When Speed is of Essence: Perishable Goods Auctions

Isa Hafalir[a,*], Onur Kesten[b], Katerina Sherstyuk[c], Cong Tao[d]

[a] *University of Technology Sydney, Australia*
[b] *University of Sydney, Australia*
[c] *University of Hawaii at Manoa, United States of America*
[d] *University of Technology Sydney, Australia*

Abstract

We study a remarkable auction used in several fish markets around the world, notably in Honolulu and Sydney, whereby high-quality fish are sold fast through a hybrid auction that combines the Dutch and the English formats in one auction. Speedy sales are of essence for these perishable goods. Our theoretical model incorporating "time costs" demonstrates that such Honolulu-Sydney auction is preferred by the auctioneer over the Dutch auction when there are few bidders or when bidders have high time costs. Our laboratory experiments confirm that with a small number of bidders, Honolulu-Sydney auctions are significantly faster than Dutch auctions. Bidders overbid in Dutch, benefiting the auctioneer, while the Honolulu-Sydney format benefits bidders more compared to Dutch across all treatments. We further observe bidder attempts to tacitly lower prices in Honolulu-Sydney auctions, substantiating existing concerns about pricing in some fish markets.

Keywords: auction theory, time costs, laboratory experiments.
JEL: C7, C92, D02, D44, L0.

1. Introduction

Many fish and flower 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 auctions is of essence given the perishable nature and large volumes being traded in a short amount of time; 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.[1]

*Corresponding author.
Email addresses: isa.hafalir@uts.edu.au (Isa Hafalir), onur.kesten@sydney.edu.au (Onur Kesten), katyas@hawaii.edu (Katerina Sherstyuk), cong.tao@uts.edu.au (Cong Tao)

[1] According to Hawaii-Seafood.org (2015) description of the Honolulu fish auction, "Hundreds of fish are displayed on pallets on the auction floor. The United Fishing Agency auctioneer moves down the rows of fish surrounded by buyers who openly bid against each other for value, the best prices and quality fish. The majority of fish are sold individually. This competition continues until all the fish are sold. Up to 100,000 pounds of fish can be auctioned in a day... The... system allows for the efficient sale of the range of fish species, size and quality to suit each special market niche." See also Peterson (1973) for an early detailed record.

We explore a seemingly peculiar and largely under-studied dynamic auction format employed in several perishable goods markets around the world, such as in Honolulu and Sydney fish markets. In this auction, the auctioneer sets a starting price that is neither as low as in an English auction nor as high as in a Dutch, but at a middle ground, allowing bidders to bid at the onset (either by raising their hands during a verbal Honolulu auction or by clicking a button during an automated Sydney clock auction). If at least one bidder bids at the announced starting price, the auction proceeds as an English (ascending price) auction. If there is no initial interest, the price begins to drop, as in a Dutch (descending price) auction. However, once a bidder bids, other bidders are allowed to counter-bid, potentially reverting the auction to an English auction. Although this auction format has been documented (Feldman, 2006) and is apparently employed in a number of fish markets in France and Denmark (Guillotreau and Jiménez-Toribio, 2006; Laksá and Marszalec, 2020) as well as in Honolulu and Sydney,[2] little is understood about the reasons for its emergence and its advantages over the more traditional descending-only Dutch auction that is also commonly used for perishable goods. To the best of our knowledge, no previous theoretical or experimental investigations have been conducted.

Our goal is to understand the reason for the existence and the patterns of observed behavior exhibited in this distinctive auction format. In both the Honolulu and Sydney fish markets, bidders do not usually wait until the price reaches extremely low or close to zero values during the Dutch stage; on the contrary, bidding typically starts with little delay, and each fish is auctioned off within seconds. This behavior does not align with standard explanations based on risk-neutral, risk-averse, loss-averse, or regret-avoiding bidder preferences, as none of these preferences give an apparent reason to end the Dutch stage prematurely when bidders always have the option to bid later at a lower price.[3]

Extensive consultations and discussions with the experts, administrators and bidders participating in both the Honolulu and Sydney auctions led us to deduce that this auction process is specifically designed to expedite the proceedings, preventing lengthy periods of price increases or decreases. For auctioneers, speed is of essence given the perishable nature of the good and the need to sell thousands of individual fishes or boxes within a 4-5 hour time frame. Similarly, wholesalers and restaurant owners who are repeat buyers encounter time constraints when they aim to purchase significant amounts of highly perishable products.[4]

[2]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..." Guillotreau and Jiménez-Toribio (2006) document a similar format used in fish sales in two French ports, and Laksá and Marszalec (2020) provide an identical description of the auction in the Faroe Fish market in Denmark. See Online Appendix A for more details. Finally, at the Ayazaga flower auction in Turkey, the starting price is determined by the auctioneer, and then may go up or down depending on buyers' bids (however, this flower auction does not allow for the price to go up again, once the price starts going down). This auction was recently analyzed in Hafalir et al. (2024).

[3] Under the standard assumptions, it is a weakly dominant strategy for all bidders to wait until the price drops to zero in the Dutch stage, and then bid in the English (ascending) auction stage. Given this, the auctioneer may prefer the outcome-equivalent but less complex ascending bid English auction.

[4]Cassady (1967, p.60) notes that speed is of essence in many auction markets. In personal communication, an auction expert and experimental economics pioneer Charlie Plott also shared with us his belief that many auction procedures, such as the Honolulu-Sydney auction format, stem from the necessity to quickly conclude

Motivated by the above, we propose a model that incorporates time costs, where both the auctioneer and bidders are impatient and strictly prefer a fast auction to a slow one, and test this model in a controlled laboratory environment. Taking time costs into account, impatient bidders must balance the advantages of waiting for a lower price with the costs related to the auction's length. As a result, they may opt to bid earlier if they find waiting to be more detrimental. Our findings indicate that both bidders' and auctioneers' time costs can explain the various auction stages observed in the Honolulu-Sydney auction format.

We also examine the Dutch auction alongside the Honolulu-Sydney auction in our theoretical model and in the experiments, as Dutch auctions are also commonly used in perishable goods markets, such as fish, flowers, fresh produce, and meat (Cassady, 1967).[5] In the Sydney Fish Market, for instance, there are two clocks running Dutch auctions, typically for less valuable seafood. The third clock, on the other hand, employs the Honolulu-Sydney auction format and sells high-quality seafood such as sashimi-grade tuna or live lobsters.

In our model with time costs, the well-known Revenue Equivalence result (Myerson, 1981; Riley and Samuelson, 1981) does not apply, meaning that different auction formats yielding the same allocation might produce varying utilities for the auctioneer. Comparing the Honolulu-Sydney to Dutch auctions, we find that utility comparisons are uncertain and depend on the time cost parameters of both the auctioneer and bidders. The blend of nominal revenue, which represents the object's sale price, and time cost effects, which reflect the auctioneer's welfare loss due to the auction's duration, establish the utility comparison between different auction formats.

In a Honolulu-Sydney auction, the auctioneer selects the optimal starting price, whereas the Dutch auction's starting price is typically set at the highest possible value. This "starting price effect" could potentially favor the Honolulu auction as it might result in a shorter auction duration compared to the Dutch, especially when there are few bidders. Intuitively, with small number of bidders, the expected selling price is significantly lower than the highest possible value (which is the Dutch auction's starting price), and this puts the Dutch auction at a disadvantage in terms of time costs. This effect decreases as the number of bidders grows and the expected selling price increases.

It is important to note that while using a reserve price can speed up the sales, it can also lead to inefficiencies in the auction. For perishable goods, promptly selling them is crucial, as their value diminishes over time and they can become unsellable later. This is why reserve prices are generally not used in practice at the Honolulu and Sydney Fish markets. Therefore, in this paper, we do not consider reserve prices.

Our experimental results provide strong evidence of the speed advantage of Honolulu-Sydney auctions compared to Dutch with a small number of bidders; as predicted, this advantage decreases with more bidders. However, we also find that Honolulu-Sydney auctions have lower prices than Dutch, as the former are more susceptible to suppressed price competition when there are few bidders, while the latter exhibit consistent overbidding.

the auction.

[5]We do not consider the English auction separately as the English auction is a special case of the hybrid (Honolulu-Sydney) format in our model. When the starting price is set to zero, the auction proceeds as a standard ascending-price auction. In contrast, the Dutch auction is not a special case of the hybrid we consider, because, irrespective of the starting price, the price in the Dutch auction can never go up.

As a result, Honolulu-Sydney auction benefits relative to Dutch are somewhat lower than predicted for the auctioneer, but higher than predicted for the bidders.

The paper proceeds as follows. In Section 2, we briefly discuss the relevant literature. The theoretical model of Honolulu-Sydney and Dutch auctions with time costs is presented in Section 3. Experimental design is discussed in Section 4. Section 5 presents experimental results and participant feedback on both auction formats. We conclude in Section 6.

2. Brief review of the literature

Much of the extant auction literature focuses on the ascending English and the descending Dutch auctions and their sealed-bid analogs in various types of environments (see, for example, Klemperer (1999), Klemperer (2004) and Milgrom (2004) for excellent overviews). We contribute to this literature by studying an original auction format that has already been in use around the world for several decades.

To the best of our knowledge, Katok and Roth (2004) is the only existing analytical study that discusses "alternative" Dutch auctions where the price may go down and then back up. However, they consider auctions of multiple homogeneous goods with divisible lots, and attribute the unusual price dynamics to the presence of synergies between parts of the lot. In Honolulu-Sydney auctions, each fish is sold separately, is indivisible, and units differ in quality, suggesting heterogeneous goods and separable values across units.[6]

The speed of auctions has been recognized as an important consideration for auction design in many contexts, notably the Federal Communication Commission spectrum auctions (Banks et al., 2003; Kwasnica et al., 2005); however, it has not been formally incorporated into the objective function of the auctioneer. For multi-unit auctions with single-unit demand bidders, Andersson and Erlanson (2013) propose a hybrid Vickrey-English-Dutch auction and show numerically that it has a speed advantage over Vickrey-English and Vickrey-Dutch formats. Yet they do not discuss a real-world application of this auction mechanism.[7]

Katok and Kwasnica (2008) study the effect of Dutch auction clock speed on bidding behavior in Dutch auctions. They suggest a theoretical model that explains more overbidding in slower auctions by bidders' intrinsic cost of time, and support their explanation with experimental data. In comparison, in our experiments, we keep the speed of the clock constant, induce time costs through bidder payoffs, and compare bidder behavior in Honolulu-Sydney and Dutch auctions with high and low bidder costs of time. Although we observe that some bidders delay their bids more than is optimal given the induced cost of time, overall, our data provide strong evidence of behavior consistent with positive time costs. In a recent work, Azevedo et al. (2020) propose a "Channel auction" that features an upper-bound price that descends (like a Dutch auction) and a lower-bound price that ascends (like an English

[6] "The oral method of the Dutch auction ... is used mainly for the sale of nonstandardized items where quality differences require flexibility..." (Cassady, 1967, p.63). Graddy (2006) further writes that "Fish is more perishable,... and individual fish are more heterogeneous than most agricultural products."

[7] Laboratory experiments also document that people value time along with money. In a recent work, Breaban et al. (2020) conduct an experiment where the subjects must stay in the laboratory for a set time but can bid on the amount of time to leave early.

auction), creating a narrowing channel of prices. In contrast to our paper, Azevedo et al. (2020) focus on a framework where the main aim is mitigating costly information acquisition (rather than time costs). In another recent work, Komo et al. (2024) show that a hybrid auction that begins with an English auction at the monopoly price, then, should there be no takers, concludes with a Dutch auction, is "weakly shill-proof."

There is vast experimental literature documenting overbidding in first-price sealed bid and Dutch auctions (Cox et al., 1982), often attributing it to bidder risk aversion (Cox et al., 1988) or regret aversion (Filiz-Ozbay and Ozbay, 2007). In line with the previous studies, we observe overbidding in our Dutch experimental auctions. We further use post-auction questionnaires to compare bidder sentiments of satisfaction, regret and sensitivity to time costs between Dutch and Honolulu-Sydney auctions.[8]

3. Model and Theoretical Results

We consider a single-item auction with n bidders in which both the auctioneer and the bidders are impatient. Bidders' private values are independently and identically distributed according to a twice differentiable cumulative distribution function F and a corresponding density function f over $[0, 1]$.

If the auction ends when bidder i with value v wins at price p after t units of time has passed, the auctioneer's utility is

$$U_A = p \cdot c_A(t)$$

and the winning bidder's utility is

$$U_B = (v - p) \cdot c_B(t),$$

where the time-adjustment function of the auctioneer $c_A(t)$ and that of a bidder $c_B(t)$ are strictly decreasing functions in time t. More specifically, we have $c_A(\cdot), c_B(\cdot) : [0, 2] \to [0, 1]$[9] and $c'_A(\cdot)$, $c'_B(\cdot) < 0$.[10] The bidders who don't win the item receive zero utility.

