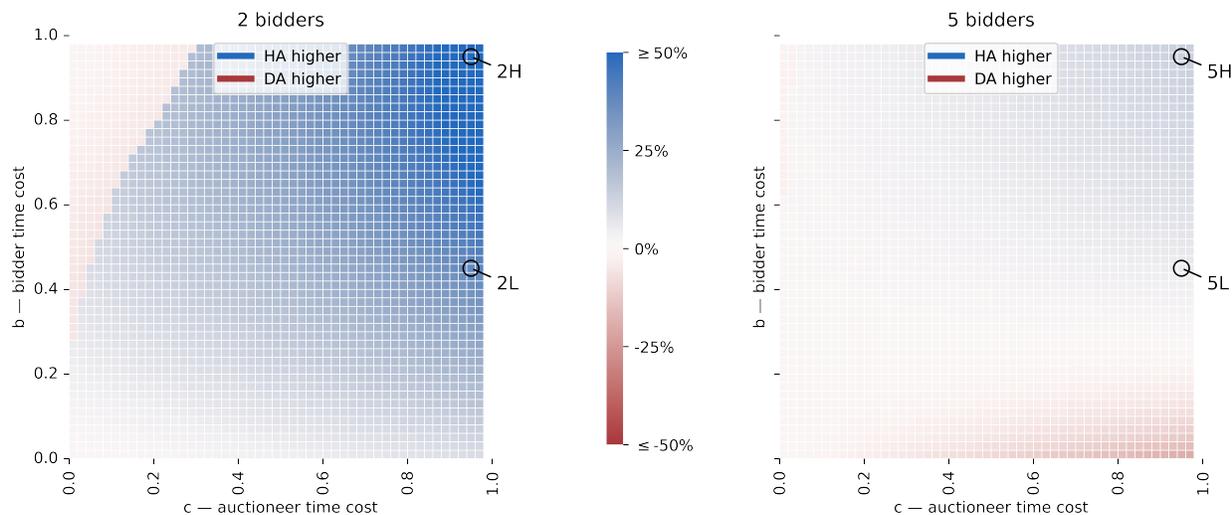


Figure C.6: Social welfare differences, $\frac{H-D}{D}$

Predicted (correspondingly, actual) social welfare for the experimental auctions are calculated based on the actual values drawn, as the sum of predicted (correspondingly, actual) auctioneer and buyer utilities. 12 out of 2216 experimental auctions that ended without a winner are assessed zero welfare. These measures are displayed in Figure C.7 and Table C.2.

Table C.2: Predicted and actual social welfare by treatment

	2H		2L		5H		5L	
	Predicted	Actual	Predicted	Actual	Predicted	Actual	Predicted	Actual
Social welfare								
Dutch	16.9	15.3	19.0	19.0	30.0	30.5	30.5	30.8
Honolulu	26.5	19.4	25.9	22.0	33.5	26.0	35.2	29.8
H/D, %	156.8%	126.8%	136.3%	115.8%	111.7%	85.2%	115.4%	96.8%

Both predicted and actual measures are calculated based on bidders values drawn.

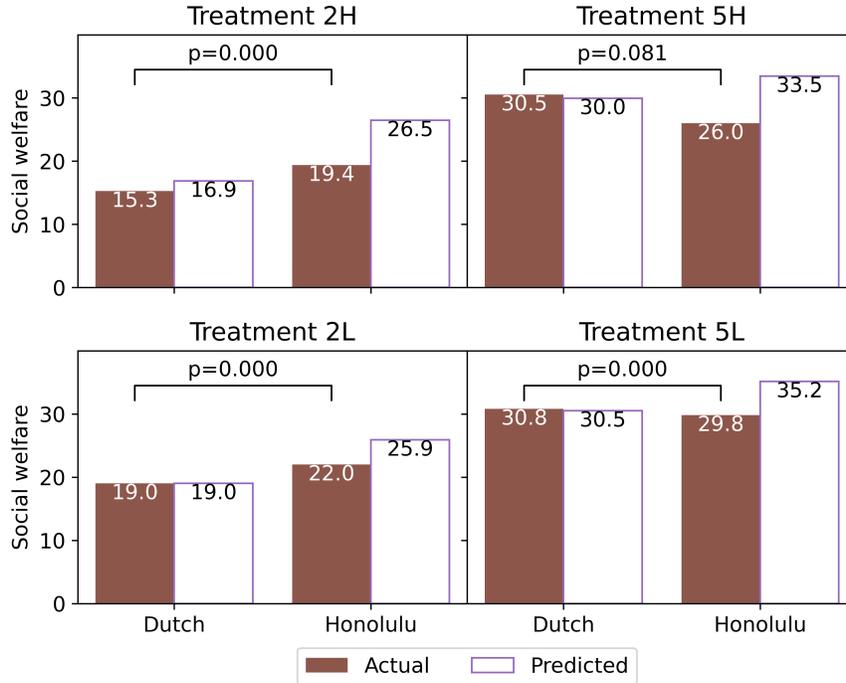


Figure C.7: Social welfare in the experiment

The social welfare is predicted to be higher in Honolulu auctions as compared to Dutch in all experimental treatments. In the actual experiment, the welfare is significantly different (higher) in Honolulu auctions compared to Dutch in two-bidder auctions, but is not significantly different, or lower, in Honolulu as compared to Dutch in five-bidder auctions.

D Hypotheses tests of experimental auction comparative performances

This section provides details of hypotheses testing on comparative performances of Honolulu and Dutch auctions. The hypotheses as based on the theoretical predictions given in Remarks 1 - 2 and Predictions 1- 4. These predictions and the corresponding hypotheses are listed below, with D and H denoting the corresponding performance characteristics under Dutch and Honolulu auctions, respectively:

1. (Efficiency: Remarks 1 - 2) Both auctions are efficient.

Corresponding hypotheses

- (a) $D = H$ for 2-bidder and 5-bidder auctions, high and low cost

2. (Auction duration: Prediction 1) Honolulu-Sydney auctions are faster than Dutch auctions, i.e., their average duration is shorter. The relative advantage of Honolulu-Sydney auctions over Dutch in terms of duration decreases with the number of bidders.

Corresponding hypotheses

- (a) $D > H$ for 2-bidder and 5-bidder auctions, high and low cost
- (b) $H^5/D^5 > H^2/D^2$, high cost
- (c) $H^5/D^5 > H^2/D^2$, low cost

3. (Selling prices: Prediction 2) The difference in average selling prices between Honolulu and Dutch auctions is small; it does not exceed 10 percent.

Corresponding hypotheses

- (a) $0.9 \leq H^2/D^2 \leq 1.1$, for 2-bidder and 5-bidder auctions, high and low cost

Hypotheses based on the actual value draws as given in Table 4:

- (a) $H^2/D^2 = 0.917$, high cost
- (b) $H^2/D^2 = 1.011$, low cost
- (c) $H^5/D^5 = 0.988$, high cost
- (d) $H^5/D^5 = 0.991$, low cost

4. (Auctioneer utility: Prediction 3) Assume the auctioneer cost of time is relatively high. Then Honolulu-Sydney auctions are always preferred to Dutch in the two-bidder case. For auctions with more than two bidders, Honolulu-Sydney auctions are preferred to Dutch when bidder cost of time is high, and Dutch auctions are preferred to Honolulu-Sydney when bidder cost of time is low.

Corresponding hypotheses:

- (a) $H^2 > D^2$, high cost
- (b) $H^2 > D^2$, low cost
- (c) $H^5 > D^5$, high cost
- (d) $H^5 > D^5$, low cost⁵

⁵The bidder cost of time in the “low”-cost treatment is high enough so that the prediction is still $H^5 > D^5$. However, given the predicted difference is small, and based on earlier experimental evidence of over-bidding relative to the risk-neutral predictions in Dutch auctions, we may expect to observe $H^5 < D^5$ under the low cost.

