When Speed is of Essence: Perishable Goods Auctions

Isa Hafalir (with O. Kesten, K. Sherstyuk, C. Tao)

UTMDC

Motivation and Questions

Perishable Goods Auctions

- Large quantities of perishable goods such as fresh fish and flowers are sold sequentially by unit or lot in many markets across the world
- Different auction formats are used, but speed is an important factor in all cases

Perishable Goods Auction Formats

- Some fish markets use the descending price Dutch auction
- Other markets, in particular in Honolulu and Sydney, use an "unusual" auction format:
  The starting price is "in the middle range," and the auction can behave as
  - pure English (ascending price) auction
  - pure Dutch (descending price) auction
  - Dutch auction then English auction

The Honolulu-Sydney Auction

- For a given starting price, if at least one bidder bids at the opening price, the English auction begins (price continues to go up till only one active bidder remains)
- Otherwise, the price starts going down until a bidder "jumps in." At this point,
  - if no other bidder challenges the bid, then the auction ends (Dutch auction)
  - if at least one other bidder increases the price, then the English auction begins (first-Dutch-then-English auction)
- In practice, all three dynamics are observed. Moreover, bidders almost always jump in at strictly positive prices.

Research Question: Why this Unusual Auction format?

- Within the standard modeling framework, risk aversion, loss aversion, regret, and asymmetries can explain neither the auctioneer's choice of this auction format, nor the bidder behavior in the auction
  - Under the standard assumptions, it is a weakly dominant strategy for all bidders to wait until the price drops to zero, then bid as in the English (ascending) auction
  - Given this, the auctioneer may prefer the outcome-equivalent but less complex ascending bid English auction
- BUT:
- Speed of the auction is very important for both the bidders and the auctioneer
- Hence, we consider a theoretical model with impatient bidders and auctioneer and test it in the lab
- We investigate under what conditions the Honolulu-Sydney Auction fares better than the Dutch auction for the auctioneer and the bidders

Model and Model Predictions

Modeling Choices

- Private values model
  - Most bidders and auctioneers are experts, and common aspects (such as fish quality) are common knowledge
  - Individual and private aspects seem to matter more
- Single-unit auction model
  - Katok and Roth (2004) study Dutch auctions of multiple homogeneous goods with divisible lots and synergies
  - In Honolulu auction and Sydney auctions for prime grade fish, each unit of fish sold separately is indivisible, and units differ in quality, suggesting heterogeneous goods and separable values across units
- Impatient bidders and auctioneer, with linear costs of delay
  - Katok and Kwasnica (2008) suggest that innate bidder impatience may explain the observed differences in bids between "fast" and "slow" Dutch auctions
  - In contrast, we induce bidder impatience by shrinking the monetary payoffs in proportion to auction duration, and target "fast" auctions
- Risk-neutral auctioneer and bidders

Model

- There are n bidders. Bidders' private valuations are i.i.d over $[0, 1]$ according to F.
- If the auction ends after t units of time at the price p, winner with value v has a utility of

$$(v - p) \cdot c_B(t)$$

and auctioneer has a utility of

$$p \cdot c_A(t)$$

where $c_A(\cdot)$ and $c_B(\cdot)$ are weakly decreasing and positive functions.

- Losers' utilities are 0.
- In the Honolulu auction, the auctioneer chooses a starting price s.

Bidders' and auctioneer's games

- We assume that bidders stay in the auction till the price reaches their value in the "English auction" phase
- Given s, the bidder with value v choses "jump in" price p to maximize

$$F(p)^{n-1}(v-p)\,c_B(s-p)+\int_p^v (v-x)\,c_B(s+x-2p)\,dF_1^{(n-1)}(x)$$

- Denote the solution by $p(v,s)$. We'd have $p(v,s)\leq v$
- We have $EU_A(s)=$

$$\int_0^1\left(\int_0^{p(v,s)} p(v,s)\,c_A(s-p(v,s))\,g(v,x)\,dx+\int_{p(v,s)}^v xc_A(s+x-2p(v,s))\,g(v,x)\,dx\right)dv$$

where $g(v,x)$ is the joint density of highest (denoted by v) and second highest (denoted by x) of n random variables i.i.d according to F.