In our utility specification, we incorporate time adjustment functions in a multiplicative form within the utility functions. An alternative approach would be to use additive time adjustment functions, as in Katok and Kwasnica (2008). We choose the multiplicative formulation primarily for its analytical simplicity. Additionally, this approach ensures that

[8] We are grateful to Yan Chen for suggesting that the Honolulu-Sydney format allows to alleviate the loser's regret for not bidding early enough to win in the Dutch auction, as it provides a "second chance to bid." We investigate this conjecture by comparing bidder post-auction affective states under the Honolulu-Sydney and Dutch auction formats.

[9] Note that the maximum amount of time the Honolulu-Sydney auction can take is 2, and the Dutch auction can take is 1.

[10] While the auction clock could theoretically run arbitrarily fast, practical cognitive constraints limit bidders' processing speed, imposing a natural lower bound on feasible auction duration. Further, the existence of time costs facilitates the use of time as a signaling device. This would suggest that a sealed bid auction format would Pareto dominate dynamic auctions. However, transparency and market tradition could explain the continued preference for dynamic auctions over sealed-bid formats, despite the latter's advantage in terms of time costs. We thank the Associate Editor for the insightful comments that prompted us to clarify these issues.

bidders do not receive negative utility as long as the price paid is lower than their valuations - something that is not always guaranteed with the additive formulation.

3.1. Honolulu-Sydney Auction

The Honolulu-Sydney auction proceeds as follows. It begins with an initial price announced by the auctioneer. If no one bids at the initial price, the price starts going down until someone bids (i.e., operates as a Dutch auction). When a bidder bids, if at least one other bidder also bids at the current price, the price starts going up due to the excess demand for the item. The price continues to rise until only one bidder remains (i.e., operates as an English auction). If there is an interest at the starting price, the auction instantly becomes an English auction without any price drop, provided that at least one more bidder shows interest at the starting price. Hence, the Honolulu-Sydney auction can work in a pure Dutch, Dutch-then-English, or a pure English format depending on bidding behavior.

In this setting with impatient bidders, the time cost bidders incur from participating in the auction creates a non-trivial cost-benefit trade-off. On the one hand, an early bid helps save the cost of waiting at the expense of potentially paying a high price. In particular, early bidding is beneficial and helps avoid unnecessary wait times if a bidder anticipates excess demand around the opening price (otherwise, the price will first drop and rise again to the initial price level leading to unnecessary waiting costs). Consequently, each bidder is incentivized to start bidding before the price drops all the way to zero in the opening. On the other hand, considering that the auction may end up working as a pure Dutch auction (e.g., the first bid is above the valuation of the remaining bidders and discourages other bidders from starting an English stage), waiting before bidding first may help reduce the final price provided that no other bidder shows interest.

Next, we formalize this auction and the involved trade-offs. We consider a symmetric perfect Bayesian equilibrium of the Honolulu-Sydney auction where, when the starting price is s, each bidder with value v bids at the price $p(v, s)$ and in the English stage, each bidder will remain in the auction until the price reaches her value.

Consider the auction starting at a price s. The price will decrease until a bidder bids for the first time. Considering symmetric bidding strategies, let us represent this bid price as a function of bidder value given the starting price by $p(v, s) \in [0, s]$ and assume $p(v, s)$ to be strictly increasing in v whenever $0 < p(v, s) < s$ (allowing for "pooling at the starting price and at 0"). After one bidder bids at p, in the ascending auction stage, due to the "$(v - p) \cdot c_B(t)$" formulation of utilities and $c_B(t)$ being non-negative, all bidders with value greater than p will remain in the auction until the price reaches their values. Consider a bidder with value v who bids when the price decreases to p. Her expected utility is given by:

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

where $G(x)$ denotes the probability distribution of the highest of $n - 1$ random variables independently distributed according to F, i.e., $G(x) = F(x)^{n-1}$. This is because, (i) with probability $G(p)$, no other bidder will increase the price after p, and $s - p$ time has passed since then, and (ii) for a given price $x > p$, with probability $G(x)$, the highest competing bidder has a value less than x and $s + x - 2p$ amount of time would pass if the price first drops from s to p and then increases to x. As bidders are utility maximizers, for each bidder value v, and given the starting price s, each bidder will choose the bid price $p(v,s)$ to solve:

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

It is easy to see that $p(v,s) < v$, since $p(v,s) \geq v$ clearly results in an expected utility of zero or less.

The auctioneer's expected utility when choosing the starting price s is given by:

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

where $h(v,x)$ is the joint density of the highest (denoted by v) and the second highest (denoted by x) of n random variables identically and independently distributed according to F.[11] This formulation follows because (i) if x is smaller than $p(v,s)$, then the selling price will be $p(v,s)$ and $s-p(v,s)$ time would pass until the auction ends, and (ii) if x is greater than $p(v,s)$, then the selling price will be x and $s+x-2p(v,s)$ time would pass until the auction ends.

In the Honolulu-Sydney auction, the auctioneer would choose the starting price s to maximize $EU_A^H(s)$.

Note that the equilibrium that we consider for the Honolulu-Sydney auction is efficient. This is because, (i) we assume that the bid functions in the Dutch stage are weakly increasing in values, and (ii) in the English (ascending) stage, each bidders remains in the auction until the price reaches her value.[12] This gives us the following remark.

Remark 1. *In equilibrium, Honolulu-Sydney auction results in an efficient allocation, in that the item is allocated to the highest-value bidder.*

To get more insights into the equilibrium of the Honolulu-Sydney auction, in the Appendix we consider Example 1 with 2 bidders, $F(v) = v$, and $c_B(t) = c_A(t) = 1 - \frac{t}{2}$. We then solve for Bayesian Nash equilibrium of this example.

Our first result is the following:

Proposition 1. *In a Bayesian Nash equilibrium of the Honolulu-Sydney auction, we can observe all three price dynamics:(i) pure Dutch (descending only), (ii) pure English (ascending-only), and (iii) Dutch and then English (descending then ascending) auction price dynamics.*

[11] We have $h(v,x) = n(n-1)f(v)f(x)F(v)^{n-2}$.

[12] This implies that, in equilibrium, the first bidder to bid in the Dutch phase is the ultimate winner of the auction. However, other bidders have nothing to lose and have a potential gain (in case of the off-the-equilibrium behavior of other players) by remaining in the ascending stage of the auction until the price reaches their values.

Proof. *Consider Example 1. In this example, the starting price will be approximately 0.28. Let v_1 denote bidder 1's value, and v_2 denote bidder 2's value. If $v_1 \geq 0.9$ and $v_2 \geq 0.28$, then we will observe pure English auction dynamics. If $v_1 < 0.9$ and $v_2 < p(v_1, 0.28)$, then we will observe pure Dutch auction dynamics. If $v_1 < 0.9$ and $v_1 > v_2 > p(v_1, 0.28)$, then we will observe first-Dutch-then-English auction price dynamics.* ■

This result implies that all three observed price dynamics: price only going down, price only going up, and price going down, then up, are theoretically possible.

3.2. Dutch Auctions

To compare our predictions for the Honolulu-Sydney auction with its main competitor, we now turn to the analysis of the Dutch auction with impatient bidders.

The equilibrium analysis of the Dutch auction is more straightforward. We examine a standard Dutch auction where the price continuously declines from 1 until a bidder shows interest, i.e., bids on the item, at which point the object is awarded at that price. We concentrate on a symmetric equilibrium in which all bidders bid according to a strictly increasing and differentiable function $\beta(\cdot) \to [0, 1]$. In this equilibrium, a bidder with a value of v bidding as though their value is v' will attain the expected utility of:

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

A necessary condition for β to be a symmetric equilibrium strategy is that the first-order derivative of the expression above with respect to v', evaluated at $v' = v$, must be zero. Consequently, we derive the following differential equation for β:

$$-\beta'(v)G(v)\left[c_B(1 - \beta(v)) + (v - \beta(v))c_B'(1 - \beta(v)\right] + (v - \beta(v))c_B(1 - \beta(v))g(v) = 0$$

The auctioneer's expected utility in the Dutch auction is given by

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

It is worth noting that the Dutch equilibrium we consider here is efficient, given that we assume bid functions are strictly increasing in values.

Remark 2. *In equilibrium, the Dutch auction results in an efficient allocation, in that the item is allocated to the highest-valued bidder.*

As it is analytically challenging to work with general time-adjustment functions, we consider linear time-adjustment functions in Online Appendix B. More specifically, we consider the case where for each bidder, the payoff shrinks linearly with time by a factor $c_B(t) = 1 - bt$. Likewise, the auctioneer's payoff shrinks linearly with time by the factor $c_A(t) = 1 - ct$. We use these linear time-adjustment functions to obtain our numerical results.

3.3. Comparison of the Two Auction Formats

With the ability to numerically solve for the equilibria for both Dutch and Honolulu-Sydney auctions in the case of linear time-adjustment functions, we can evaluate their performance based on various criteria, such as auction duration, the auctioneer's expected utility, and bidders' ex-ante expected utility in equilibrium.

First, let us examine an extreme scenario with patient bidders and an impatient auctioneer, $b = 0$ and $c > 0$. In this case, it is not difficult to see that the optimal starting price in the Honolulu-Sydney auction would be 0.[13] Consequently, the Honolulu-Sydney auction transforms into an English auction, and in both the Dutch and Honolulu-Sydney auctions, the behavior of the bidders becomes identical to that of the standard risk-neutral case. Under these circumstances, we can determine the exact conditions that make Honolulu-Sydney or Dutch auctions more favorable.

In this scenario, we have the following.

$$\begin{aligned} EU_A^H &= \int_0^1 x\left(1-cx\right)dG\left(x\right) \\ EU_A^D &= \int_0^1 \beta^N\left(x\right)\left(1-c\left(1-\beta^N\left(x\right)\right)\right)dF^n\left(x\right) \end{aligned}$$

where β^N represents the standard risk-neutral equilibrium bid function in Dutch auctions and is given by

$$\beta^N(x) = \frac{1}{G(x)}\int_0^x y dG(y)$$

Owing to the revenue equivalence result[14], we know that

$$\int_0^1 x dG\left(x\right) = \int_0^1 \beta^N\left(x\right)dF^n\left(x\right)$$

Let us denote this value (which is the expected selling price in the standard auctions with no time cost) by R.

Then, we can write

$$\begin{aligned} EU_A^H &= R - c\int_0^1 x^2 dG\left(x\right) \\ EU_A^D &= R - c\int_0^1 \beta^N\left(x\right)\left(1-\beta^N\left(x\right)\right)dF^n\left(x\right) \end{aligned}$$

Thus, we can state that:

$$EU_A^H > EU_A^D$$

[13]When bidders have no time costs, they will not bid at a positive price, since they have nothing to gain by it. Then, since the auctioneer has a strictly positive time cost, she will start the auction at the price of 0.

[14]The revenue equivalence holds for this case since bidders have no time costs.

if and only if

$$\int_0^1 x^2 dG(x) < \int_0^1 \beta^N(x)\left(1-\beta^N(x)\right) dF^n(x),$$

or:

$$\int_0^1 x^2 dG(x) + \int_0^1 \left(\beta^N(x)\right)^2 dF^n(x) < R = \int_0^1 x dG(x).$$

It becomes apparent that as the number of bidders, n, increases, the left side of the inequality will exceed the right side, as both terms on the left and the single term on the right approach 1. Therefore, with a larger number of bidders, the Dutch auction becomes more appealing to the auctioneer. We summarize these observations as follows:

Proposition 2. *When the bidders are patient, $b = 0$, and the auctioneer is impatient, $c > 0$, for any given value distribution, there exists n^* such that when the number of bidders is small enough, i.e., $n < n^*$, the auctioneer prefers the Honolulu-Sydney auction over the Dutch auction, and when $n \geq n^*$, the auctioneer prefers the Dutch auction over the Honolulu-Sydney auction.*

In fact, when F is uniform, some algebraic manipulation allows us to conclude that the Dutch auction yields a higher expected utility than the Honolulu-Sydney when there are at least three bidders.