5. (Buyer utility: Prediction 4) Buyers prefer Honolulu-Sydney auction to Dutch under a wide range of parameter values. For auctions with a small number of bidders, the advantage of Honolulu-Sydney auctions over Dutch in terms of buyer utility increases with bidder cost of time. The relative advantage of Honolulu-Sydney auctions over Dutch decreases with the number of bidders.

Corresponding hypotheses:

- (a) $H > D$, high and low cost, 2 and 5 bidders
- (b) $H^h/D^h > H^l/D^l$, 2 bidders
- (c) $H^2/D^2 > H^5/D^5$, high cost
- (d) $H^2/D^2 > H^5/D^5$, low cost

To test the above hypotheses, we regressed auction efficiency, duration, selling prices, and auctioneer and buyer utilities on auction type and treatment dummies, as displayed in Tables D.1 - D.2 below. We then used the regression coefficients to estimate the test statistic equal to the difference between LHS and the RHS expressions in the corresponding hypotheses, $coeff \equiv (LHS - RHS)$ (e.g., $coeff \equiv H^5/D^5 - H^2/D^2$ for high cost for hypotheses 2(b) above), and bootstrapped standard errors on the statistic to test each hypotheses. The hypotheses tests results are given in Table 5 in the main text. Additionally, Table D.3 in this Appendix shows the hypotheses test results for selling prices based on the actual value draws as given in Table 4.

Table D.1: Baseline regression estimation for hypotheses testing, by the number of bidders

	Efficiency			Auctioneer payoff		Buyer payoff	
	pooled	2 bidders	5 bidders	2 bidders	5 bidders	2 bidders	5 bidders
<u>REGRESSION</u>							
HNL auction	1.54** (0.52)	1.32 (0.97)	3.02 (1.89)	-3.14*** (0.54)	-7.30** (2.22)	6.10*** (0.68)	6.30** (1.95)
high cost		-0.62 (1.90)	3.12* (1.60)	-0.19 (1.02)	-2.04 (2.58)	-3.55*** (0.69)	1.78 (1.45)
high cost HNL		0.60 (1.09)	-3.17 (2.01)	2.05* (0.99)	1.70 (2.95)	-0.95 (1.05)	-5.25** (2.14)
Constant	95.85*** (0.72)	95.44*** (1.31)	95.48*** (1.57)	11.01*** (0.31)	29.30*** (2.52)	8.10*** (0.43)	1.50 (1.40)
Observations	2216	1404	812	1404	812	1392	812
R^2	0.003	0.003	0.020	0.029	0.141	0.144	0.106
<u>PREDICTION</u>							
H^h – HNL high cost		96.74	98.45	9.73	21.66	9.69	4.33
H^l – HNL low cost		96.76	98.49	7.86	22.01	14.20	7.80
D^h – Dutch high cost		94.82	98.60	10.82	27.27	4.54	3.28
D^l – Dutch low cost		95.44	95.48	11.01	29.30	8.10	1.50

OLS estimation. Standard errors clustered by session in parentheses.

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table D.2: Baseline regression estimation for hypotheses testing, by bidder cost of time

	Auction duration		Selling price		Buyer payoff	
	high cost	low cost	high cost	low cost	high cost	low cost
<u>REGRESSION</u>						
HNL auction	-9.26*** (1.81)	-9.85*** (0.99)	-3.61*** (0.71)	-5.47*** (1.06)	5.15*** (0.80)	6.10*** (0.69)
5 bidders	-15.60*** (1.09)	-16.48*** (1.84)	15.62*** (1.11)	16.49*** (1.83)	-1.26* (0.65)	-6.59*** (1.47)
5 bidders HNL	13.34*** (3.62)	12.35*** (1.45)	0.73 (0.78)	0.10 (2.34)	-4.10** (1.19)	0.20 (2.07)
Constant	29.90*** (1.01)	29.49*** (0.50)	20.63*** (1.03)	21.07*** (0.51)	4.54*** (0.54)	8.10*** (0.43)
Observations	1140	1076	1140	1076	1133	1071
R^2	0.239	0.310	0.421	0.444	0.133	0.199
<u>PREDICTION</u>						
H^5 – HNL 5 bidders	18.38	15.50	33.37	32.30	4.33	7.80
H^2 – HNL 2 bidders	20.64	19.63	17.02	15.61	9.69	14.20
D^5 – Dutch 5 bidders	14.30	13.00	36.26	37.57	3.28	1.50
D^2 – Dutch 2 bidders	29.90	29.49	20.63	21.07	4.54	8.10

OLS estimation. Standard errors clustered by session in parentheses.

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table D.3: Hypotheses tests of predictions on relative prices in Honolulu and Dutch auctions based on actual values drawn

Characteristic	Prediction-based hypotheses*	cost	Observed coeff.	Bootstr. std. err.	p -value	Prediction supported?
Selling price	$H^2/D^2 = 0.917$	high cost	-.092	.024	0.000	no
	$H^2/D^2 = 1.011$	low cost	-.260	.040	0.000	no
	$H^5/D^5 = 0.988$	high cost	-.068	.007	0.000	no
	$H^5/D^5 = 0.991$	low cost	-.134	.045	0.003	no

* H – Honolulu, D Dutch; 2 – 2-bidders, 5 – 5-bidders. Hypotheses for the selling price ratios are based on Table 4 predictions. Observed coefficients are for the difference between the LHS and the RHS expressions in the corresponding hypotheses.

E Test results on price dynamics in Honolulu auctions

Table E.1: Wilcoxon signed-rank tests on price dynamics in Honolulu auctions

Treatment	Alternative hypothesis	Price dynamics	Statistic	<i>p</i> -value	# of Obs*
All treatments	Actual > Predicted	Dutch then English	119.0	0.000	15
		Dutch only	22.5	0.030	
		English only	0.0	0.000	
	Actual ≠ Predicted	Dutch then English	1.0	0.000	
		Dutch only	12.5	0.059	
		English only	0.0	0.001	
2-bidder	Actual > Predicted	Dutch then English	36.0	0.004	8
		Dutch only	11.0	0.191	
		English only	0.0	0.004	
	Actual ≠ Predicted	Dutch then English	0.0	0.008	
		Dutch only	11.0	0.383	
		English only	0.0	0.008	
2H	Actual > Predicted	Dutch then English	10.0	0.063	4
		Dutch only	0.0	0.063	
		English only	0.0	0.063	
	Actual ≠ Predicted	Either	0.0	0.125	
2L	Actual > Predicted	Dutch then English	10.0	0.063	4
		Dutch only	8.5	0.188	
		English only	0.0	0.063	
	Actual ≠ Predicted	Dutch then English	0.0	0.125	
		Dutch only	1.5	0.375	
		English only	0.0	0.125	
5-bidder	Actual > Predicted	Dutch then English	27.0	0.016	7
		Dutch only	2.5	0.046	
		English only	0.0	0.014	
	Actual ≠ Predicted	Dutch then English	1.0	0.031	
		Dutch only	2.5	0.093	
		English only	0.0	0.028	
5H	Actual > Predicted	Dutch then English	9.0	0.125	4
		Dutch only	1.0	0.143	
		English only	0.0	0.054	
	Actual ≠ Predicted	Dutch then English	1.0	0.250	
		Dutch only	1.0	0.285	
		English only	0.0	0.109	
5L	Actual > Predicted	Dutch then English	6.0	0.125	3
		Dutch only	0.0	0.125	
		English only	0.0	0.125	
	Actual ≠ Predicted	Either	0.0	0.250	

*The tests compare actual and predicted frequencies, with session averages as units of observation.