Results

Proposition

In a Bayesian Nash equilibrium, we can observe both (i) no bidder increases the price after some bidder jumps in, and (ii) some bidders increase the price after a bidder jumps in. Moreover, for some low values of s, some bidders may jump in immediately at the opening price.

Proposition

The optimal starting point for the auctioneer is strictly higher than 0 *unless the bidders are patient.*

Proposition

A patient auctioneer's optimal starting point is 1.

Linear cost case

- Suppose that $c_A(t) = a - ct$ and $c_B(t) = a - bt$. Moreover, F is uniform.
- Define

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

then, there is a unique solution, $k(p, v, s)$, to $K(p, v, s) = 0$ in $p \in [0, v]$. We have

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

Dutch Auction

- Consider Dutch auctions, where price falls from 1. A bidder with value v, who jumps in at price p has a payoff of

$$G\left(\beta^{-1}(p)\right)(v-p)(a-b(1-p))$$

- This results in

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

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

- Auctioneer's expected utility:

$$\int_0^1 \beta(x)(a-c(1-\beta(x)))\,dH(x)$$

  where $H(x)=F(x)^n$

Comparison of Honolulu and Dutch Auctions

- Suppose $b = 0$ abd $c > 0$. In this case, optimal s would be 0.
  - Honolulu becomes English, and under both auctions, bidders behave as in the standard risk-neutral case
  - We characterize the exact condition that makes Honolulu or Dutch auctions better
  - For Uniform distribution case Dutch is better if and only if $n \geq 3$.
  - Due to continuity, this would also hold when b is small enough.
- We have a numerical code that calculates equilibrium jump-in times, payoffs, and expected durations for Dutch and Honolulu auctions.
- For not large n, in a much greater region Honolulu auction is better than Dutch auction for the auctioneer

Model predictions

We will refer to Honolulu-Sydney auctions as "Honolulu."

- Bidder and auctioneer delay costs can account for all three types of dynamics observed in Honolulu auctions.
- Optimal starting price in Honolulu auction is never 0 (unless bidders are patient), and is never $\bar{v}$ (unless the auctioneer is patient).
- In the symmetric bidders case, the bidder with the highest value buys the good (value efficiency)
- Comparison of Honolulu and Dutch auctions is not obvious: for different parameters, each auction format may yield higher expected utility for the auctioneer

Predictions: Comparison of Honolulu and Dutch Auctions

We use a numerical code to generate model predictions: prices, duration, and auctioneer and buyer utilities.

- Honolulu auctions have shorter duration than Dutch under a wide range of parameters
- Honolulu is better than Dutch for the auctioneer if the number of bidders is small or bidder cost of delay is high
- For auctions with a large number of bidders, Dutch auction is often better than Honolulu auction for the auctioneer

Experiment and Experimental Results

Experimental Design – Auctions

- Given the above predictions, the experiment is designed to compare Honolulu and Dutch auctions.
- Bidder Values: Uniform on $[0, 50]$.
- Speed of the clock: one tick per second (fast)
- Auction Price:
  - Changes by 1 unit with every tick of the clock
  - Dutch price starts at 50;
  - Honolulu prices start at the optimal price for auctioneer (assuming risk neutrality)
- Treatment variables:
  - Bidder cost of delay: High (payoff shrinks by 1.9 percent) or Low (by 0.9 percent) per tick of the clock.
  - Number of bidders per auction: 2 and 5

  Treatments: 2 or 5 bidders, High or Low Cost: 2H, 5H, 2L, 5L
- Auction sequences: Honolulu – Dutch (HD) or Dutch – Honolulu (DH), 18-28 periods under each format