Corollary 1. *When $b = 0$, $c > 0$, and values are uniformly distributed, the Dutch auction yields a higher expected utility than the Honolulu-Sydney auction if and only if $n \geq 3$.*

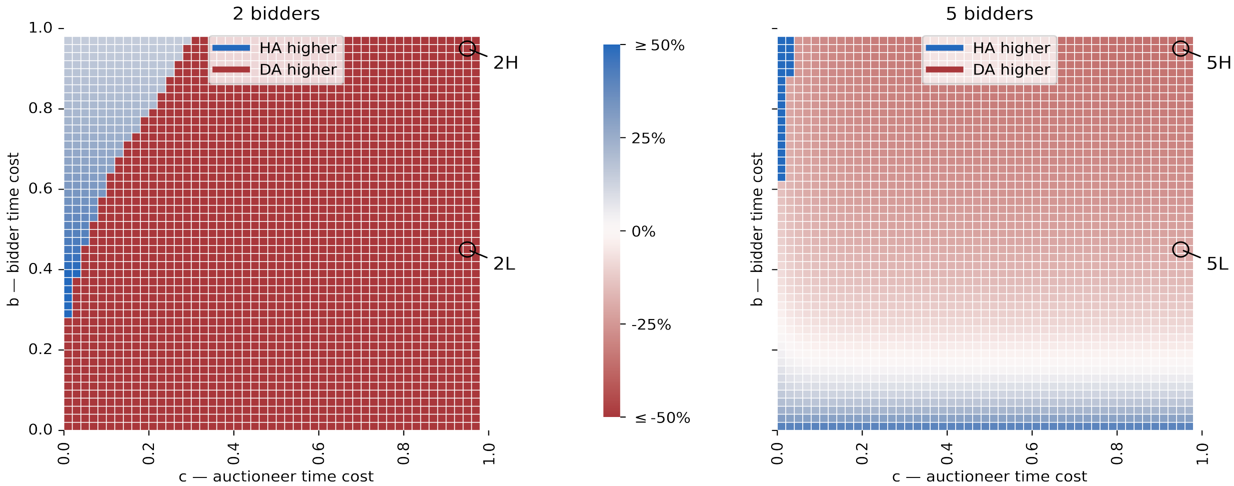
By the continuity of the auctioneer's utility function, this result extends to the case of impatient bidders when $b > 0$ is sufficiently low. Our numerical calculations presented below illustrate this point.

A key feature of the Honolulu-Sydney auction is that the auctioneer can select the starting price. When this starting price is set below the maximum possible value, it can shorten the auction duration by reducing the time required for the price to reach a level that triggers bidding. We refer to this as the "starting-price effect." In contrast, Dutch auctions typically begin at the highest possible price, which can lead to longer durations, especially when bidders are not interested in early prices. This distinction partially explains the speed advantage of the Honolulu-Sydney format to be demonstrated in the numerical and experimental results below, and mirrors practices at the Sydney Fish Market, where hybrid-format clocks for premium fish start near expected market prices, while Dutch clocks for lower-grade fish begin at a maximum.[15]

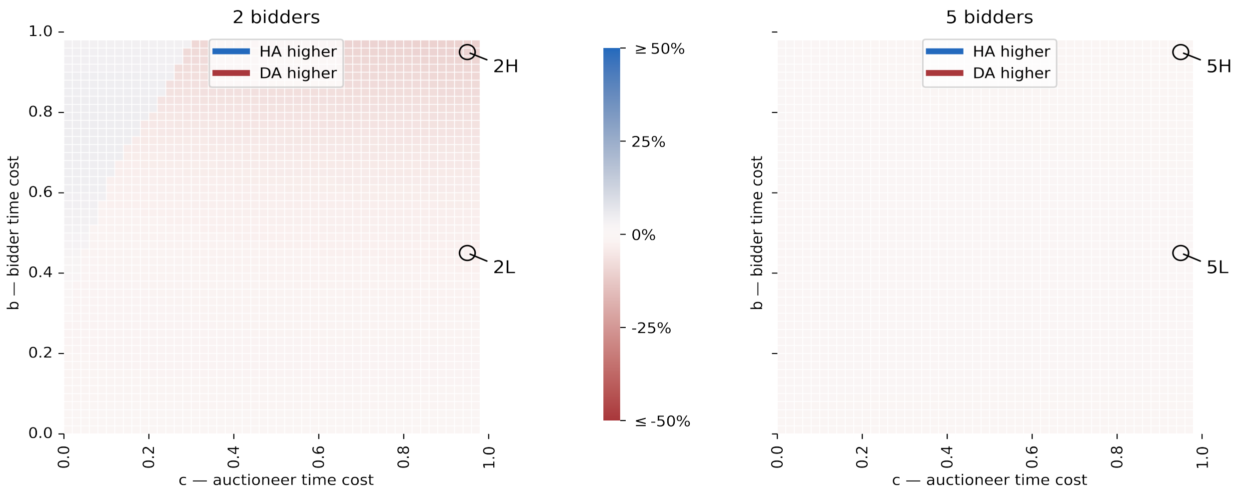
3.4. Numerical results

Our numerical algorithm enables us to compute the equilibrium bids, expected utilities, and expected selling prices and durations for both Dutch and Honolulu-Sydney auctions under a wide range of parameter specifications. In our calculations, we assume F to be uniform and allow for variations in the number of bidders (n), the bidders' time cost parameter (b),

[15]We thank an anonymous referee for prompting us to comment on this important point.



(a) Auction duration



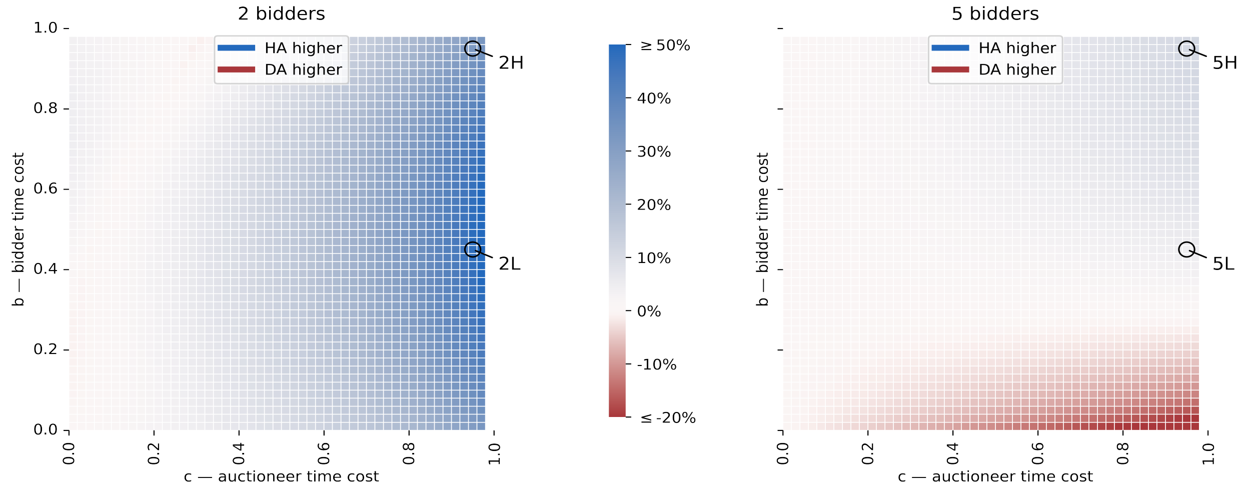
(b) Selling prices

Figure 1: Predicted duration and price differences: Honolulu-Sydney vs. Dutch auctions

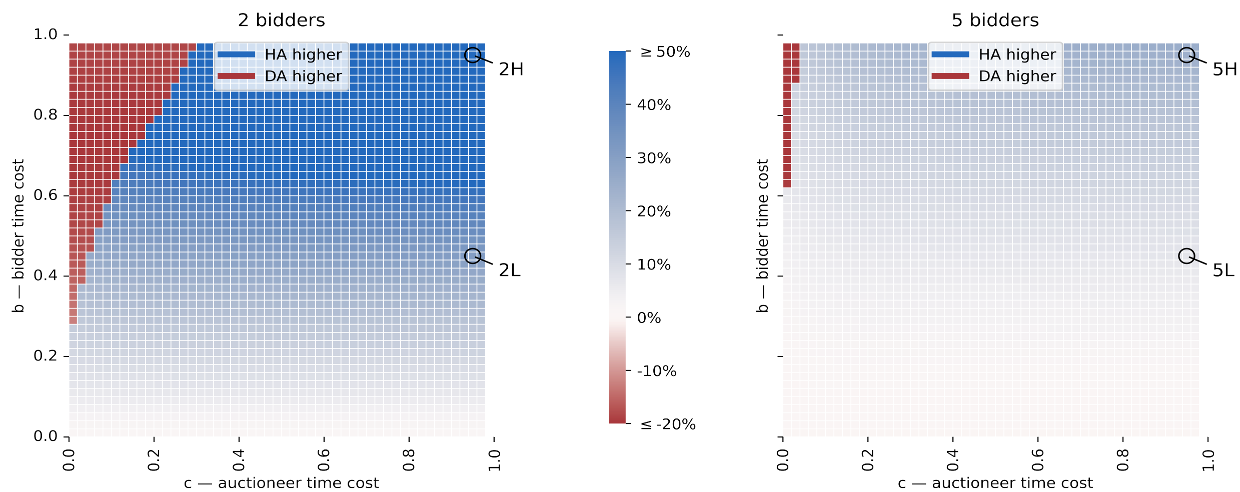
and the auctioneer's time cost parameter (c). The calculations confirm that, as observed in our extreme example, the Honolulu-Sydney auction's relative performance advantage (in terms of auctioneer utility) against the Dutch auction is less pronounced as the number of bidders grows. This observation aligns with real-world scenarios: Honolulu-Sydney auctions are employed for "premium seafood," which typically involves a smaller number of bidders compared to more conventional fish auctions, where Dutch auctions are commonly utilized.

The numerical estimations allow us to derive the following predictions regarding the relative performance of Dutch and Honolulu-Sydney auctions in terms of duration, selling price, and auctioneer and bidder utilities, depending on the number of bidders and the bidder and auctioneer's cost of time, as illustrated in Figures 1 – 2. The figures plot the differences in the corresponding metrics between the two auction formats relative to Dutch, $\frac{H-D}{D}$. [16]

[16] Online Appendix C and Figures C.2-C.5 therein provide more details.



(a) Utility for the auctioneer



(b) Utility for the bidder

Figure 2: Predicted utility differences: Honolulu-Sydney vs. Dutch auctions

Predictions (Relative performance of Honolulu-Sydney and Dutch auctions)**.** *Assume the distribution of bidder values is uniform, and the time-adjustment function is linear. Then, under a wide range of parameter values,*

1. *(Auction duration) 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.*
2. *(Selling prices) The difference in average selling prices between Honolulu-Sydney and Dutch auctions is small; it does not exceed 10 percent.*
3. *(Auctioneer utility) 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.*

4. *(Buyer utility) 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.*

3.5. Summary of Theoretical and Numerical Results

The table below summarizes our theoretical and numerical findings. It further refers to the corresponding findings from the laboratory experiment that we discuss next.

Table 1: Summary of results

Auction performance	Theory	Experiment
Price dynamics	Proposition 1	Result 1
Efficiency	Remark 1 (Honolulu-Sydney) Remark 2 (Dutch)	Result 2
Duration	Prediction 1	Result 3
Selling prices	Prediction 2	Result 4
Auctioneer utility	Proposition 2 Prediction 3	Result 5
Bidder utility	Prediction 4	Result 6

4. Experiment Objectives and Design

The experiment is designed to evaluate and compare the performance of Honolulu-Sydney (referred to as "Honolulu" hereafter for brevity) and Dutch auctions in view of the above theoretical analyses. Specifically, we address the following questions. First, do Honolulu auctions manifest the predicted price adjustment flexibility, with prices going up, or down, or down then up, depending on the demand, as predicted? Second, are they as efficient as Dutch auctions? Third, are Honolulu auctions considerably faster than Dutch if the number of bidders is small? Fourth, are the relative advantages of Honolulu auctions over Dutch in terms of speed, auctioneer utility, and bidder payoffs more pronounced when the number of bidders is small and bidder cost of time is high? Further, we explore how the differences in the experimental auction outcomes from the theoretical predictions, if any, can be explained by bidder behavior. Finally, we compare bidder feedback on the two auction institutions.

4.1. Auction Design

Values, Auction Duration and Payoffs. Our intent is to reproduce, in a laboratory setting, the auction institutions and environments similar to those in the existing fish markets, with speedy sales and noticeable costs of delay for participants.

All experimental participants are assigned the roles of bidders; the auctioneer role is carried out by computer. At the beginning of an auction period, each participant is randomly assigned a private item value drawn from the uniform integer distribution on $[0, 50]$ experimental points and is randomly matched with $n-1$ other participants to compete for a unit of a fictitious good (where n is the total number of bidders and takes the value of 2 and 5 in our experiments).

The participants are explicitly instructed that their earnings from the purchase will depend on the difference between their value for the good and the price they pay, and on how long the auction lasts; see experimental instructions included in the Experimental Materials.