F Auction duration with zero-cost prediction

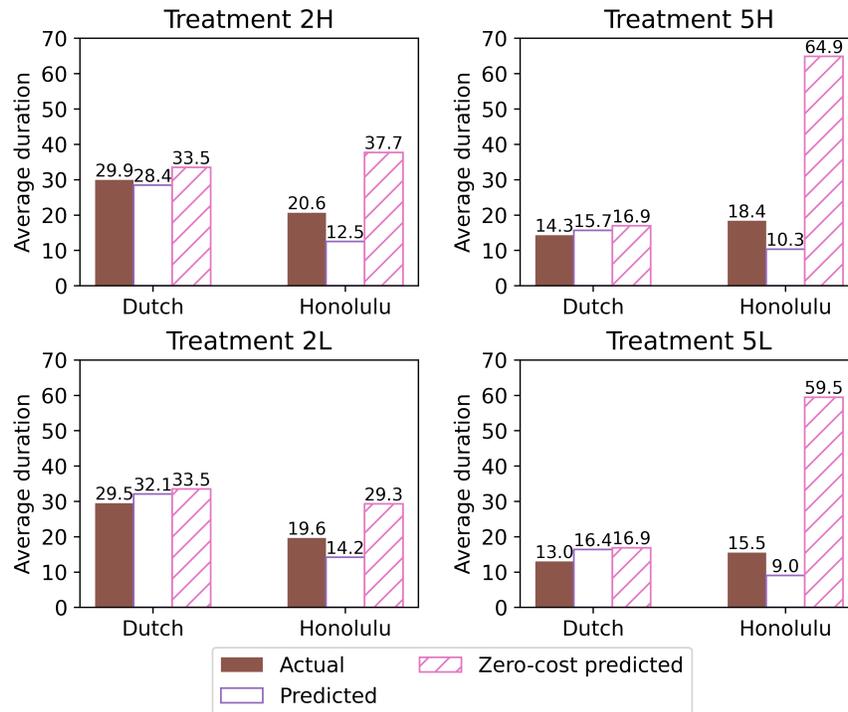


Figure F.1: Auction duration by treatment

G Additional analyses of bidding behavior

Here we provide additional details on individual behavioral patterns reviewed in Section 5.2. Behavior varied widely across individuals, resulting in large differences of bidder payoffs.

To compare bidder payoffs across individuals with different value draws, we normalize the actual payoffs under a given institution as percentages of the theoretically predicted:⁶

$$\%Pay = \frac{Actual\ Total\ Payoff}{Predicted\ Total\ Payoff} \times 100\%.$$

We then categorize participants into Top and Bottom earners, depending on whether their percentage payoff falls above or below the median in their treatment. Figure G.1 displays participant median percentage payoff (the cutoff value separating the Top and Bottom earners), and average percentage payoffs for Top and Bottom earners, by treatment. The differences

⁶The drawback of this measure are possibly extreme values for bidders who are predicted to earn zero or near zero, due to low value draws. We address this issue by censoring percentage payoff at -10% and 210% ; the payoff percentages for only eight bidders in Dutch auctions and four bidders in Honolulu auctions (out of 158 total bidders) had to be censored. As an alternative, one could consider the average per period point deviations from the theoretical prediction by period; however, such measure would not be comparable across treatments. All qualitative findings are robust to the use of this alternative measure.

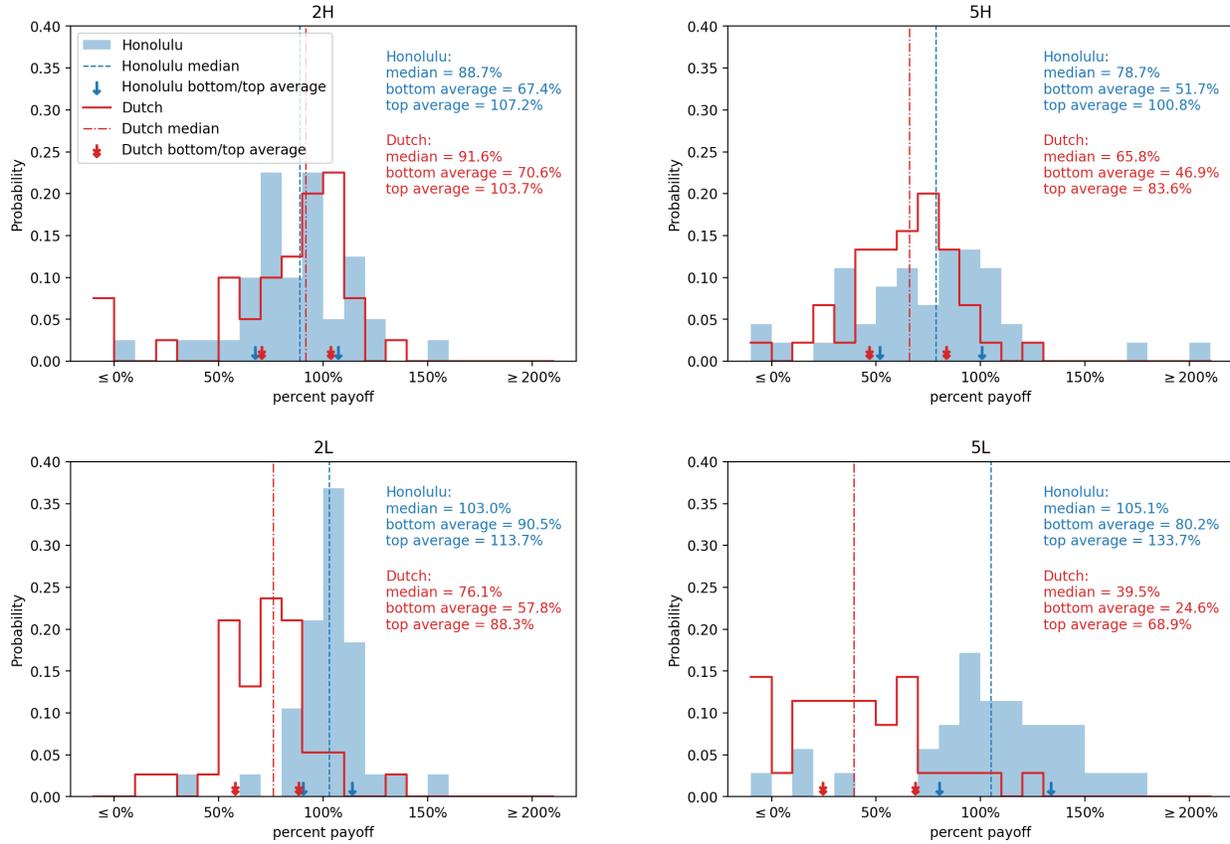


Figure G.1: Distribution of percent payoffs, by treatment

between Top and Bottom earners are substantial in all treatments under both auction formats, with average Top earners often making higher earnings than predicted, while average Bottom earners making as low as 25 percent of the predicted payoffs in some treatments. Below we compare the decisions of Top-earning bidders with those of Bottom-earning bidders to understand which bidding patterns are associated with earning success.