Additional Design Elements: Behavioral Surveys

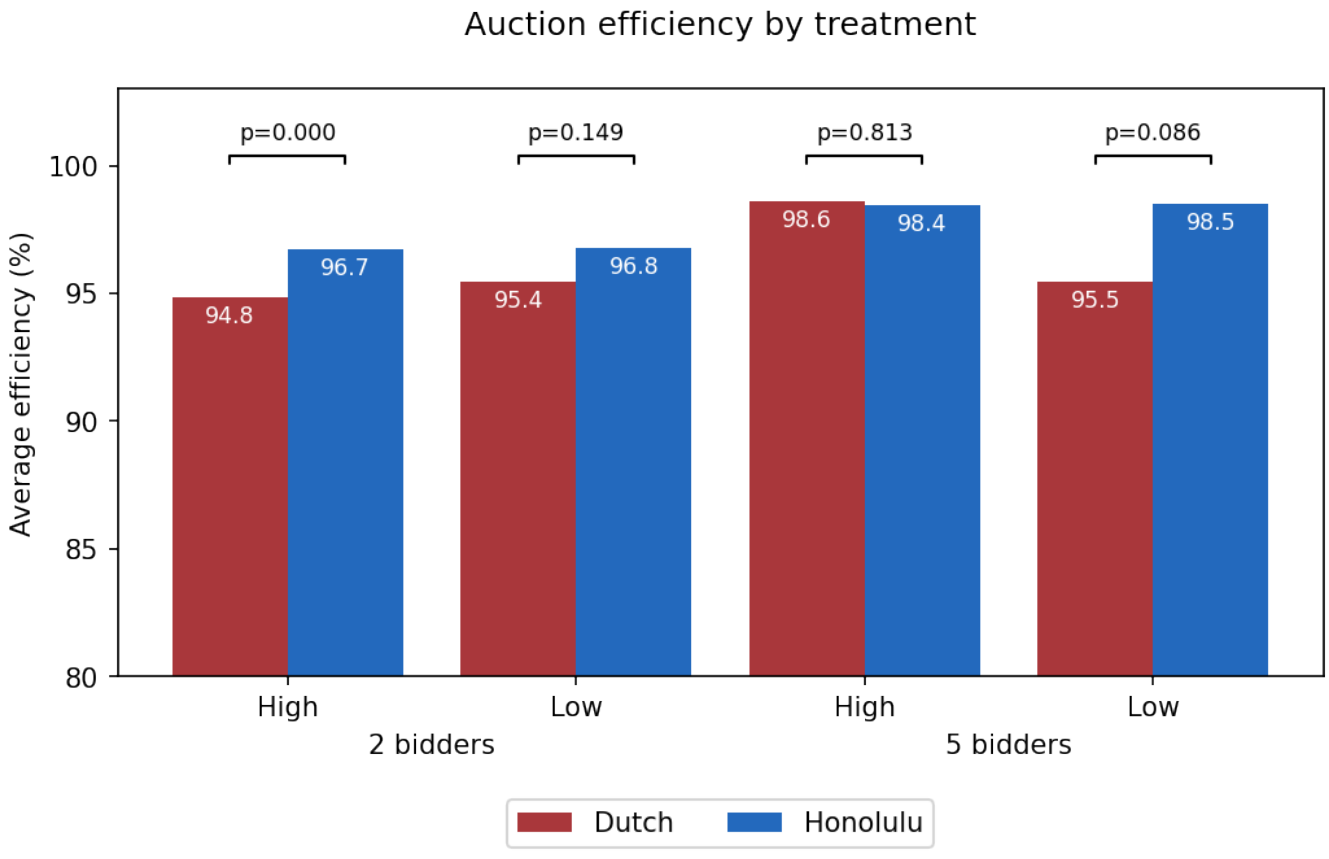
- We use survey instruments to assess behavioral features that may be relevant to these auctions
- Pre-auction surveys:
  - The International Cognitive Ability Resource (ICAR) tests (Raven's matrices, `https://icar-project.com/`)
  - Risk and time preferences validated surveys (Dohmen et al 2016)
- Following each auction part (Honolulu and Dutch):
  - Assess regret using questions on the affective state as in Camille et al. (2004)
- Post-auction questionnaire:
  - Demographics
  - Regret aversion (Schwart et al. 2002)
  - Competitive preferences (Fallucchi et al. 2020)