The payoff of a bidder with value v who makes a purchase at price p after t units of time is calculated as:

$$U_B = (v - p)\, c_B(t), \tag{1}$$

where the "time-adjustment factor" $c(t)$, as it is referred to in the experimental instructions, depends on the common to all bidders time cost parameter b:[17]

$$c_B(t) = \begin{cases} (1 - bt) & \text{if } v \geq p; \\ (1 + bt) & \text{if } v < p. \end{cases} \tag{2}$$

For both Dutch and Honolulu auctions, a virtual clock is used to determine the auction duration. The virtual clock ticks every second. For each tick of the virtual clock, the price changes (decreases or increases, depending on the auction format and its stage) by one point,[18] and the available buyer payoff shrinks according to the time-adjustment factor $c_B(t)$. At each point when the auction is open, each participant is given real-time information on the current price of the item, the auction time elapsed, and their unadjusted $(v - p)$ and time-adjusted $(v - p) \cdot c_B(t)$ payoffs if they were to buy the item at this price and time. Examples of a participant auction screen are given in the Experimental Materials. The bidder who buys the item in the auction receives their time-adjusted payoff at the time and price of sale; all other bidders receive zero payoffs in this auction.

The auctioneer payoff from a sale at price p and time t, used to assess the auction performance, is calculated as

$$U_A = p \cdot c_A(t),$$

where $c_A(t) = (1 - ct)$, and c is the auctioneer's cost of time parameter.

Auction institutions. The Dutch auction is implemented in the standard way: the auction opens at the price of 50, and the price decreases by one point with every tick of the virtual clock. The first subject to click the "Bid" button buys the item and receives a payoff equal to her displayed adjusted payoff at the time of her bid.

Under the Honolulu format, the auction opens at the auctioneer's optimal starting price set by the experimenter. Then either a bidder bids at the opening price, or the Dutch stage

[17] Consistent with the model in Section 3, buyer positive payoffs (earnings) shrink in proportion of auction duration; yet the negative payoffs (losses) increase in proportion to auction duration. We replaced the time-adjustment function $(1 - bt)$ by $(1 + bt)$ for the negative payoff range to avoid undesirable effects of bidder losses possibly shrinking with longer auction duration if a bidder stays active in the ascending stage of the auction when the price surpasses their value. Since such behavior never occurs in equilibrium, the model predictions are not affected by this modification.

[18] Therefore, the price changes by 2% of the maximum item value every second, which is a fairly fast clock according to Katok and Kwasnica (2008). Their fast, medium and slow clocks are equivalent to 5%, 0.5% and 0.17% change per second, respectively.

begins with the price decreasing by one point with every tick of the virtual clock until a bidder bids, becoming a "provisional buyer." Other bidders are then given 10 seconds to challenge this buyer by indicating their willingness to continue bidding. During this "Contest" stage, the virtual clock is stopped, and the price and time do not change. If no one challenges, then the auction ends and the provisional buyer is assigned the object at the price and time of their bid. If anyone challengers by clicking "Bid," the auction proceeds into the ascending price (English) stage, with the virtual clock ticking and the price rising by one point every second, until all but one bidder leave the auction. The remaining bidder is assigned the item at the last dropout price and time, and receives their corresponding time-adjusted payoff, while all others receive zero.

We compare the performance of Dutch and Honolulu auctions using a within-subject design, with a sequence of auctions under one institution followed by a sequence of auctions under the other institution. The sessions are conducted under either DH (Dutch-then-Honolulu), or HD (Honolulu-then-Dutch) sequence, and are counter-balanced for order.

Treatments. To explore the effect of the number of bidders and the bidder cost of time on the auction performances, we implement a 2×2 between-subject design, with the number of bidders per auction $n \in \{2, 5\}$, and the bidder cost of time parameter $b \in \{H = 0.95, L = 0.45\}$, corresponding to the experimental buyer payoff shrinking by 1.9% and 0.9% with every tick of the virtual clock in the H (high cost) and L (low cost) environments, respectively. The auctioneer cost of time parameter is fixed at $c = 0.95$, corresponding to a 1.9% auctioneer payoff reduction per tick.[19] The combinations of parameter values n, b and c determine the optimal (for the auctioneer) starting prices s in Honolulu auctions, which are numerically estimated (see Section 3) and used in the corresponding treatments. The treatments are labeled $2H, 2L, 5H, 5L$, respectively, and summarized in Table 2.

Parameter values are chosen to provide a considerable variation in the relative performances of Honolulu and Dutch auctions across treatments. The time cost parameters are set high enough to have a noticeable effect on participant payoffs. We further accounted for the likely overbidding relative to the risk-neutral prediction in the Dutch auctions (Cox et al., 1982; Katok and Kwasnica, 2008) by choosing parameter values that would, in theory, favor Honolulu auctions over Dutch in all treatments, as we expected the Dutch auction to benefit the auctioneer more than predicted due to higher than predicted prices and shorter than predicted durations.[20] Figures 1 - 2 illustrate the theoretically predicted differences between the formats in expected auction durations, selling prices, and auctioneer and buyer payoffs under the four different treatments, with treatments parameter locations indicated by circles on each panel; see also Table 4 below. Consistent with Predictions 1– 4, Honolulu auctions are expected to be shorter than Dutch and more preferred by the auctioneer and

[19] Parameter values b and c are given for the unit value scale of the theoretical model of Section 3 and then rescaled to the experimental value range of $[0, 50]$.

[20] In calibrating the experimental parameters, we conducted four pilot sessions with 40 participants to inform the experimental design. The pilot sessions had the value range of $[0, 100]$, a slower clock of one price tick per 1.3 seconds, and lower cost of time parameters; these auctions proved to be extremely slow and did not reflect the fast nature of the auctions we seek to model. We also observed that the cost of time was negligible under the original design. Consequently, we re-scaled the value range to $[0, 50]$ interval, increased the clock speed to one price tick per second, and increased the cost of time parameters.

Table 2: Experimental design and session summary

Treatment	# of bidders	Bidder cost of time*	Starting price	# of auctions per institution	Sequence	# of sessions	# of participants
					Dutch-Honolulu	2	20
2H	2	0.019	21	18	Honolulu-Dutch	2	20
					Total	4	40
					Dutch-Honolulu	3	26
2L	2	0.009	12	18	Honolulu-Dutch	1	12
					Total	4	38
					Dutch-Honolulu	2	20
5H	5	0.019	32	25-28**	Honolulu-Dutch	2	25
					Total	4	45
					Dutch-Honolulu	2	20
5L	5	0.009	27	28	Honolulu-Dutch	1	15
					Total	3	35
All treatments						15	158

* Bidder cost of time parameters b and the starting prices are re-scaled for the experimental value and price range of $[0, 50]$.
** One 5H session had only 18 auctions per institution.

the bidders under all treatments, but the advantages of Honolulu over Dutch in terms of duration and auctioneer utility are predicted to become less pronounced in five-bidder auctions than in two-bidder auctions.

4.2. Experimental procedures

The auction experiment is programmed using oTree (Chen et al., 2016), with student participants recruited using ORSEE recruitment system (Greiner, 2015). Eight to 12 participants are recruited for each two-bidder auction session, and 10 to 15 participants for each five-bidder auction session. Before proceeding with the auctions, the experimenter reads aloud the experimental instructions and answers any questions, while the participants follow the instructions and complete tests for understanding on the computer screen. Each session includes two practice and 18-28 paid Honolulu auction rounds followed by an identical number of Dutch auction rounds (HD sequence) or vice versa (DH sequence). The session participants are randomly re-matched into groups of two (in 2-bidder treatments) or five (in 5-bidder treatments) for each round. Each auction institution is followed by a brief questionnaire soliciting participant feedback on the institution and participant affective states.[21] At the conclusion of a session, the participants are paid in private their cumulative earnings from the auctions, plus a show-up fee. The total duration of each session is between one and a half and two hours, including instructions.

We conducted a total of 15 independent sessions, with 158 unique student participants at the experimental laboratories of the University of Hawaii and the University of Technology Sydney, with 3-4 sessions per treatment. The sessions are summarized in Table 2. The average payments (including the participation fees of $5 USD or $10 AUD) were $28.95 USD and $52.57 AUD, respectively. Experimental instructions, screenshots and the post-auction

[21] Qualitative questions measuring regret and affective states are based on Camille et al. (2004). Each experimental session also included short pre- and post-auction surveys that assessed participants cognitive ability, risk, time and competitiveness preferences, and basic demographics. See Cacho (2024) for details.

survey are included in the Experimental Materials supplement.

5. Experimental Results

5.1. Auction performance

Price dynamics. As predicted, we observe all three price dynamics under Honolulu auctions in the experiment: descending price only (Dutch), ascending price only (English), and descending followed by ascending prices (Dutch-then-English) (Table 3).

Table 3: Price dynamics in Honolulu auctions

		Dutch then English		Dutch only		English only*	
Treatment	Statistics	Predicted	Actual	Predicted	Actual	Predicted	Actual
2H	Count	137	222	156	113	67	25
	Percentage	38.1%	61.7%	43.3%	31.4%	18.6%	6.9%
2L	Count	163	250	65	77	114	15
	Percentage	47.7%	73.1%	19.0%	22.5%	33.3%	4.4%
5H	Count	94	135	41	27	75	48
	Percentage	44.8%	64.3%	19.5%	12.9%	35.7%	22.9%
5L	Count	35	115	35	25	126	56
	Percentage	17.9%	58.7%	17.9%	12.8%	64.3%	28.6%

* To account for possible participant delays in executing their bids, bids within two points (two price ticks) from the starting price are considered as immediate bids, with the corresponding auction dynamics classified as English (ascending price) only.

Yet the Dutch-then-English price dynamics are significantly more frequent, and the English-only dynamics are less frequent than predicted under all treatments, as supported by the Wilcoxon signed-rank tests comparing the actual percentage of these price dynamics to predicted ($p < 0.01$ and $p < 0.05$ for 2-bidder and 5-bidder auctions respectively, and $p < 0.01$ for all treatments pooled; see Table E.1 in Online Appendix E.) This suggests that the participants often allowed prices to drop before bidding even if they would be better off bidding at the opening price. We explore this behavioral pattern in more detail in Section 5.2 below.

Result 1. *As predicted, experimental Honolulu auctions are characterized by price adjustment flexibility, displaying all three price dynamics: descending only (Dutch), ascending only (English) and descending-then-ascending (Dutch-then-English). Compared to the theoretical predictions, the Dutch-then-English pattern is significantly more frequent, while the English-only pattern is less frequent.*

We next compare the main performance characteristics of Honolulu and Dutch auctions by treatment, as summarized in Table 4 and Figures 3 and 4. Results of hypotheses testing on the comparative performances of the two institutions, benchmarked against the theoretical predictions as given in Remarks 1, 2 and Predictions 1– 4, are summarized in Table 5. All test results reported in Table 5 and in the remainder of the paper rely on session-clustered bootstrap estimations, unless noted otherwise. The estimation details can be found in Online Appendix D.[22]

Table 4: Predicted and actual auction characteristics by treatment

	2H		2L		5H		5L	
	Predicted	Actual	Predicted	Actual	Predicted	Actual	Predicted	Actual
Value efficiency								
Dutch	100%	94.8%	100%	95.4%	100%	98.6%	100%	95.5%
Honolulu	100%	96.7%	100%	96.8%	100%	98.4%	100%	98.5%
Auction duration								
Dutch	28.4	29.9	32.1	29.5	15.7	14.3	16.4	13.0
Honolulu	12.5	20.6	14.2	19.6	10.3	18.4	9.0	15.5
H/D, %	44.0%	68.9%	44.2%	66.4%	65.6%	128.7%	54.9%	119.2%
Selling price								
Dutch	21.6	20.6	17.9	21.1	34.3	36.3	33.6	37.6
Honolulu	19.8	17.0	18.1	15.6	33.9	33.4	33.3	32.2
H/D, %	91.7%	82.5%	101.1%	73.9%	98.8%	92.0%	99.1%	85.6%
Auctioneer payoff								
Dutch	11.0	10.8	7.9	11.0	24.9	27.3	23.8	29.3
Honolulu	14.8	9.7	11.9	7.9	27.3	21.7	27.1	22.0
H/D, %	134.5%	90.0%	150.6%	71.8%	109.6%	79.5%	113.9%	75.1%
Buyer payoff								
Dutch	5.9	4.5	11.1	8.1	5.1	3.3	6.7	1.5
Honolulu	11.7	9.7	14.0	14.2	6.1	4.3	8.1	7.8
H/D, %	198.3%	215.6%	126.1%	175.3%	119.6%	130.3%	120.9%	520.0%

Predictions are based on bidder values drawn. Actual values displayed are averages. Value efficiency is in percent, auction duration is in seconds, and prices and auctioneer and buyer payoffs are in experimental points. Buyer payoff is conditional on buying. Bidder ex-ante utility can be obtained by dividing buyer utility by the number of bidders.