Dominated decisions A strictly dominated decision would involve bidding above value in the Dutch auction, leading to a sure loss. A weakly dominated decision in the Honolulu auction would involve either risking a loss by bidding above value in the Dutch and Contest stages of Honolulu auctions, or staying in bidding above value in the English stage; or “leaving money on the table” by dropping out of bidding in the Contest or English stages at a price below one’s value. Table G.1 lists the frequencies of dominated decisions in Dutch and Honolulu auctions. Almost all bids in Dutch auctions are undominated, as compared to 78 to 95 percent of (weakly) undominated decisions in Honolulu auctions. The share of undominated decisions is no lower or higher for Top earners than for Bottom earners, under all stages of the auctions and under all treatments; the differences between Top and Bottom earners are highly significant for the pooled data, as well as for the most of the treatments and stages ($p < 0.05$, Wilcoxon sign-rank test, as displayed in Table G.2).

Table G.1: Frequencies of strictly and weakly dominated decisions, by treatment

Stage	Decision	2H		2L		2-bidder	5H		5L		5-bidder
		Top	Bottom	Top	Bottom	All	Top	Bottom	Top	Bottom	All
<u>DUTCH AUCTION</u>											
	Bid above value	0	9	0	1	10	0	2	0	15	17
		0.0%	5.5%	0.0%	0.6%	1.4%	0.0%	2.2%	0.0%	15.3%	4.2%
	Undominated bid	189	156	167	170	682	117	91	98	83	389
		100.0%	94.5%	100.0%	99.4%	98.6%	100.0%	97.8%	100.0%	84.7%	95.8%
<u>HONOLULU AUCTION</u>											
Dutch stage	Bid above value	0	9	0	1	10	1	3	1	5	10
		0.0%	5.9%	0.0%	0.6%	1.5%	1.0%	2.7%	1.0%	5.2%	2.5%
	Undominated bid	181	144	147	165	637	96	110	98	92	396
		100.0%	94.1%	100.0%	99.4%	98.5%	99.0%	97.3%	99.0%	94.8%	97.5%
Contest stage	Leave below value	7	12	12	12	43	7	12	6	11	36
		10.8%	24.5%	29.3%	32.4%	22.4%	3.0%	4.8%	2.7%	4.8%	3.8%
	Undominated leave	58	37	29	25	149	229	239	214	220	902
		89.2%	75.5%	70.7%	67.6%	77.6%	97.0%	95.2%	97.3%	95.2%	96.2%
	Bid above value ²	0	6	0	0	6	5	24	1	1	31
		0.0%	3.8%	0.0%	0.0%	1.1%	3.2%	12.1%	0.6%	0.6%	4.5%
	Undominated bid	114	152	154	139	559	150	174	156	173	655
		100.0%	96.2%	100.0%	100.0%	98.9%	96.8%	87.9%	99.4%	99.4%	95.5%
English stage	Leave below value	16	41	26	29	112	13	23	8	27	71
		7.1%	15.2%	9.8%	10.9%	10.9%	5.5%	7.7%	3.3%	10.4%	6.8%
	Stay above value	5	22	3	12	42	7	45	10	25	87
		2.2%	8.2%	1.1%	4.5%	4.1%	2.9%	15.1%	4.1%	9.6%	8.4%
	Undominated decision	204	206	235	225	870	218	230	226	208	882
		90.7%	75.5%	89.0%	84.6%	85.0%	91.6%	77.2%	92.6%	80.0%	84.8%
Final outcome	Leave below value -all	23	53	38	41	155	20	35	14	38	107
		6.4%	14.7%	11.1%	12.0%	11.0%	4.1%	6.2%	2.9%	7.5%	5.3%
	- <i>foregone purchase</i> ³	23	53	38	41	155	13	21	7	24	65
		6.4%	14.7%	11.1%	12.0%	11.0%	2.7%	3.7%	1.5%	4.8%	2.3%
	Bid above value -all	5	25	3	13	46	7	45	10	25	87
		1.4%	6.9%	0.9%	3.8%	3.3%	1.4%	8.0%	2.1%	5.0%	4.3%
	- <i>actual loss</i> ³	0	11	1	6	18	0	6	1	6	13
		0.0%	3.1%	0.3%	1.8%	1.3%	0.0%	1.1%	0.2%	1.2%	0.1%
	Undominated decision	332	282	301	288	1203	461	482	452	441	1836
		92.2%	78.3%	88.0%	84.2%	85.7%	94.5%	85.8%	95.0%	87.5%	90.4%

¹ The table lists the number of decisions in each category, and their percentage out of all decisions at the corresponding auction stage. Decisions within 2 points of bidder value are considered to be “at value.”

² Dutch stage provisional winners are excluded from the Contest stage decisions.

³ Decisions in the corresponding category where the final auction price was below value (for foregone purchases), or the purchase was made at a price above value (for actual losses).

Table G.2: Wilcoxon signed-rank tests on the share of undominated decisions for Top and Bottom earners

Treatment	Hypothesis	Type of decision	Statistic	<i>p</i> -value	# of Obs*
All treatments	Top > Bottom	Dutch auction bid	45.0	0.004	15
		Dutch stage bid	19.0	0.037	
		Contest stage leave	89.0	0.054	
		Contest stage bid	36.0	0.055	
		English stage leave	110.0	0.001	
		Honolulu auction final outcome	113.0	0.001	
2-bidder	Top > Bottom	Dutch auction bid	10.0	0.034	8
		Dutch stage bid	6.0	0.054	
		Contest stage leave	27.0	0.125	
		Contest stage bid	6.0	0.054	
		English stage leave	32.0	0.027	
		Honolulu auction final outcome	33.0	0.020	
2H	Top > Bottom	Dutch auction bid	6.0	0.054	4
		Dutch stage bid	3.0	0.090	
		Contest stage leave	8.0	0.188	
		Contest stage bid	6.0	0.054	
		English stage leave	10.0	0.063	
		Honolulu auction final outcome	10.0	0.063	
2L	Top > Bottom	Dutch auction bid	1.0	0.159	4
		Dutch stage bid	1.0	0.159	
		Contest stage leave	7.0	0.322	
		Contest stage bid	Not applicable**		
		English stage leave	6.0	0.438	
		Honolulu auction final outcome	7.0	0.313	
5-bidder	Top > Bottom	Dutch auction bid	10.0	0.021	7
		Dutch stage bid	5.0	0.143	
		Contest stage leave	20.0	0.188	
		Contest stage bid	14.0	0.232	
		English stage leave	26.0	0.023	
		Honolulu auction final outcome	27.0	0.016	
5H	Top > Bottom	Dutch auction bid	3.0	0.079	4
		Dutch stage bid	2.0	0.327	
		Contest stage leave	6.0	0.438	
		Contest stage bid	8.0	0.188	
		English stage leave	10.0	0.063	
		Honolulu auction final outcome	10.0	0.063	
5L	Top > Bottom	Dutch auction bid	6.0	0.125	3
		Dutch stage bid	1.0	0.159	
		Contest stage leave	6.0	0.125	
		Contest stage bid	0.0	0.910	
		English stage leave	4.0	0.375	
		Honolulu auction final outcome	5.0	0.250	

*The tests compare the share of undominated decisions for top and bottom earners in each session.

**For the contest stage bid decisions under treatment 2L, all decisions are undominated, so the test is not applicable.

Observation 1. *The share of undominated decisions is significantly higher under Dutch than under Honolulu auctions. Top earners make dominated decisions less frequently than Bottom earners under both auction formats under most treatments.*

Bidding patterns in Dutch auctions While there is no analytical solution for the equilibrium bidding strategy in the Dutch auction if the bidder cost of time is positive, $b > 0$ (Section 3), the equilibrium bidding strategy can be closely approximated by a linear function of bidder value:

$$DutchBid \approx \alpha_0 + \alpha_1 \times v, \quad (2)$$

where v is bidder value, and α_0 and α_1 are the constant and the coefficient on value, respectively, which may both depend on the number n of bidders and bidder cost of time parameter b . By the continuity of the bidding function in the cost of time parameter, and given the analytical solution $DutchBid = \frac{(n-1)}{n} * v$ for the case of no time costs, $b = 0$, we expect the intercept to be close to zero, $\alpha_0 \approx 0$, and the coefficient on value to satisfy $\alpha_1 \in (0, 1)$, for all n and b .