Results

- We conducted a total of 19 sessions, including 4 pilots
  - 9 sessions at the University Technology Sydney (UTS)
  - 10 sessions at the University of Hawaii (UH)
- 198 participants total, with 8-15 participants per session
- Treatments: 2H, 5H, 2L and 5L
- The analysis focuses on comparison across treatments, excludes pilot sessions (15 sessions, 158 participants total)

1: Value efficiency

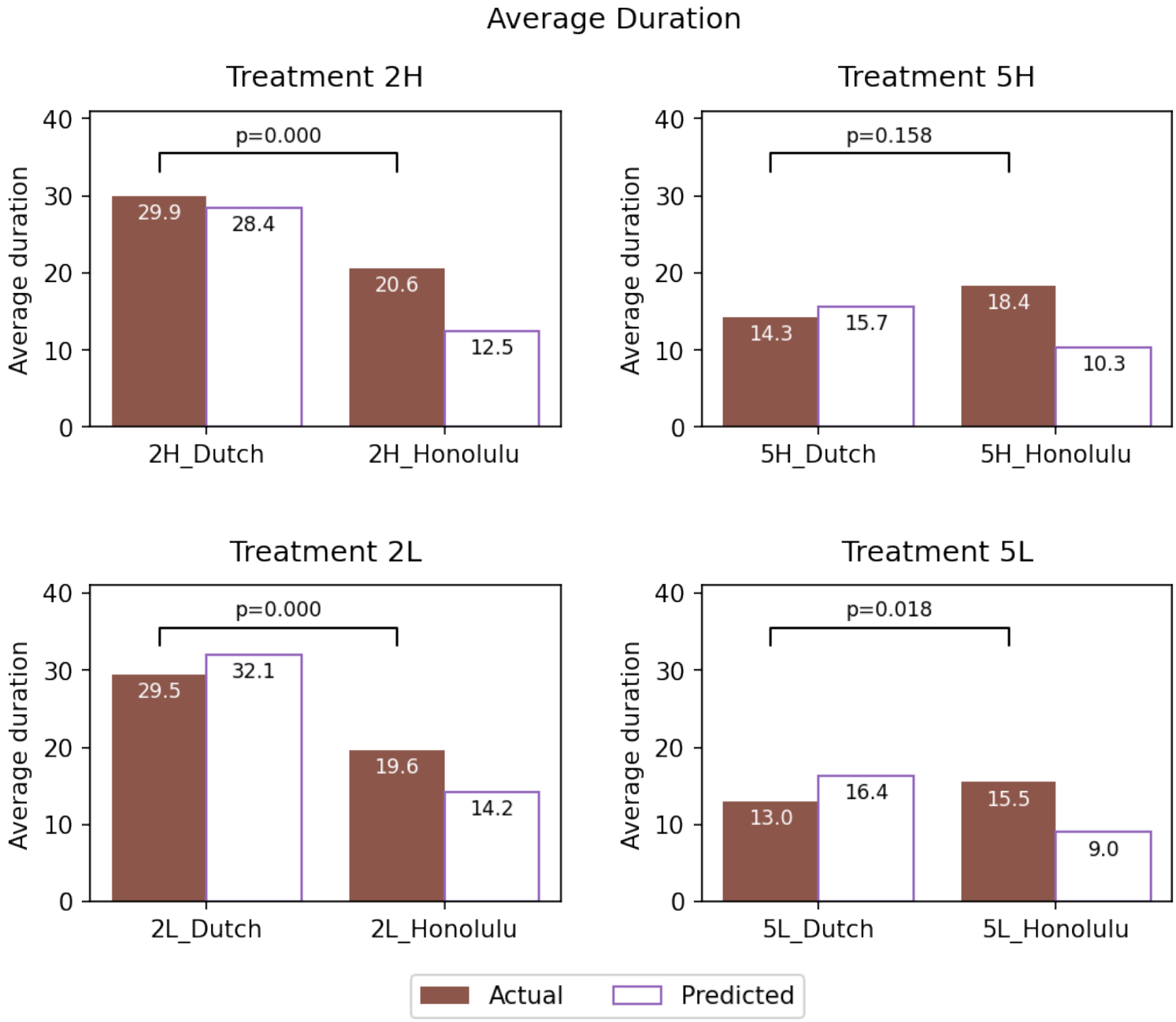
- Value efficiency is high under both Dutch and Honolulu auction formats: 95% or higher efficiency in all treatments
- Honolulu auctions have higher efficiency than Dutch ($p < 0.1$)