Value efficiency. Value efficiency[23] is 95% or higher in all treatments under both auction formats. However, Honolulu auctions have about 1.5 percent higher efficiency than Dutch overall ($p < 0.001$ for the pooled data), and higher efficiency in three out of four treatments ($p < 0.1$, one-sided); see Figure 3 and Table 5. This higher efficiency is likely due to the majority of Honolulu auctions ending with the English stage, which is known to have the highest efficiency among all common auction formats.

Result 2. *Efficiency is high under both auction formats and in all treatments, as predicted. Overall, Honolulu auctions are more efficient than Dutch.*

Auction duration. As is evident from Figure 4a and Table 4, Honolulu auctions are significantly faster than Dutch in 2-bidder case ($p < 0.001$); we observe approximately one-third

[22]We are grateful to an anonymous referee for noting that since the same subjects participate in both auction institutions consecutively, there may be a carryover in behavior from one auction to the next, potentially affecting auction outcomes. We find that these effects are not statistically significant overall, allowing us to pool the corresponding data for the analysis. See Online Appendix I for a detailed analysis of order effects.

[23]The value efficiency is defined in the usual way, as the percent of the buyer item value to the highest value in the market.

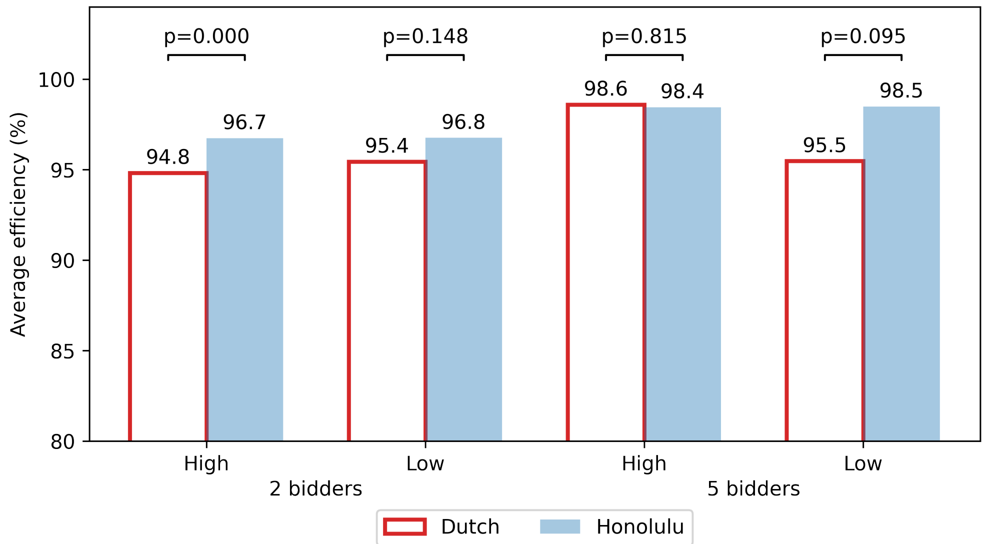


Figure 3: Auction efficiency by treatment

(32.1%) shorter duration in Honolulu auctions, although, on average, the difference is smaller than predicted. Yet, Honolulu auctions are no faster and actually slower than Dutch in 5-bidder treatments, while they are predicted to be 39% faster. This is explained by longer-than-predicted Honolulu auctions combined with somewhat shorter-than-predicted Dutch auctions. The comparative statics prediction is confirmed: the relative advantage of Honolulu auctions over Dutch decreases with the number of bidders, $H5/D5 > H2/D2$, for both high and low costs ($p < 0.01$, one-sided, in both cases; Table 5). Moreover, the observed auction durations are significantly shorter than those predicted under zero cost of time for all treatments and both auction formats (Figure F.1 in Online Appendix F).

Result 3. *Honolulu auctions are significantly faster than Dutch with two bidders. Yet Honolulu auctions take longer than predicted and are no faster than Dutch in five-bidder auctions. As predicted, the relative advantage of Honolulu auctions over Dutch, in terms of duration, decreases with the number of bidders.*

Selling prices. From Figure 4b and Table 4, Dutch auctions have higher than predicted ($p < 0.01$) selling prices in all treatments other than 2H. This is not surprising as overbidding is commonly observed in Dutch auctions (Cox et al., 1982; Katok and Kwasnica, 2008). For Honolulu auctions, selling prices are lower than predicted ($p < 0.001$) with 2 bidders, and they are still lower (in 5L) or not significantly different from predicted (in 5H) with 5 bidders (Figure 4b). The relative price differences between Honolulu and Dutch auctions significantly exceed the predicted by Proposition 2 ten percent for 2-bidder auctions ($p < 0.01$), but is not significantly different from ten percent for 5-bidder auctions ($p > 0.05$); see Table 5.[24]

[24] We further tested the hypotheses on the relative prices in Honolulu and Dutch auctions based on the bidder values drawn, as listed in Table 4. The percentage price differences between Honolulu and Dutch auctions are significantly different from those predicted in all treatments; see Table D.3 in Online Appendix D.

Table 5: Hypotheses tests of theoretical predictions

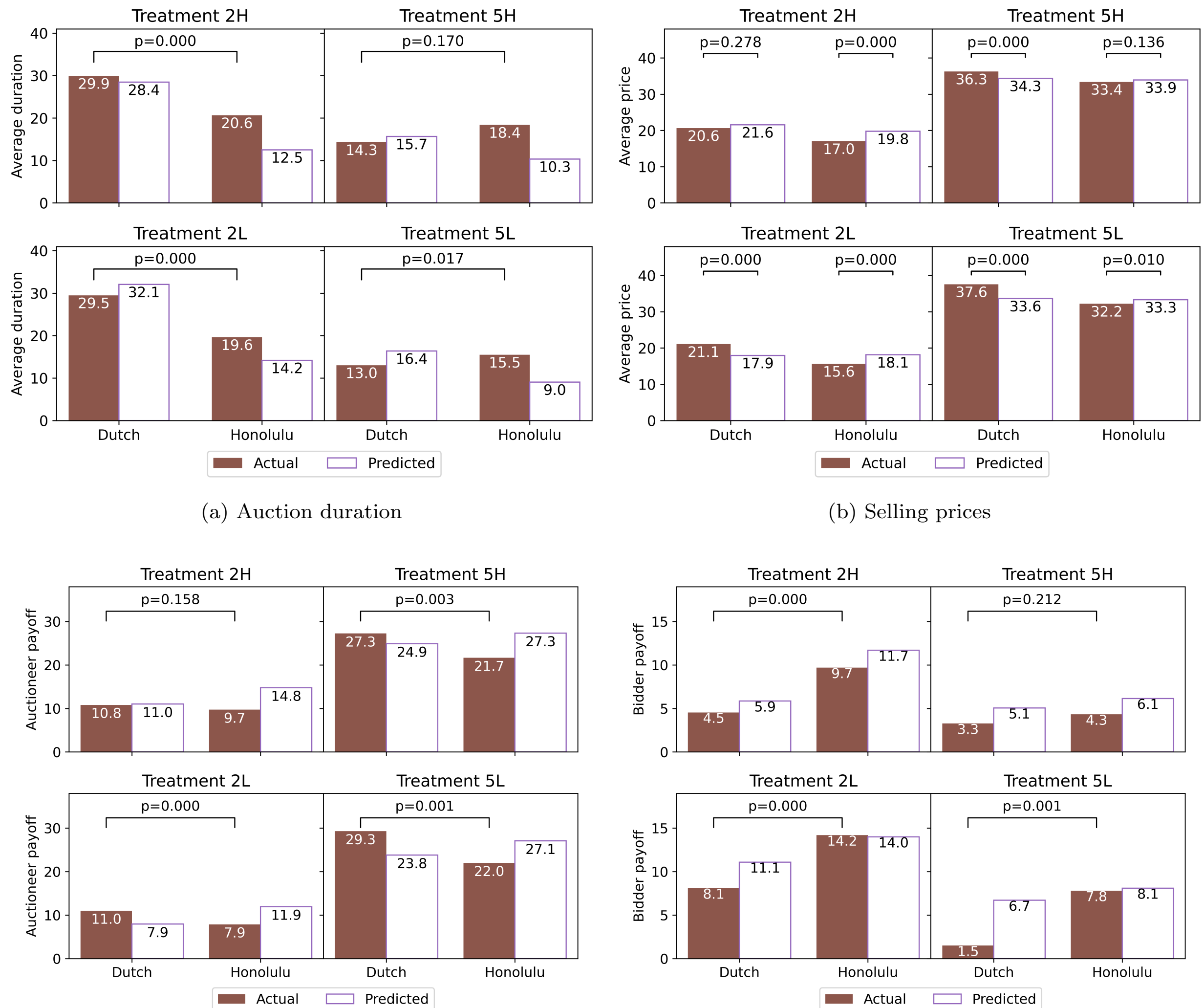
Characteristic	Prediction-based hypotheses*	bidders/ cost	Observed coeff.	Bootstr. std. err.	p-value	Prediction supported?
Efficiency	$H = D$	pooled	1.54	.45	0.000	no
	$H^h = D^h$	2 bidders	1.92	.48	0.000	no
	$H^l = D^l$	2 bidders	1.32	.91	0.148	yes
	$H^h = D^h$	5 bidders	-.15	.64	0.815	yes
	$H^l = D^l$	5 bidders	3.02	1.81	0.095	no
Duration	$D^2 > H^2$	high cost	9.26	1.70	0.000	yes
	$D^2 > H^2$	low cost	9.85	.93	0.000	yes
	$D^5 > H^5$	high cost	-4.08	2.90	0.921	no
	$D^5 > H^5$	low cost	-2.50	1.05	0.991	no
	$H^5/D^5 > H^2/D^2$	high cost	.60	.22	0.004	yes
	$H^5/D^5 > H^2/D^2$	low cost	.53	.13	0.000	yes
Selling price	$H^2/D^2 > 0.9$	high cost	-.075	.024	0.001	no
	$H^2/D^2 > 0.9$	low cost	-.159	.041	0.000	no
	$H^5/D^5 > 0.9$	high cost	.020	.007	0.998	yes
	$H^5/D^5 > 0.9$	low cost	-.043	.044	0.163	yes
Auctioneer utility	$H^2 > D^2$	high cost	-1.09	.77	0.921	no
	$H^2 > D^2$	low cost	-3.14	.55	1.000	no
	$H^5 > D^5$	high cost	-5.60	1.85	0.997	no
	$H^5 > D^5$	low cost	-7.30	2.205	0.999	no
Buyer utility	$H^2 > D^2$	high cost	5.15	.77	0.000	yes
	$H^2 > D^2$	low cost	6.10	.68	0.000	yes
	$H^5 > D^5$	high cost	1.05	.84	0.106	no
	$H^5 > D^5$	low cost	6.30	1.90	0.001	yes
	$H^h/D^h > H^l/D^l$	2 bidders	.379	.326	0.123	no
	$H^2/D^2 > H^5/D^5$	high cost	.81	.41	0.025	yes
	$H^2/D^2 > H^5/D^5$	low cost	-3.44	19.31	0.571	no

* H – Honolulu, D Dutch; h – high-cost, l – low-cost; 2 – 2-bidders, 5 – 5-bidders. Hypotheses for efficiency are based on Remarks 1- 2; for duration, selling prices, auctioneer and buyer utilities – on Predictions 1 – 4. Observed coefficients are for the difference between the LHS and the RHS expressions in the corresponding hypothesis; see Online Appendix D for the estimation details.

Result 4. *Honolulu auctions have significantly lower prices than Dutch, with the price gap significantly larger than predicted in two-bidder auctions, but within the predicted range in five-bidder auctions.*

Although the prices have a direct effect on the auctioneer's and bidders' utility, the standard revenue comparison is largely irrelevant because of the time costs. Auctioneer utility comparison is more relevant as it incorporates both revenue and time cost considerations.

Auctioneer payoffs. As illustrated in Figure 4c and Table 4, the auctioneer utility is not significantly different between Honolulu and Dutch auctions in 2H treatment ($p = 0.158$, two-sided). In other treatments, Dutch auctions benefit the auctioneer significantly more than Honolulu auctions, even when the opposite is predicted ($p > 0.9$ for the prediction-based hypothesis of $H > D$ for all treatments, Table 5). This is explained by auctioneer



(a) Auction duration

(b) Selling prices

(c) Auctioneer payoffs

(d) Bidder payoffs

Figure 4: Auction performance by treatment

benefiting less than predicted from Honolulu auctions, while benefiting more than predicted from Dutch auctions. The shortfall of auctioneer utility in Honolulu auctions as compared to the predictions appears greater with two bidders, likely due to lower than predicted prices, as well as longer than predicted duration (Table 4); whereas the excess of auctioneer utility over predictions in Dutch auctions is likely due to higher than predicted prices.