The fitted regression lines of bids on value by treatment and by earning category, compared to theory, are displayed in Figure 5. Overall, the bidding behavior tracks the theoretical predictions rather well for both Top and Bottom earners; the slopes of the bidding functions on value are not significantly different from the theoretically predicted ($p > 0.05$) in all treatments, except for the Bottom earners in the 5L treatment.

However, overbidding is common in all but the 2H treatment, and especially for the Bottom earners; see also Table G.3. Moreover, Top earners bid significantly lower and closer to the theoretical predictions than Bottom earners ($p < 0.05$ for 2-bidder auctions and $p < 0.001$ for 5-bidder auctions); see Figure 8, left panel.⁷ Further, bidding is significantly ($p < 0.01$) closer to theory in the high-cost treatments (with the average over-bidding at 0.75 points only) than in the low-cost treatments (with the average over-bidding at 4.39 points). Yet the regression estimations of bids on value presented in Table G.3 indicate that the bids are not statistically different between high- and low-cost treatments ($p > 0.1$), suggesting that less overbidding compared to predictions under the high cost of time may be due to higher predicted bids rather than changes in bidder behavior.⁸

⁷Reported p -values are obtained by regressing the bid deviations from the predictions on the payoff segment dummies, with bootstrapped standard errors clustered on the session.

⁸Katok and Kwasnica (2008) document more overbidding in slower Dutch clock auctions, attributing this phenomenon to bidders' intrinsic impatience. While the speed of the virtual clock is the same in all treatments in our experiment, the higher induced cost of time translates into faster payoff shrinkage and may have a similar effect on behavior as a faster clock, leading to less overbidding.

Table G.3: Dutch auction bids regression estimation

Earning Category	2-bidder auctions			5-bidder auctions		
	Theory	Bottom	Top	Theory	Bottom	Top
item value	0.56*** (0.00)	0.63*** (0.06)	0.58*** (0.05)	0.81*** (0.00)	0.21*** (0.08)	0.88*** (0.06)
item value high cost	0.11*** (0.00)	-0.11 (0.10)	0.01 (0.07)	0.02*** (0.00)	0.54*** (0.09)	-0.10 (0.06)
high cost	0.06*** (0.01)	3.49 (3.79)	-0.67 (1.84)	0.04*** (0.00)	-24.69*** (4.59)	4.26 (2.66)
Dutch auction first		1.84 (2.44)	-0.31 (0.74)		1.10 (1.37)	-0.11 (0.61)
Constant	-0.41*** (0.01)	1.23 (2.51)	0.96 (1.06)	-0.10*** (0.00)	30.96*** (4.11)	-0.59 (2.50)
Observations	1404	336	356	2030	191	215
Adjusted R^2	1.000	0.490	0.613	1.000	0.437	0.844

OLS estimation. Bootstrapped standard errors clustered by session in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

The joint hypothesis that the coefficients on “item value high cost” and “high cost” are both equal to zero cannot be rejected for either Bottom or Top earners ($p > 0.1$) in both 2-bidder and 5-bidder auctions, except for 5L bottom earners. Hence, we cannot reject the hypothesis that bids as a function of value are the same in high-cost and low-cost cases, for both 2-bidder and 5-bidder auctions.

Observation 2. *Bidders overbid in all but one treatment in the Dutch auctions. Bidding closer to the theoretical prediction is associated with significantly higher bidder earnings, whereas overbidding is associated with lower earnings. Bidders overbid significantly less in auctions with the high cost of time.*

Bidding patterns in Honolulu auctions Figures 6 and 7 present evidence that Dutch-stage bids are flatter in value than predicted, with over-bidding compared to the prediction at low values and under-bidding at high values, as indicated by simple regression estimations included in the top panels of the figures. The additional Dutch-stage bid estimation results are given in Table G.4. The overall effect is dominated by high-value bidders bidding at lower-than-predicted prices, resulting in the Dutch stage lasting, on average, over 4 price ticks longer than predicted in all treatments. In two-thirds (68%) of all auctions with two bidders, and in almost three-quarters (74%) of all auctions with five bidders, the Dutch stage lasted more than two price ticks longer than predicted.

Table G.4: Honolulu auctions Dutch stage bids regression estimation

Treatment	2L		2H		5L		5H	
	Theory	Actual	Theory	Actual	Theory	Actual	Theory	Actual
item value	0.30*** (0.00)	0.03 (0.03)	0.50*** (0.00)	0.07** (0.03)	0.70*** (0.00)	0.20*** (0.01)	0.71*** (0.00)	0.41*** (0.03)
item value Top earner		0.04* (0.02)		0.23*** (0.08)		0.00 (0.01)		-0.04 (0.08)
Top earner		-1.00 (1.19)		-4.22* (2.56)		0.17 (0.55)		2.69 (4.38)
Dutch auction first		-0.28 (0.53)		-2.75 (1.77)		-0.04 (0.41)		-2.42 (2.19)
Constant	-2.05*** (0.06)	3.76*** (0.98)	-2.43*** (0.05)	7.58*** (1.98)	-1.10*** (0.02)	15.17*** (0.28)	-1.12*** (0.01)	10.25*** (1.97)
Observations	684	313	720	334	980	196	1050	210
Pseudo R^2	0.643	0.014	0.723	0.046	1.004	0.064	1.040	0.062

Tobit estimation, with bid upper bound for each treatment censored at the corresponding starting price.

Bootstrapped standard errors clustered by session in parentheses.

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

On the auction level, Dutch-stage bidding delays are associated with significantly lower purchase prices in both 2-bidder and 5-bidder auctions. On average, one price-tick increase in the Dutch-stage duration above the prediction is associated with 0.48 point reduction in the purchase price from the equilibrium level in 2-bidder auctions, and 0.21 point reduction in 5-bidder auctions ($p < 0.01$ in both cases).⁹

Observation 3. *Longer-than-predicted duration of Honolulu auction is explained by Dutch-stage bidding delays by high-value bidders.*

Regression estimations of behavior presented in Table G.5 confirm that under-bidding at the Dutch stage is more prevalent for bidders with high-value draws, and is significantly less common in 5-bidder auctions ($p < 0.01$ in both cases). Dutch-stage bidding delays persist in later rounds ($p < 0.05$), suggesting an anti-competitive motive behind many of the delays. Bidders are significantly more likely to stay above value in 5-bidder auctions than in 2-bidder auctions ($p < 0.01$), possibly due to a lower risk of buying above value in auctions with more than two active bidders. The precedence of both leaving the auction at a price below value and bidding above value at the English stage is reduced significantly in later rounds ($p < 0.05$), indicating participant learning. Consistent with the theoretical prediction, the cost of time parameter does not have a significant effect on bidding at the English stage.

Finally, the table documents significant differences in behavior between Top and Bottom earners. Compared to Bottom earners, Top earners are significantly less likely to delay

⁹Based on regressing the purchase price deviation on bidding delay, with bootstrapped standard errors clustered on session.