2: Auction duration and price dynamics

- As predicted, Honolulu auctions are much faster than Dutch auctions when the number of bidders is small (2-bidder auctions)
- Yet Honolulu auctions take longer than predicted, and are slower than Dutch in 5-bidder auctions
- All three price dynamics, – pure Dutch, pure English, and Dutch-then-English, – are observed in Honolulu auctions;
- Yet Dutch-then-English dynamics were more frequent than predicted
  - High-value bidders waited to bid longer than predicted, leading to more frequently occurring and longer-lasting Dutch stages
  - Hence longer than predicted overall duration in Honolulu

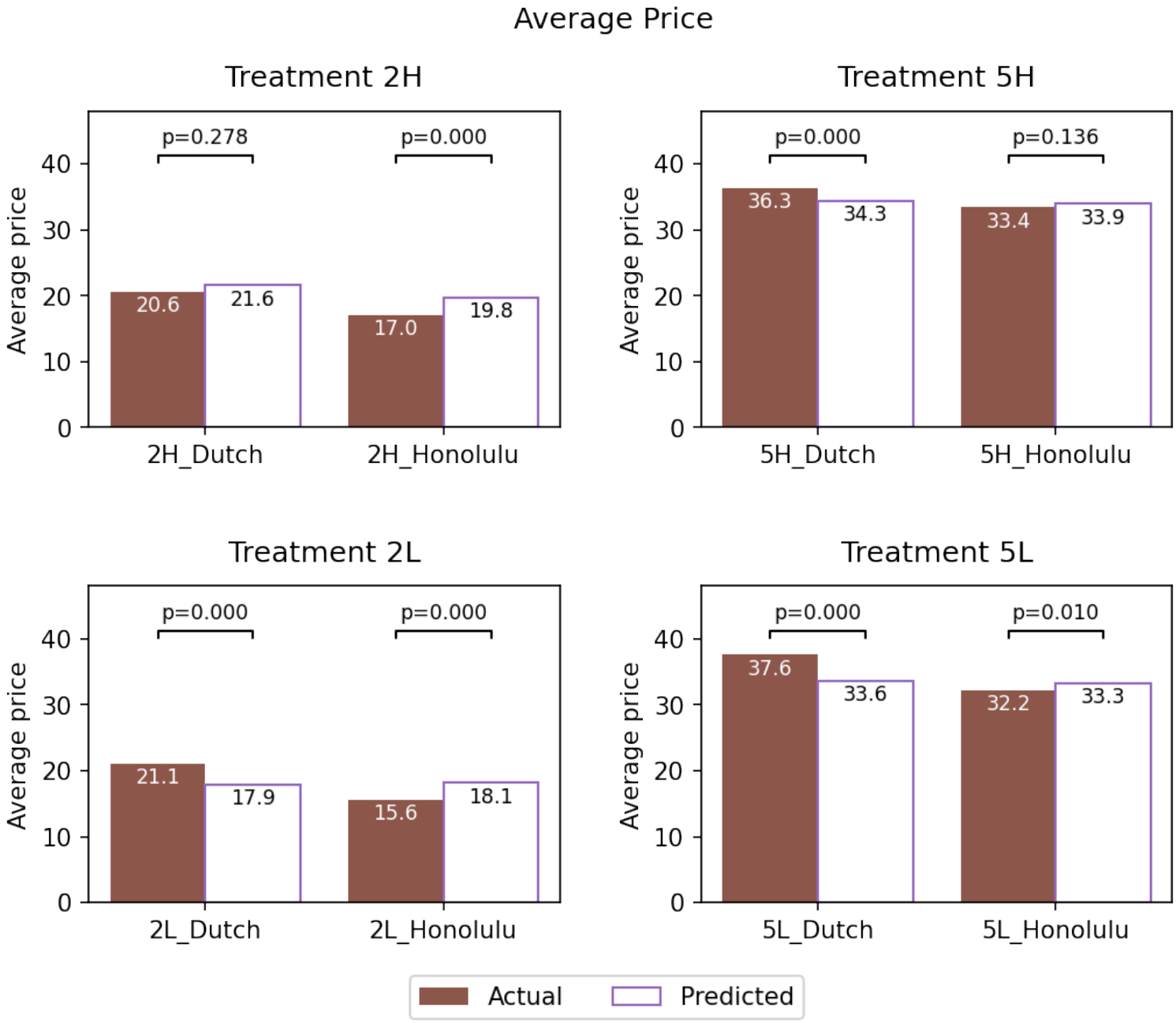
Auction duration by treatment



3: Selling prices

- Dutch auctions have higher than predicted prices in all treatments other than 2H (2-bidder, high cost of time)
  - This is a common observation for Dutch auctions
- Honolulu auction prices were no higher (in 5-bidder auctions) or lower (in 2-bidder auctions) than predicted
  - Low-value bidders often dropped out too early at the ascending price stage
- As a result, Dutch auctions had higher prices than Honolulu in both 2-bidder and 5-bidder settings