Result 5. *Auctioneer payoffs under Dutch and Honolulu are not significantly different in 2-bidder, high-cost treatment. In other treatments, Dutch auctions benefit the auctioneer more than Honolulu auctions, even when the opposite is predicted.*

Bidder payoffs. Figure 4d and Table 4 indicate that buyers are significantly better off or no worse off under Honolulu auctions than under Dutch in all but one treatment ($p = 0.106$ for 5H and $p < 0.01$ for all other treatments, for one-sided hypothesis $H > D$, Table 5). For 2-bidder auctions, buyer average payoff under Honolulu is twice as high as under Dutch in 2H treatment, and 75 percent higher in 2L treatment, exceeding the predicted differences.

The high cost of time leads to a significant reduction of buyer payoffs under both Dutch and Honolulu 2-bidder auctions; yet there is not enough evidence to conclude that Honolulu auctions become more beneficial relative to Dutch as the cost of time increases ($p = 0.123$ for the hypothesis $H^h/D^h > H^l/D^l$, Table 5). For 5-bidder auctions with high costs (5H treatment), the advantage of Honolulu relative to Dutch is significantly smaller than in 2-bidder 2H treatment, as predicted ($p = 0.025$); yet it is not smaller in 5L treatment compared to 2L ($p = 0.571$), likely due to significant over-bidding in the 5L Dutch auctions.

Result 6. *Bidders are significantly better off or no worse off in Honolulu auctions as compared to Dutch in all treatments. The benefit of Honolulu auctions compared to Dutch with 5 bidders persists more than predicted in some treatments.*

Overall, we obtain strong support for the theoretical predictions on the versatility of price dynamics and efficiency of Honolulu auctions (Proposition 1 and Remark 1), as well its speed advantages and higher buyer benefits relative to Dutch auctions (Predictions 1, 4). However, compared to the predictions regarding prices and auctioneer utilities (Predictions 2, 3), Honolulu auctions underperform relative to Dutch.[25] To summarize:

Conclusion. *As predicted, Honolulu auctions are highly efficient, and are considerably faster than Dutch auctions with a small number of bidders. While the auctioneer's benefits from Honolulu auctions relative to Dutch are lower than predicted, the bidders' relative benefits often exceed the predictions.*

5.2. Behavioral patterns

We now explore individual behavioral patterns that would explain the observed auction performances. Additional analyses of bidding behavior are included in the Online Appendix G. Figure 5 depicts individual bids in the Dutch auctions against bidder values, and Figures 6 and 7 graph individual bids by stage in Honolulu auctions, separated by treatment, with added regression lines of theoretically predicted and actual bids on values. To understand which behavioral patterns are associated with earning success, we distinguish the behavior of Top earners, whose payoffs relative to theory fall above the median in their treatment, with that of the Bottom earners, who earn below the median.[26]

First note that the individual behavior is overwhelmingly consistent with the presence of positive time costs under both institutions and under all treatments. In Dutch auctions, bidders overbid in all treatments, except for 2H, relative to the theoretical prediction that incorporates the time cost, as documented in Figure 8, left panel. These bidding data are closer to the prediction with time costs, as the absence of time costs is predicted to result in

[25] We are grateful to Anthony Kwasnica for the following suggestion. In addition to comparing Honolulu-Sydney and Dutch auctions from the auctioneer and the bidder separate standpoints, one could assess the aggregate social welfare, defined as the sum of the auctioneer and bidder utilities. We analyze the social welfare in Online Appendix C.6. Honolulu-Sydney auctions are predicted to outperform the Dutch along the social welfare metric, and more so in auctions with fewer bidders. Indeed, the social welfare is significantly higher in our Honolulu-Sydney experimental auctions with two bidders, although it falls short of the Dutch auctions social welfare with five bidders.

[26] See Online Appendix G for the payoff measure used to distinguish Top and Bottom earners.

even lower bids. On average, bidders bid 2.52 points above the prediction that incorporates the time costs, compared to 4.85 points above the no-cost prediction.[27]

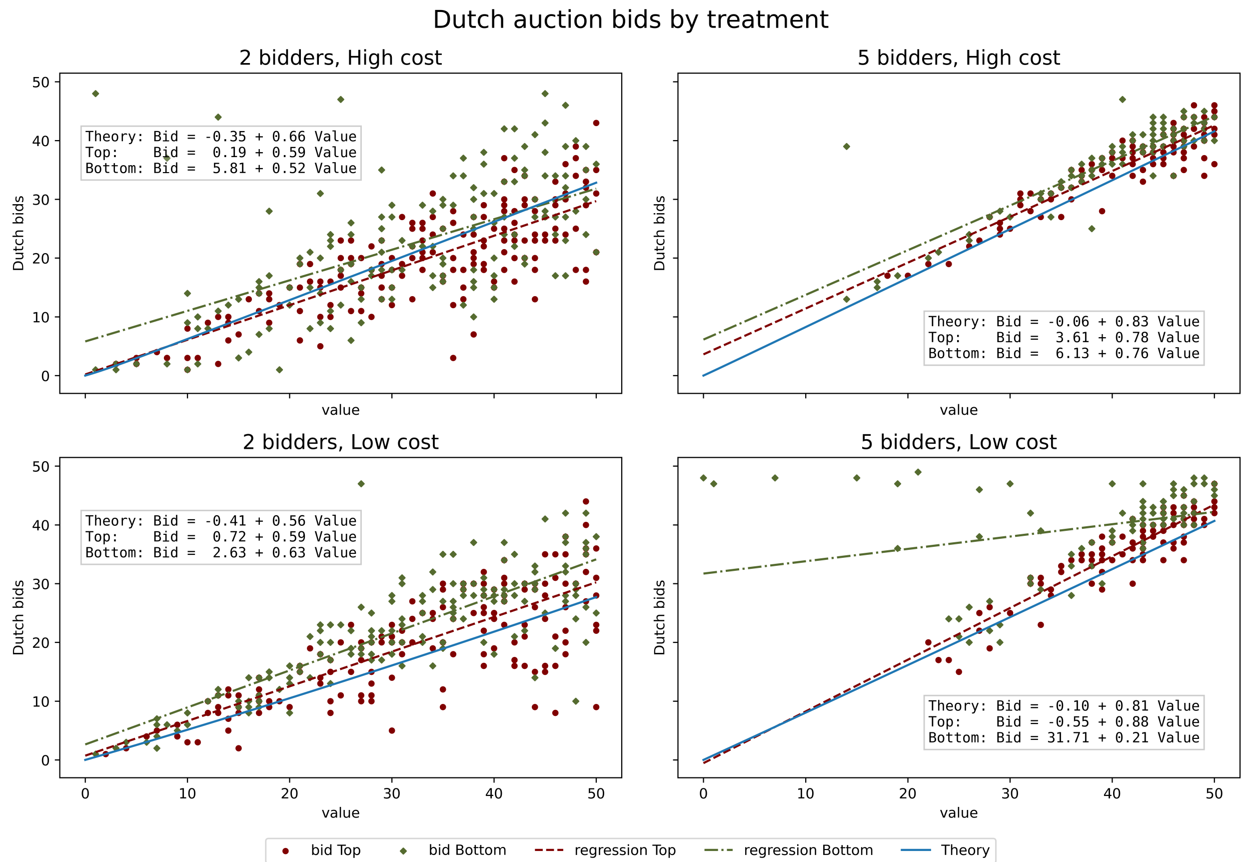


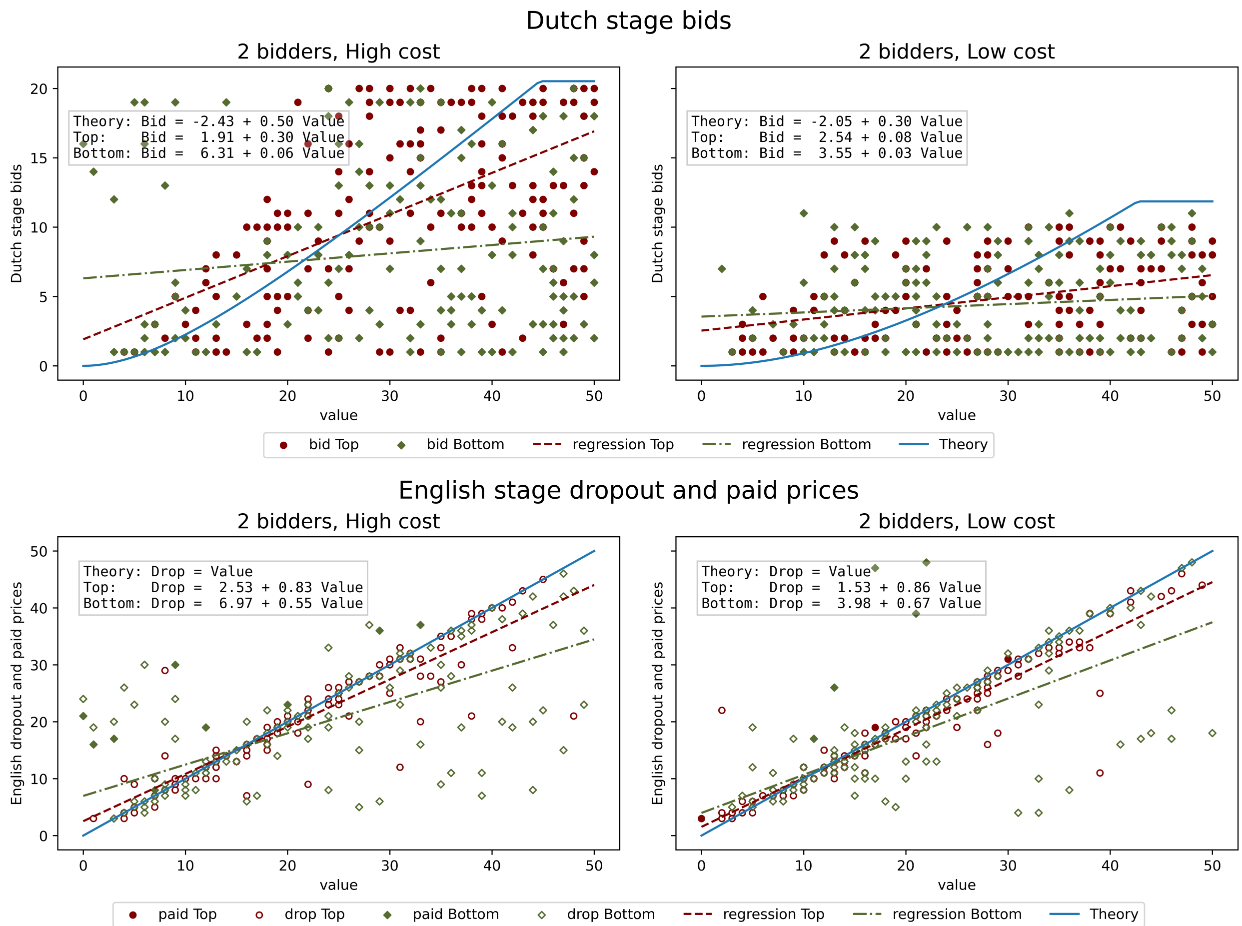
Figure 5: Dutch bids by value, by treatment

For Honolulu auctions, in the absence of time costs it is a weakly dominant strategy for bidders to allow the prices to drop to zero in the Dutch stage. Yet, the overwhelming majority of Dutch-stage bids (72% of bids in 2-bidder auctions and all bids in 5-bidder auctions) are at prices above zero; the share of near-zero (within two points of zero, to allow for bidding errors) bids not consistent with the equilibrium prediction is only 23.6% in 2-bidder auctions. Moreover, out of 96 Dutch- stage bids predicted to be near zero, more than half were at prices above zero. We conclude:[28]

Result 7. *The overwhelming majority of decisions in both Dutch and Honolulu auctions are consistent with the presence of time costs.*

[27] Katok and Kwasnica (2008) show that the well-documented phenomenon of overbidding in Dutch experimental auctions is more prominent in slower auctions, suggesting an intrinsic cost of time. Our data demonstrate that overbidding is consistent with the presence of induced time costs.

[28] Figure F.1 in Online Appendix F depicts actual auction durations alongside the predictions with and without time costs. It presents additional strong evidence in favor of positive time costs.