Table G.5: Regression estimation of individual decisions in Honolulu auctions, by stage

	(1)		(2)		(3)		(4)	
	Dutch stage		Contest stage		English stage		Final outcome	
<hr/> Bid/leave below equilibrium <hr/>								
item value	0.13***	(0.01)	0.01	(0.01)	0.02***	(0.00)	0.06***	(0.00)
5 bidders	-1.89***	(0.28)	-0.97	(0.63)	-0.34	(0.38)	-1.22***	(0.37)
high cost	0.02	(0.29)	-0.23	(0.43)	0.10	(0.46)	0.21	(0.36)
5 bidders high cost	0.18	(0.50)	0.26	(0.85)	-0.20	(0.57)	-0.35	(0.53)
Dutch auction first round	0.13	(0.32)	0.25	(0.43)	-0.14	(0.34)	-0.09	(0.29)
Top earner	0.03**	(0.01)	-0.03	(0.02)	-0.04***	(0.01)	-0.04***	(0.01)
Constant	-0.37**	(0.16)	-0.36	(0.23)	-0.67***	(0.17)	-0.29***	(0.09)
Constant	-4.12***	(0.38)	-2.55***	(0.54)	-1.76***	(0.45)	-2.17***	(0.34)
<hr/> Competitive bid/leave: base outcome <hr/>								
Bid above value								
item value	-0.13	(0.10)	-0.10**	(0.05)	-0.14***	(0.01)	-0.04***	(0.01)
5 bidders	0.97	(9.95)	11.95***	(3.43)	2.50***	(0.88)	0.14	(0.76)
high cost	1.80	(9.00)	13.47***	(2.21)	0.53	(0.86)	0.47	(0.72)
5 bidders high cost	-2.08	(10.98)	-10.74***	(4.05)	-0.47	(1.03)	-0.15	(0.93)
Dutch auction first round	-2.36	(6.09)	-2.21	(2.21)	-0.90	(0.56)	-1.02**	(0.50)
Top earner	-0.01	(0.07)	-0.07	(0.07)	-0.03**	(0.01)	-0.02*	(0.01)
Constant	-2.21	(4.32)	-1.85	(2.59)	-1.31***	(0.39)	-1.49***	(0.41)
Constant	-2.77	(8.71)	-14.36***	(2.12)	0.45	(0.97)	-1.39*	(0.83)
Observations	3434		2381		2064		3434	
Pseudo R^2	0.360		0.137		0.171		0.169	

Multinomial logit estimation. Bootstrapped standard errors clustered on session in parentheses.

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

their bids at the Dutch stage ($p < 0.05$), and both to drop out early and over-bid at the English stage ($p < 0.01$ in both cases). An English-stage dropout price regression estimation presented in Table G.6 confirms that Top earners' dropout prices are closer to the value than those of the Bottom earners.

Observation 4. *Compared to Bottom earners, Top earners bid closer to the equilibrium predictions at all stages.*

Table G.6: English stage dropout price regression estimation

Earning Category	2-bidder auctions			5-bidder auctions		
	All	Bottom	Top	All	Bottom	Top
item value	0.76*** (0.04)	0.67*** (0.06)	0.86*** (0.04)	0.67*** (0.06)	0.59*** (0.11)	0.78*** (0.03)
item value high cost	-0.11 (0.11)	-0.12 (0.13)	-0.03 (0.10)	-0.04 (0.12)	0.03 (0.18)	-0.08 (0.10)
high cost	2.76 (2.09)	2.95 (2.49)	1.10 (2.28)	2.02 (4.02)	0.91 (6.06)	2.43 (3.12)
Dutch auction first	0.81 (0.83)	0.66 (1.19)	0.71 (0.60)	-1.49* (0.79)	-1.84 (2.04)	-1.17* (0.70)
Constant	2.32*** (0.87)	3.62*** (1.08)	1.11 (1.43)	11.07*** (1.92)	13.18*** (3.11)	8.22*** (0.92)
Observations	512	270	242	689	380	309
R^2	0.658	0.523	0.857	0.619	0.552	0.745

Linear regression. Bootstrapped standard errors clustered by session in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

H Bidder heterogeneity: clustering based on similarity

We further address heterogeneity in bidder behavior using multi-dimensional clustering based on similarity method. The analysis provides an additional support that the behavior of high earners is qualitatively different and closer to the equilibrium bidding strategy, especially at the Contest and English stages, than that of low earners who tend to either over-bid or under-bid.

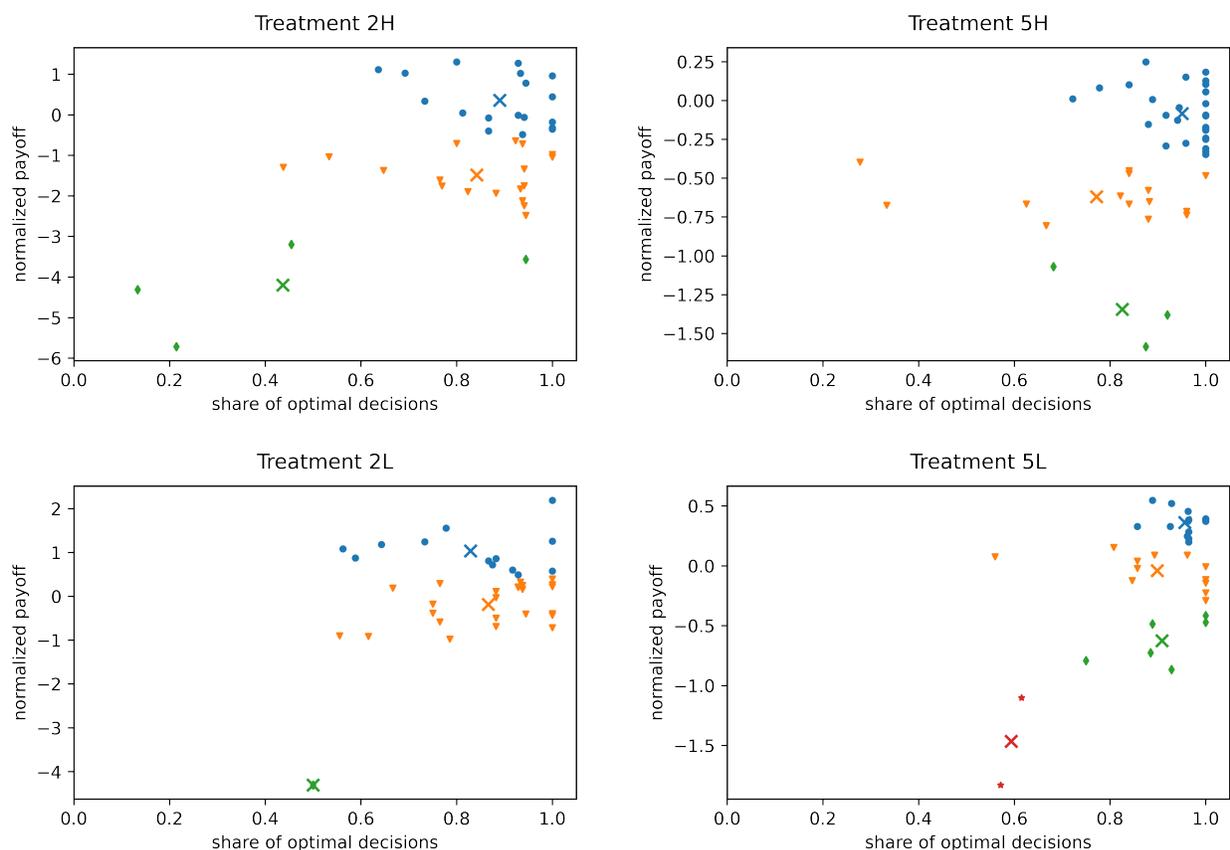
We apply a commonly used clustering based on similarity method called K-means algorithm (Lloyd, 1982) to study bidder heterogeneity in Honolulu-Sydney auctions. We characterize each bidder on two aspects, her normalized payoff, and the optimality of her strategy.