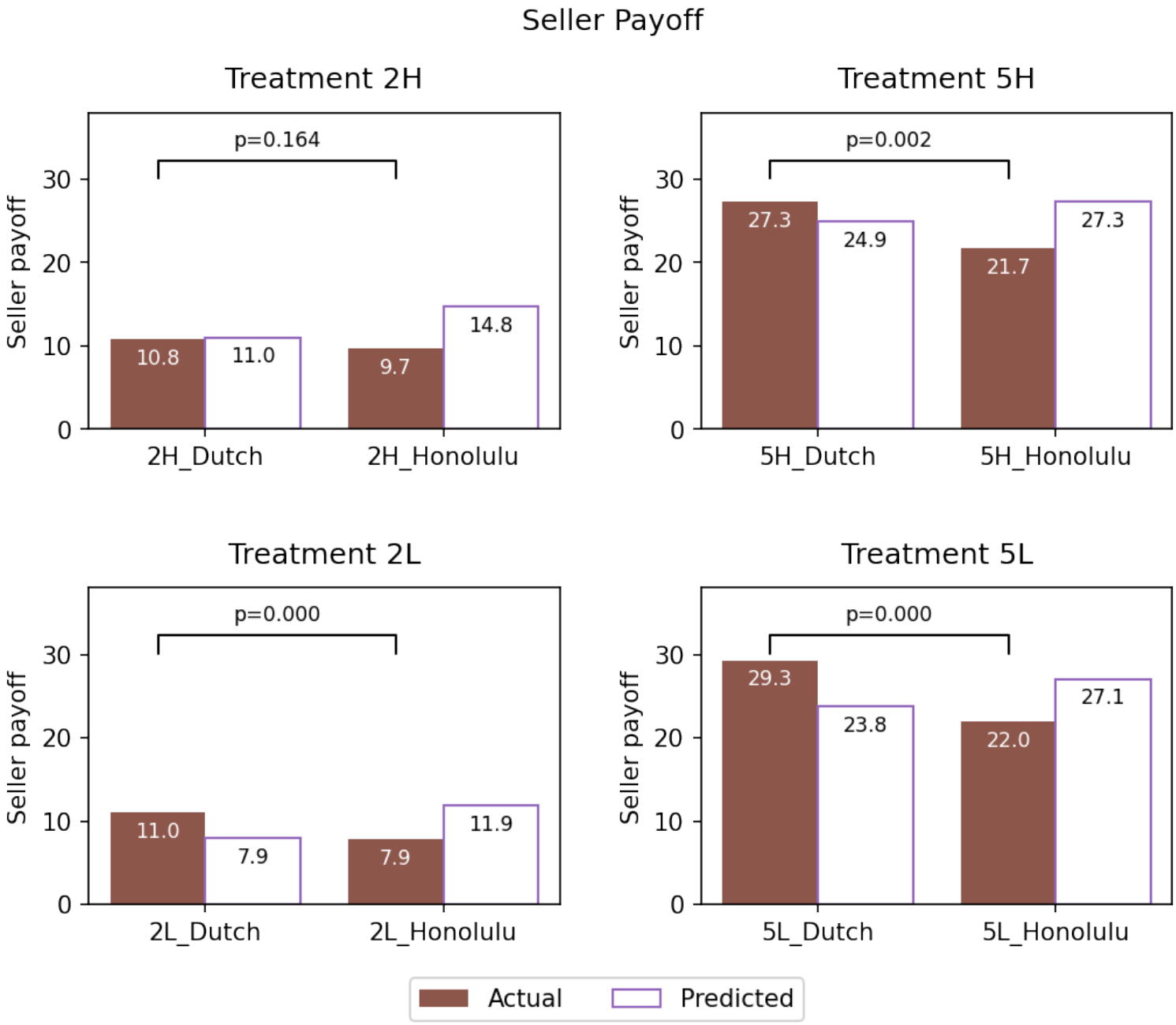
Selling prices by treatment



4: Auctioneer payoff

- Seller payoffs under Dutch and Honolulu are indistinguishable for 2-bidder, high-cost (2H) treatment
- In other treatments, Dutch auctions benefit the auctioneer more than Honolulu auctions, even when the opposite is predicted.
  This is due to:
  - The Dutch auctions' higher-than-predicted prices and shorter-than-predicted duration
  - The Honolulu auctions longer than predicted duration and sometimes lower than predicted prices; many bidders wait for the prices to drop near zero before bidding, leading to both seller and buyer reduced payoffs due to delay