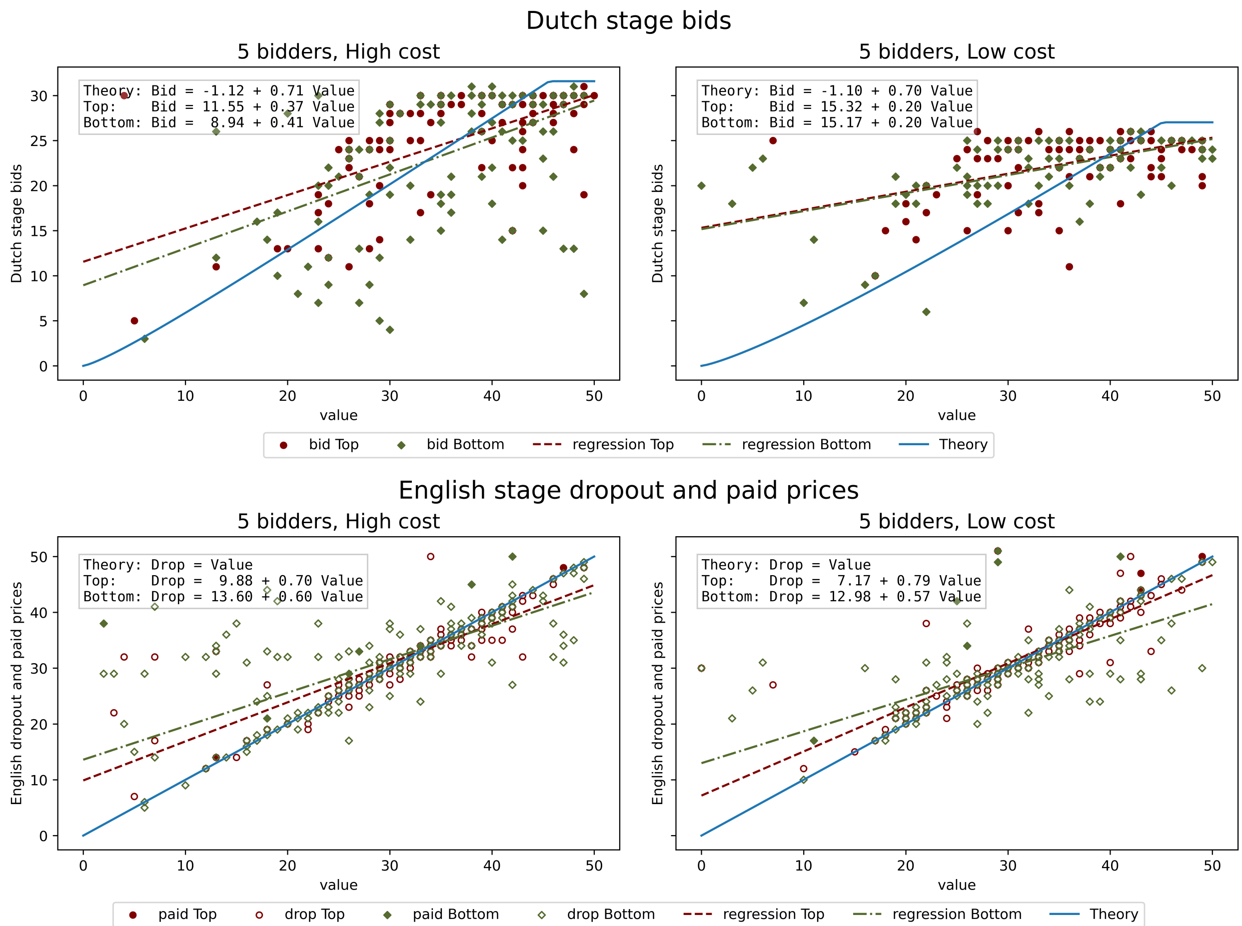
Note: For the English stage, the only paid prices displayed are those above value.

Figure 6: Honolulu auction bidding behavior by stage, 2 bidder treatments

Second, we look for the reasons of the observed under-performance of Honolulu-Sydney auctions relative to Dutch. Figure 8, right panel, documents that, in drastic contrast to Dutch auctions, submitted Dutch-stage bids in Honolulu auctions are, on average, at prices no higher or lower than predicted for both Top and Bottom earners in all treatments. Specifically high-value bidders bid at lower-than-predicted prices, resulting in the Dutch stage lasting, on average, over 4 price ticks longer than predicted in all treatments.[29] On the auction level, these Dutch-stage bidding delays are associated with a significant reduction of purchase prices; see Online Appendix G for details.

Further, Figures 6 and 7 document a sizable share of early dropouts at the English stage of Honolulu auctions. In fact, 22% of both Contest-stage and English-stage dropouts in 2-bidder auctions, and 4% Contest-stage and 10% of English-stage dropouts in 5-bidder auctions, were at prices below value (see also Table G.1 in Online Appendix G). A bidder dropping out below their value, thus "leaving money on the table", resulted in a lower than competitive auction price (a price strictly below this bidder's value) in all cases in 2-bidder

[29]See additional Dutch-stage bid estimation results in Table G.4 in Online Appendix G.



Note: For the English stage, the only paid prices displayed are those above value.

Figure 7: Honolulu auction bidding behavior by stage, 5 bidder treatments

auctions and in 61% of cases in 5-bidder auctions. We conclude:

Result 8. *The underperformance of Honolulu auctions relative to Dutch auctions from the auctioneer's perspective is attributable to two primary factors: first, the systematic overbidding observed in Dutch auctions; and second, the significant prevalence of bidding delays and early participant dropout in Honolulu auctions.*

We next consider whether the bidding patterns in Honolulu auctions are mostly consistent with competitive behavior, or whether there are indications of bidder attempts to suppress price competition and lower auction prices. Lower than competitive prices that benefit bidders may be supported as equilibria in a multi-period super game even with random rematching (Kandori, 1992).

To understand the likely motives behind bidding delays in Honolulu auctions, we link bidder actions at the Dutch stage with their decisions in later stages of Honolulu auctions. A Dutch-stage individual decision is considered a delay if a bidder does not bid at the predicted price, thus allowing the Dutch-stage price to drop lower. A Dutch-stage delay followed by an early below-value dropout in the Contest- or English-stage is consistent with non-competitive

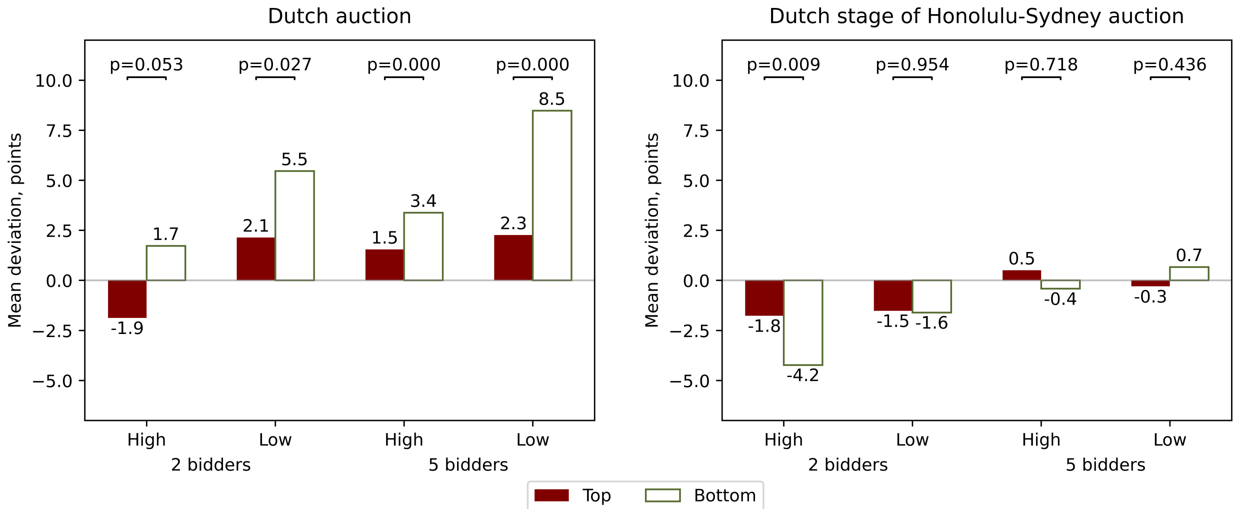


Figure 8: Bid deviations from theory in Dutch auctions and at the Dutch stage of Honolulu-Sydney auctions, for Top and Bottom earners

behavior, whereas a Dutch-stage delay followed by bidding until the price reaches one's value in the English stage is competitive and may be attributed to undervaluing time.[30] Finally, a Dutch-stage delay followed by a purchase below the predicted equilibrium price is consistent with both non-competitive behavior, and competitive behavior combined with under-valuing time.

Table 6 displays frequencies of various individual decision-outcome patterns in Honolulu auctions. Almost a half of individual decisions in 2-bidder auctions and almost three-quarters of decisions in 5-bidder auctions are consistent with the equilibrium behavior with no delays ("No Delay, Competitive Drop or Buy" category.)[31] 41% of individual Dutch-stage decisions with two bidders are classified as delays; about a half of these delays are followed by low-price drop or buy outcomes and are therefore consistent with non-competitive behavior, and the other half – by competitive decisions at the Contest- or English-stage. In comparison, only 18% of decisions with five bidders are classified as delays,[32] with three-quarters of these delays followed by competitive behaviors at later auction stages. The table provides further evidence of weaker competition in 2-bidder auctions compared to 5-bidder auctions, documenting an additional sizable share of low-price dropouts following no delays at the Dutch-stage. The difference in the frequencies of non-competitive actions between 2-bidder and 5-bidder auctions are highly significant (see Table G.5 in Online Appendix G). We conclude:

[30]Our estimate of the share of non-competitive behavior is therefore conservative, as some Dutch-stage delays followed by competitive bidding could indicate failed attempts to suppress price competition.

[31]Moreover, the modal behavior is consistent with equilibrium, i.e., it falls under either "No Delay, Competitive Drop or Buy" or "No Delay, Low Price Buy" categories, for three-quarters (73 percent) of bidders in 2-bidder auctions, and the overwhelming majority (96 percent) of bidders in 5-bidder auctions.

[32]The delays are much less frequent at the individual level than at the auction level, as the auction-level Dutch-stage outcomes are driven by the behavior of a subset of bidders who bid first.

Table 6: Decision-outcome patterns in Honolulu auctions

	2-bidder auctions		5-bidder auctions		All
Decision-outcome pattern, percent	2H	2L	5H	5L	
No Delay, Competitive Drop or Buy	47.78	46.35	72.48	73.78	62.46
No Delay, Low Price Buy	2.64	3.51	0.95	1.63	2.01
No Delay, Low Price Drop	5.00	6.73	2.86	3.88	4.37
No Delay, Overbid	3.75	2.34	4.76	3.37	3.67
Delay, Competitive Drop or Buy	17.92	24.12	14.00	13.47	16.69
Delay, Low Price Buy	17.36	12.13	2.57	2.45	7.54
Delay, Low Price Drop	5.56	4.82	2.38	1.43	3.26
Total	100.00	100.00	100.00	100.00	100.00

"Delay:" Dutch-stage non-bid at the predicted bid price; "Low Price:" below equilibrium prediction; "Competitive:" at or above equilibrium prediction; "Overbid:" bid above value. Bidding above value following Dutch-stage delays is extremely rare (7 out of 3434 observations) and is lumped with the "Competitive" category. Decisions within 2 points of the corresponding prediction are considered "at prediction."

Result 9. *Competitive bidding consistent with the theoretical predictions is the modal behavior in Honolulu auctions. Compared to 5-bidder auctions, 2-bidder auctions display a higher share of non-competitive behavior, manifested as low-price dropouts at the Contest- and English-stages often preceded by bidding delays at the Dutch stage. Up to a quarter of all decisions in Honolulu auctions are consistent with competitive behavior with undervaluing time.*

Finally, we observe that behavior closer to the competitive prediction is associated with higher earnings under both auction formats. Compared to Bottom earners, Top earners overbid less in the Dutch auctions (Figure 8, left panel). In Honolulu auctions, they are significantly less likely to delay their bids at the Dutch-stage, and both to drop out early and over-bid at the English-stage (Figures 6, 7 and Table G.5 in Online Appendix G).

Two interesting observations are due in relation to the apparent bidder attempts to lower prices through bidding delays and early dropouts in Honolulu auctions. First, these attempts do not pay off equally for all bidders; while Top earners earn, on average, above the prediction in Honolulu auctions, the Bottom earners earn below the prediction (Figure G.1 in Online Appendix G); overall, the bidders are no better off than they would have been under the predicted non-cooperative equilibrium behavior in any of the treatments (Table 4). Second, these deviations from the predicted behavior do not distort the allocative efficiency of Honolulu auctions (Result 2).