For the normalized payoff, we use the alternative measure mentioned in footnote 23 in Section 5.2, which is the average per period point deviations from the theoretical prediction by period. We avoid censoring of extreme values by using this alternative measure, at the cost of losing cross-treatment comparability. We argue that the benefit of this alternate measure outweighs the cost, because the exact position of each data point affects the global clustering result in K-means algorithm; censoring extreme values would distort the optimally chosen clusters.

For the optimality of bidder strategy, we focus on Contest or English stage decisions, and exclude the individual observations of the Dutch-stage winners who are uncontested and become the auction winner without the follow-up English stage.¹⁰ A bidder's joint

¹⁰Applying K-means clustering method to individual decisions for each stage revealed that the optimality of Dutch-stage decisions has a smaller association with individual payoffs than their decisions at later stages.

decision at the Contest and/or English stage is considered optimal if one of the following three conditions is satisfied: (1) She drops out on the Contest stage when the contest price is higher than her item value; (2) She enters the English stage but drops out at the price equal to her item value; (3) She enters the English stage and wins the item at a price equal to or below her item value. (Decisions within two unit from the value are considered at value.) We measure the optimality of a bidder's strategy by the share of optimal decisions in all of her decisions.



Note: Each dot represents one individual. The dots in the same shape belong to the same cluster, and the clustering center is marked with a cross.

Figure H.1: Clustering based on similarities in bidder characteristics in Honolulu auctions: normalized payoffs and individual decisions at the Contest and English stages

Figure H.1 shows the clustering results by treatment. In all treatments except 2-bidder low-cost (2L), the cluster with the highest average normalized payoff has also the highest optimal decision rate. The average share of optimal decisions in the top-earning cluster exceeds 95% in 5-bidder auctions, and it exceeds 90% in 2-bidder high-cost (2H) auctions. The share of optimal decisions in these three treatments generally decreases when moving from the cluster with the highest average normalized payoff to the one with the lowest

We therefore exclude the cases when the auction ended with an uncontested Dutch-stage bid. In total, 6.4% (219 out of 3434 observations) of all decisions are excluded.

payoff. There is a 18% – 40% gap in the optimal decision rate between the top-earning cluster and bottom-earning cluster. Thus, the clustering result provides evidence for bidder heterogeneity: Top earners employ closer to theoretical optimal strategies, except for the treatment 2L. For the 2-bidder low-cost treatment, clustering based on similarity does not provide much information about the relationship between earnings and optimality of bidding strategies. One possible explanation is the presence of suppressed price competition.

I Auction order effects

Since the experimental design is within-subject, i.e., the same subjects participate in both auction institutions consecutively, there may be a carryover in behavior from one auction to the next.¹¹ We check for such behavioral carryovers by testing whether bid deviations from theory in the Dutch auctions, and Dutch-stage bid deviations in Honolulu auction, differ depending on the institution’s order in a session. Given overbidding in the Dutch auctions and underbidding at the Dutch stage of Honolulu auctions, behavioral carryovers would imply lower bids in the Dutch auction if it is preceded by Honolulu auction, and higher bids at the Dutch-stage of Honolulu auction if it is preceded by the Dutch auction. The results are displayed in Figures I.1 - I.2 and the top part of Table I.1. On average, the bids are lower under either institution if it is experienced the second in the session, as compared to the first. That is, on average, Dutch bids are lower if the Dutch auction follows Honolulu auction, and Dutch-stage bids in Honolulu auction are lower if Honolulu auction is preceded by Dutch. These differences are more suggestive of learning across institutions than carryover effects. Furthermore, the differences are not statistically significant overall, allowing us to pool the corresponding data in the analysis. See also the coefficients on “Dutch auction first” indicator variable included in Tables G.3 - G.6 in Appendix G. Likewise, the differences in final price deviations from predictions do not significantly differ by auction order in either Dutch or Honolulu auctions, as documented in Figures I.3-I.4 and the bottom part of Table I.1.

¹¹As suggested by an anonymous referee, this might take the effect of stopping the price in the Dutch auction at similar prices to which the price decrease was stopped in the Honolulu auction.

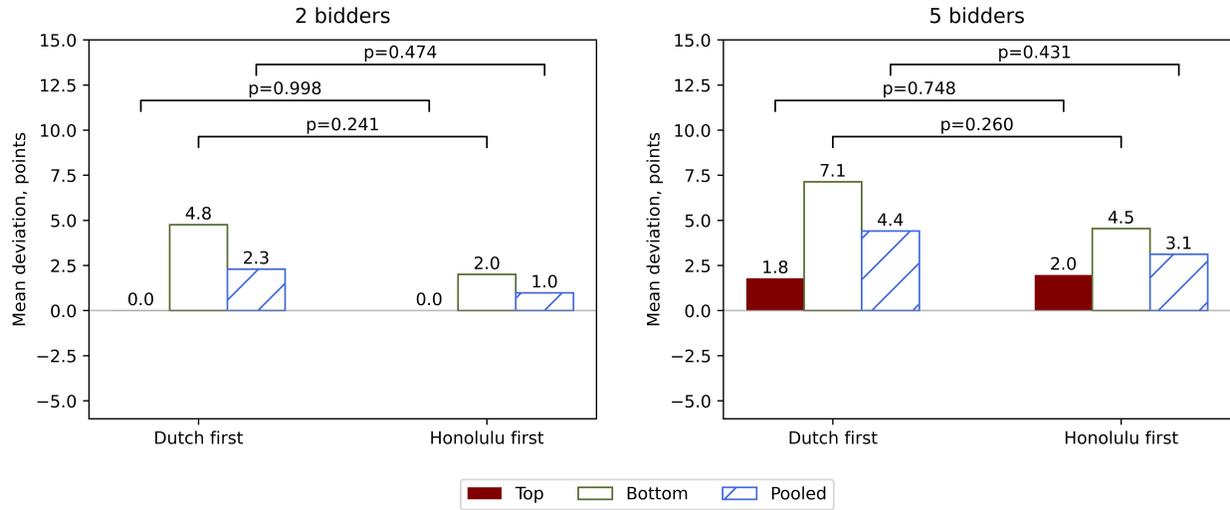


Figure I.1: Dutch auctions bid deviation from prediction by auction order

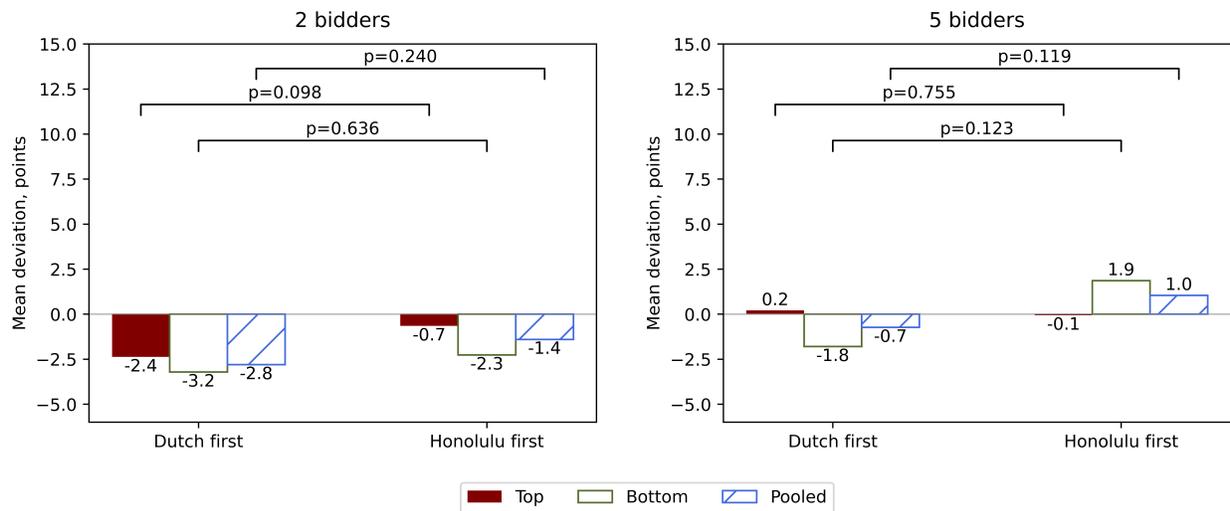


Figure I.2: Honolulu auctions Dutch Stage bid deviation from prediction by auction order