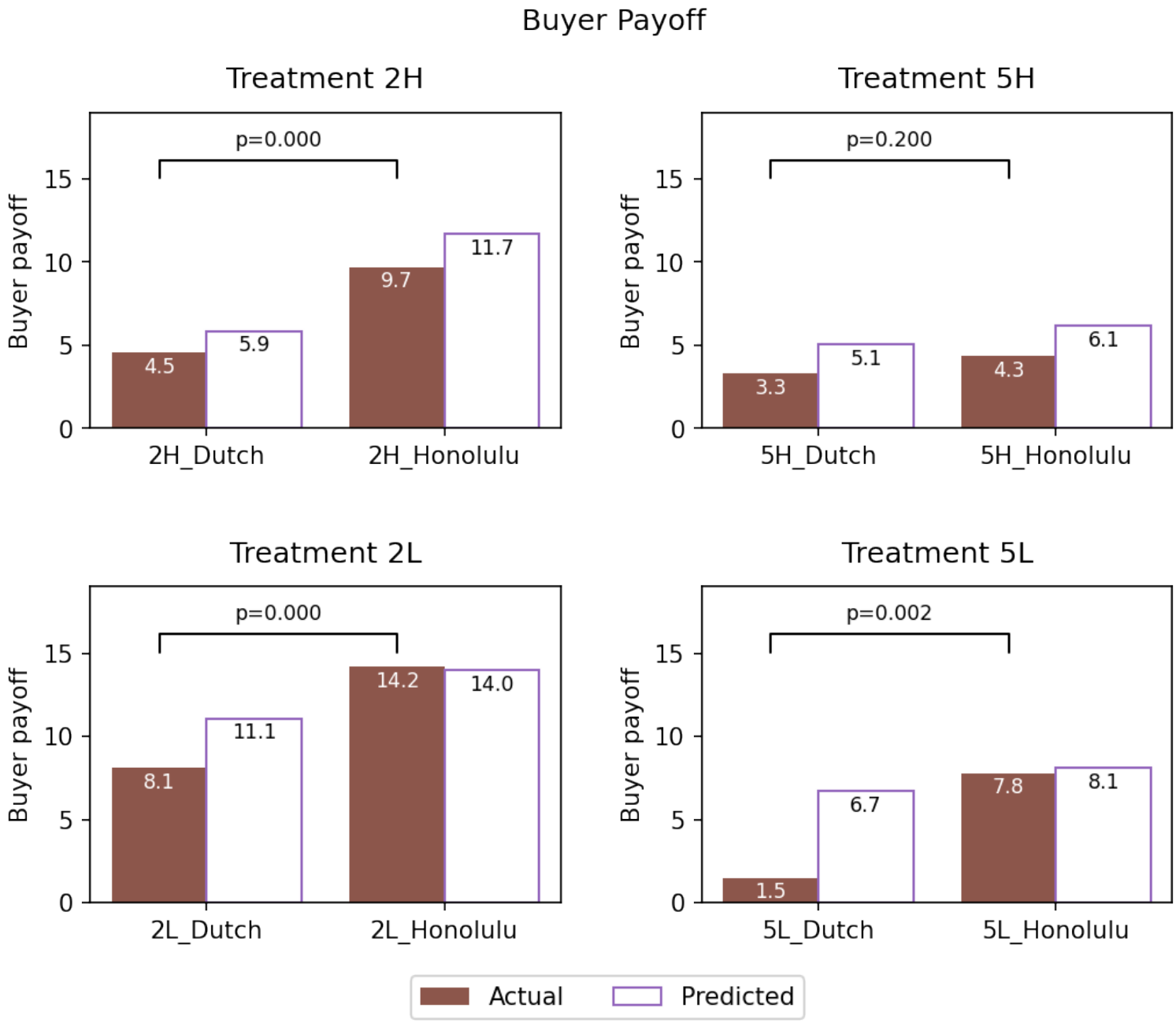
Auctioneer payoff by treatment



5: Bidder payoffs

- As predicted, buyers are better off under Honolulu auctions as compared to Dutch
- Buyers benefit from Honolulu auctions relative to Dutch even more than predicted, due to
  - over-bidding in Dutch auctions
    and
  - some under-bidding in Honolulu 2-bidder auctions

Bidder payoffs by treatment



6: Auction complexity and bidder heterogeneity

- Honolulu auctions are more complex than Dutch
  - Almost all bids in Dutch auctions are undominated, as compared to 78-95 percent of (weakly) undominated decisions in Honolulu auctions
- "Top" (above median) earners make dominated decisions less frequently than "bottom" (below median) earners under both auction formats

7: Bidder behavioral characteristics, performance and feedback

- Higher cognitive abilities (as measured by ICAR test) are associated with higher bidder payoffs
- Risk, time, and regret preferences are not significant for performance
- Informally, participants seemed to enjoy Honolulu auctions more than Dutch
- Yet they expressed more winner and loser regret under Honolulu than under Dutch
  - "A second chance to bid" under Honolulu may have prompted more thinking of "what if I did things differently."

Auction feedback: Winner regret

" When I bought the object, I often thought that I could have bought it at a lower price if I bid differently"

Auction feedback: Loser regret

" When I did not buy the object, I often thought that I could have bought it and made a profit if I bid differently"

Summary

- We confirmed that hybrid Honolulu auctions have a significant advantage over Dutch in terms of speed when the number of bidders is small
- Yet there is little difference between high-cost and low-cost treatments: bidders under-estimate the cost of time
- Buyers prefer Honolulu auctions over Dutch, as predicted
- Sellers are indifferent between Dutch and Honolulu auctions or prefer Dutch auctions even when theory predicts the opposite
- Reasons:
  - Over-bidding in Dutch auctions
  - Bidders waiting too long to bid in Honolulu auctions

Overall, the speed advantage of Honolulu auctions is confirmed in the data.
Honolulu auction represents an innovative solution for markets where time is of the essence.