5.3. Participant feedback

To evaluate what mattered to participants in their bidding decisions, and to assess their post-auction affective states, we conducted short surveys soliciting participant feedback immediately following each auction institution.[33] Consistent with the observed behavior, participants reported that they cared more about buying fast in Dutch than in Honolulu auctions, and cared more about getting a lower price in Honolulu than in Dutch. Further, they

[33]See Cacho (2024) for an extended analysis of participants behavioral features.

reported experiencing significantly less winner and loser regret in Honolulu than in Dutch auctions (Figures 9- 10). Finally, participants felt about equally happy when they made a purchase in Honolulu and in Dutch, but felt significantly less unhappy when they did not buy in Honolulu as compared to Dutch; see Table J.1 in Online Appendix J. These responses suggest that, in addition to having a speed advantage over Dutch auctions when the number of bidders is small, Honolulu auctions reduce bidder regret and make the participants happier.

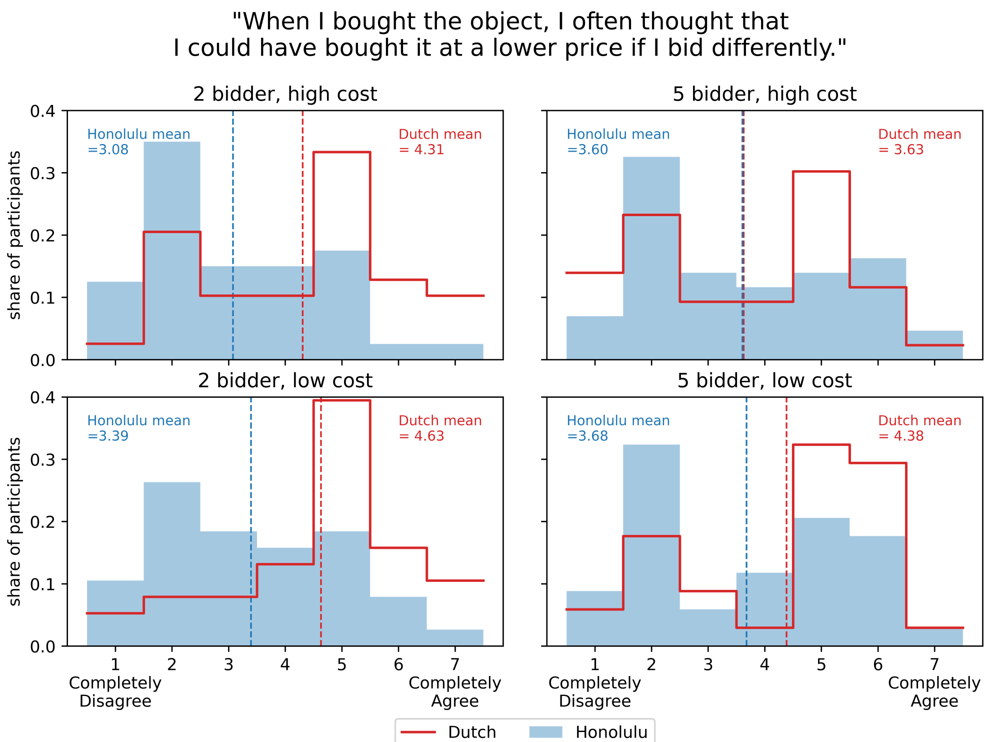


Figure 9: Post-auction questionnaire, Dutch vs Honolulu: Winner Regret

6. Conclusions

In this paper, we study a distinctive auction mechanism used in several fish markets around the world, including Honolulu and Sydney fish markets. This auction facilitates the rapid sale of premium quality fish—a necessity given the perishable nature of the goods in question. This hybrid auction format, blending the traits of both Dutch and English auctions, has shown its efficacy not only in real-world markets but also in our theoretical model and in the laboratory.

Our theoretical framework highlights the pivotal role of "time costs." Our results show that the Honolulu-Sydney auction format is more favorable for the auctioneer (as compared to the standard Dutch auction format) in scenarios where there is a limited number of bidders or when these bidders bear high time costs. This is substantiated by our experimental data, revealing that Honolulu-Sydney auctions conclude significantly faster than their Dutch

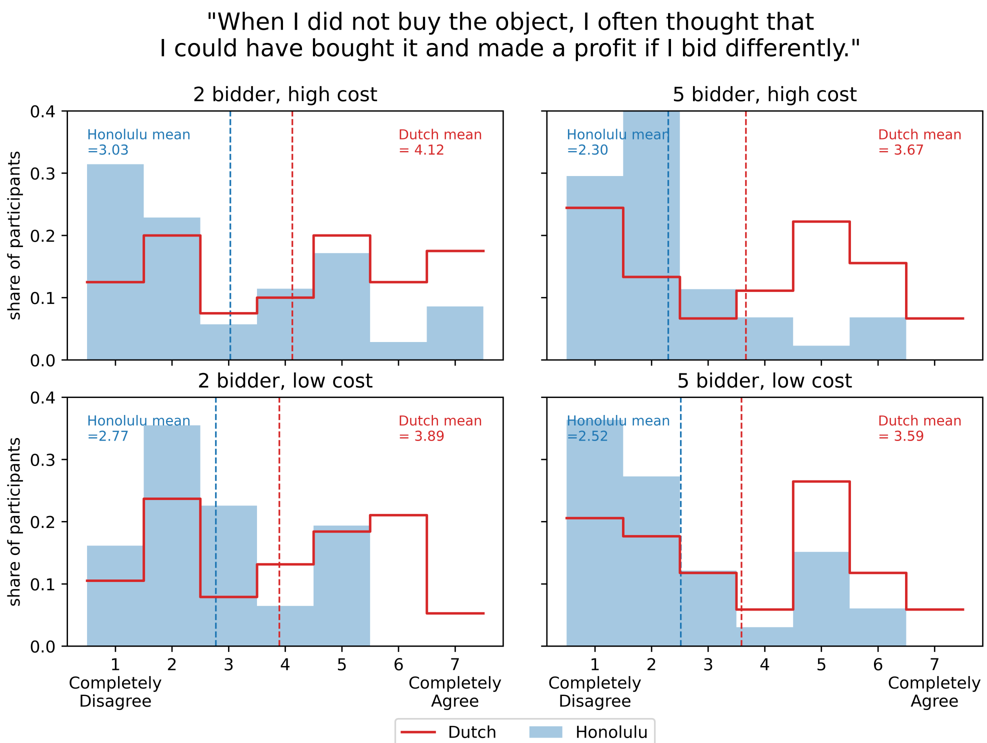


Figure 10: Post-auction questionnaire, Dutch vs Honolulu: Loser Regret

counterparts when there is a low number of bidders. The individual bidder behavior is overwhelmingly consistent with the presence of time costs.

In our experimental results, we observe overbidding in Dutch auctions, a trend advantageous for the auctioneer. On the other hand, the Honolulu-Sydney auctions consistently outperform the Dutch in terms of bidder payoffs, and appear to reduce the feeling of both winner and loser regret. This suggests that not only does the hybrid format expedite the auction process, but it also offers better outcomes for bidders.

An unanticipated albeit not surprising insight provided by our experiments is the evidence of bidder attempts to suppress price competition in Honolulu-Sydney auctions, especially when the number of bidders is small. Bidder collusion has been studied in the context of procurement auctions (Hendricks and Porter, 1989); school milk contracts (Pesendorfer, 2000), cattle (Phillips et al., 2003) and spectrum (Kwasnica and Sherstyuk, 2007) auctions, among others. Concerns about collusion in fish markets have also been raised (Graddy, 2006; Fluvia et al., 2012). Our laboratory experiment confirms that attempts to tacitly lower prices may be present in such markets, especially given that many buyers are professionals who participate in these auctions on a day-to-day basis.

In our laboratory experiment under the hybrid Honolulu-Sydney auction format, the apparent attempts to lower prices manifest themselves through delayed bidding at the descending-price stage, and dropping out of the auction early at the ascending-price stage; such attempts are especially noticeable in small two-bidder auctions. However, in our experiments, these departures from competitive bidding do not increase the overall welfare of the bidders. While bidders who frequently delay their bids and drop out of the competition early suffer from lower earnings, the benefits of their actions are acquired by those bidders who behave more competitively and bid closer to the equilibrium prediction, often collecting higher than predicted earnings. It is an open question whether professional repeat buyers in fish markets could be able to better tacitly coordinate on a bid rotation scheme and distribute the benefits among themselves more evenly.

We further obtain evidence that the hybrid Honolulu-Sydney auctions result in superior allocative efficiency compared to the Dutch auctions, in spite of the observed departures from equilibrium behavior.

In sum, the Honolulu-Sydney auction represents a creative solution for markets where time is of the essence and when the auctioneer also cares about bidder satisfaction in addition to her own payoff.

Appendix

We present the following example:

Example 1. *Consider 2 bidders, $F(v) = v$, and $c_B(t) = c_A(t) = 1 - \frac{t}{2}$.*

Below we solve for the optimal bids for an arbitrary starting price s for this simple setup. The utility of a bidder who has value v and bids at a price $p \in [0, s]$ is given by:

$$\begin{aligned} EU_B^H(p; v, s) &= p(v-p)\left(1 - \frac{s-p}{2}\right) + \int_p^v (v-x)\left(1 - \frac{s+x-2p}{2}\right) dx \\ &= \frac{1}{12}(v-p)\left(6p + 6v - 3ps + 5pv - 3sv + 2p^2 - v^2\right) \end{aligned}$$

We have

$$\frac{\partial}{\partial p} EU_B^H(p; v, s) = 6ps - 12p - 6pv - 6p^2 + 6v^2.$$

First, note that

$$\frac{\partial^2}{\partial p^2} EU_B^H(p; v, s) = 6s - 12 - 6v - 12p$$

which is negative for all p, s, and v. Hence, $EU_B^H(p; v, s)$ is a concave function of p and would be maximized (at an interior solution) when $\frac{\partial}{\partial p} EU_B^H(p; v, s) = 0$.

By solving the first-order condition $\frac{\partial}{\partial p} EU_B^H(p; v, s) = 0$, we get the unique candidate for the maximizer as

$$\frac{1}{2}\left(\sqrt{s^2 - 2sv - 4s + 5v^2 + 4v + 4} - v + s - 2\right)$$

Note that this function is increasing with s and v. Moreover,

$$p(v, s) \leq s$$

if and only if

$$s \leq \frac{v^2}{v+2}.$$

The highest value $\frac{v^2}{v+2}$ can take is $\frac{1}{3}$. Therefore, when $s \geq \frac{1}{3}$, there is always an interior solution. On the other hand, when $s \leq \frac{1}{3}$, we may have $p(v, s) > s$ for $v > \frac{1}{2}s + \frac{1}{2}\sqrt{s(s+8)}$.

Hence, in general, we have

$$p(v,s) = \min\{s, \frac{1}{2}\left(\sqrt{s^2 - 2sv - 4s + 5v^2 + 4v + 4} - v + s - 2\right)\}. \tag{3}$$

Now, let us calculate the expected utility of the auctioneer with arbitrary s:

$$\begin{aligned} EU_A^H(s) = 2\int_0^1 \Bigg(& \int_0^{p(v,s)} p(v,s)\left(1 - \frac{s - p(v,s)}{2}\right) dx \\ & + \int_{p(v,s)}^{v} x\left(1 - \frac{s + x - 2p(v,s)}{2}\right) dx \Bigg) dv \end{aligned}$$

where $p(v,s)$ is given by Equation 3. Suppressing the dependence of p on v and s and with a little algebra, we can write

$$\begin{aligned} EU_A^H(s) &= 2\int_0^1 \left(p^2\left(1 - \frac{s-p}{2}\right) + \frac{(v-p)}{12}\left(6p + 6v - 3ps + 4pv - 3sv + 4p^2 - 2v^2\right)\right) dv \\ &= 2\int_0^1 \left(\frac{1}{2}pv^2 - \frac{1}{4}p^2 s - \frac{1}{4}sv^2 + \frac{1}{2}p^2 + \frac{1}{6}p^3 + \frac{1}{2}v^2 - \frac{1}{6}v^3\right) dv \end{aligned}$$

Although an analytical solution is difficult to obtain due to the specification of $p(v,s)$, we can numerically calculate the optimal starting price as $s \approx 0.28$.

CRediT authorship contribution statement

Isa Hafalir: Conceptualization, Methodology, Formal analysis, Writing – original draft, Writing – review & editing. **Onur Kesten:** Conceptualization, Methodology, Formal analysis, Writing – original draft, Writing – review & editing. **Katerina Sherstyuk:** Conceptualization, Methodology, Validation, Formal analysis, Investigation, Data curation, Writing – original draft, Writing – review & editing. **Cong Tao:** Software, Validation, Formal analysis, Investigation, Data curation, Writing – review & editing.

Declaration of competing interest

The authors have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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Supplementary material

Online appendix for additional analyses related to this article can be found at here.
Experimental materials related to this article can be found at here.

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