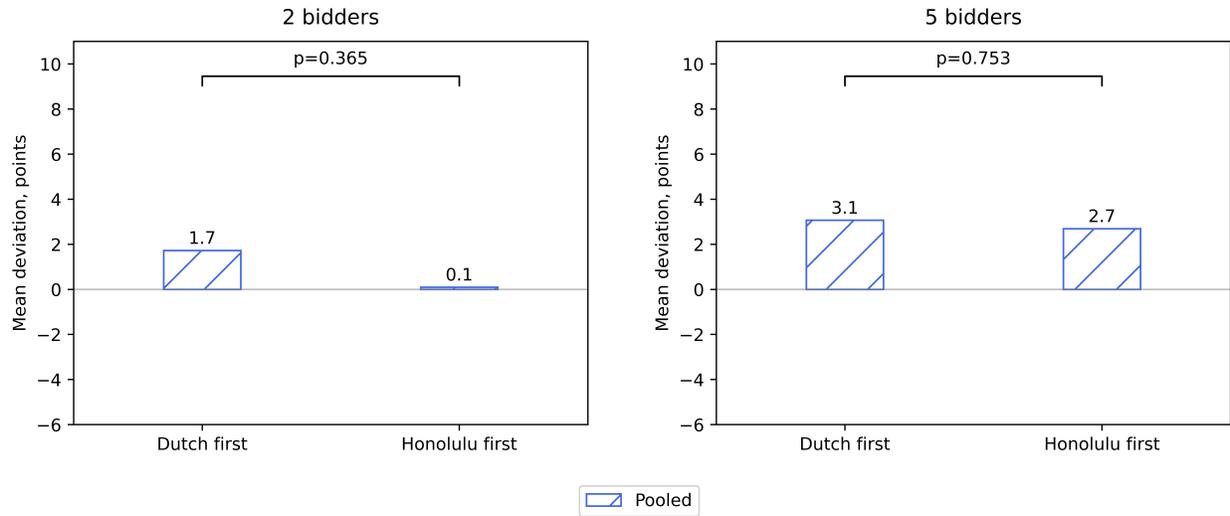


Figure I.3: Dutch auctions final price deviation from prediction by auction order

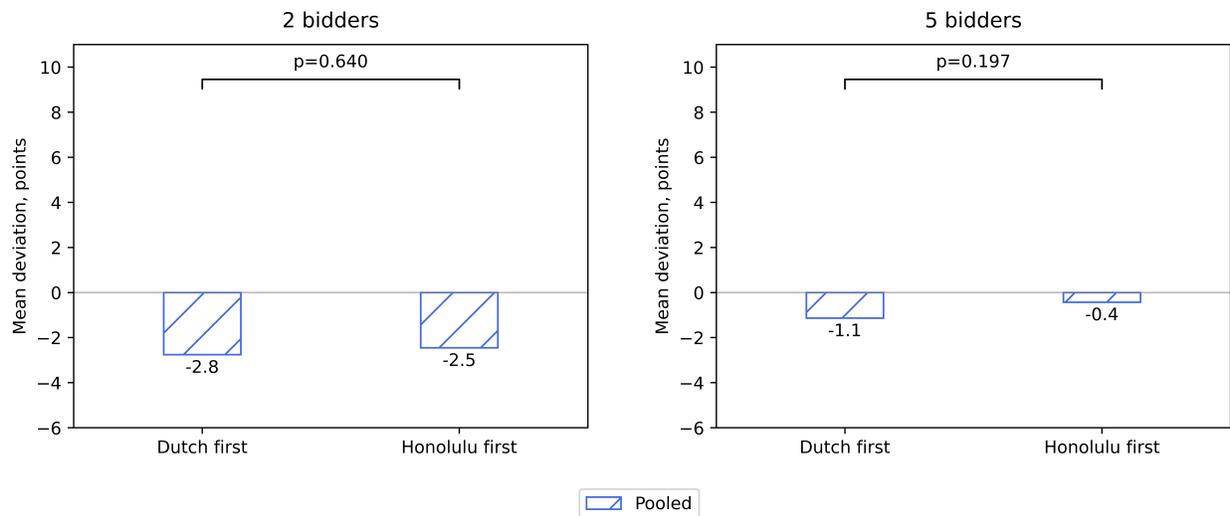


Figure I.4: Honolulu auctions final price deviation from prediction by auction order

Table I.1: Auction bids and final prices deviation from prediction summary by auction order

Treatment	2-bidder auctions			5-bidder auctions		
	Pooled	2H	2L	Pooled	5H	5L
<u>DUTCH AUCTION</u>						
Dutch bids						
Dutch first	2.30	0.12	4.00	4.41	1.89	6.80
Honolulu first	0.99	-0.53	3.45	3.12	2.84	3.46
<i>p</i> -values of the difference	0.474	0.749	0.000	0.431	0.007	0.102
Final prices						
Dutch first	1.72	-0.31	3.29	3.07	1.28	4.76
Honolulu first	0.10	-1.53	2.81	2.69	2.56	2.85
<i>p</i> -values of the difference	0.365	0.487	0.000	0.753	0.000	0.231
<u>HONOLULU AUCTION</u>						
Dutch Stage bids						
Dutch first	-2.81	-4.20	-1.72	-0.73	-1.08	-0.40
Honolulu first	-1.40	-1.51	-1.21	1.04	1.12	0.95
<i>p</i> -values of the difference	0.240	0.104	0.420	0.119	0.289	0.098
Final prices						
Dutch first	-2.75	-2.91	-2.64	-1.14	-0.52	-1.73
Honolulu first	-2.46	-2.57	-2.27	-0.43	-0.54	-0.30
<i>p</i> -values of the difference	0.640	0.723	0.539	0.197	0.983	0.000

Note: *p*-values reported in the figures and the table above are obtained by regressing the corresponding variables of interest on the “Dutch auction first” dummy, controlling for the cost and the number of bidders parameters. Standard errors are block-bootstrapped at session level.

J Post-auction survey responses

Table J.1: Post-auction survey responses summary

Survey Question	Honolulu mean score μ_H	Dutch mean score μ_D	p -value* for $H_0 : \mu_H = \mu_D$
1. “When I bid, all I cared about was buying as fast as possible”	2.86	3.27	0.025
2. “When I bid, all I cared about was paying the lowest price possible”	4.85	4.07	0.000
3. “When I bought the object, I often thought that I could have bought it at a lower price if I bid differently”	3.43	4.21	0.002
4. “When I did not buy the object, I often thought that I could have bought it and made a profit if I bid differently”	2.63	3.82	0.000
5. “Indicate how you felt when you bought an object in the auction”	5.57	5.51	0.115
6. “Indicate how you felt when you did not buy an object in the auction”	3.88	3.59	0.001

For Questions 1 – 4, the scales are from 1 (Completely Disagree) to 7 (Completely Agree).

For Questions 5 – 6, the scales are from 1 (Extremely Sad) to 7 (Extremely Happy).

* Based on bootstrapped standard errors clustered on session.

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