Time is Money:

The effect of clock speed on seller's revenue in Dutch auctions

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This study examines the role of timing in auctions under the premise that time is a valuable resource. When one object is for sale, Dutch and first-price sealed bid auctions are strategically equivalent in standard models, and therefore, they should yield the same revenue for the auctioneer. We study Dutch and first-price sealed bid auctions in the laboratory, with a specific emphasis on the speed of the clock in the Dutch auction. At fast clock speeds revenue in the Dutch auction is significantly lower than the sealed bid auction. When the clock is sufficiently slow, however, revenue in the Dutch auction is greater than the revenue in the sealed bid auction. We develop a simple model of auctions with impatient bidders that helps to reconcile prior findings in both the laboratory and the field.

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1. Introduction and related literature

The role of timing in markets has been receiving an increasing amount of attention in the economics literature. Roth and Xing (1994) start their paper by pointing out that "The timing of transactions is a little-studied feature of markets, but one which plays a large role in their ability to function." The popularity of Internet auctions, such as eBay, has made timing issues in auctions particularly salient. Traditional auction houses, such as Christie's, require bidders or their representatives to assemble at a specific place and time, and therefore auctions must be conducted fairly quickly (often lasting less than an hour). In contrast, Internet auctions allow geographically dispersed bidders to participate, making it possible to conduct auctions that last many days. One disadvantage of long Internet auctions is that they may impose high monitoring costs on the bidders, affecting the strategy of the bidders and the revenues of the auctioneer. There is some evidence that Internet auction houses are aware of this disadvantage, since they make attempts to mitigate monitoring costs by offering email notifications and proxy bidding. Recently eBay introduced the "buy-it-now" feature, aimed at impatient bidders, that allows them to win an object immediately for a certain pre-specified price. The "buy-it-now" price is typically higher than the expected price at the end of the auction, so the popularity of this feature suggests that there is a substantial number of eBay bidders who place some value on being able to end the auction quickly.[1]

This study examines the role of timing in auctions under the premise that time is a valuable resource, so timing matters. We focus specifically on two common auction formats, strategically equivalent under standard theory, but quite different in terms of market timing:

- *Dutch* (Dutch) auction is also known as a reverse clock auction; price descends until a bidder decides to accept the current price stopping the auction and buying at that price.
- *First-price sealed bid* (sealed bid) auction, where bidders submit a single sealed bid. The highest of these bids is selected as the winner, and the winning bidder pays the amount that she bid.

In theory the Dutch and the sealed bid mechanisms are strategically equivalent, even under the assumptions of risk aversion and affiliated valuations, and therefore are supposed to yield the same revenue to the auctioneer. There are, however, two seemingly conflicting sets of studies that compare revenues in the Dutch and the sealed bid auctions. One set of studies is reported by Cox, et al. (1982), and Cox, et al. (1983) and finds that Dutch auctions yield lower revenues than sealed bid auctions when conducted in the laboratory using artificial commodities. Another study, reported by David Lucking-Reiley (1999), finds that slow Dutch auctions for Magic™ Cards conducted over the Internet yield higher revenues than analogous sealed bid auctions.

While there are many possible explanations for the seemingly conflicting results, we focus on two potential explanations. One explanation is that the studies differed markedly in the

[1] There are also some sellers who use the "buy-it-now" feature to essentially run a "store" on eBay -- sell

speed of the Dutch clock used. While the Cox et al. laboratory studies used clocks that descended between .75% and 2% of their maximum value every *second*, the Lucking-Reiley field study used a clock that decreased approximately 5% per *day*.[2] Since slower auctions impose higher monitoring and opportunity costs on bidders and are generally less exciting, the slow clock may cause the bidders to end the auction early.

The second explanation is that laboratory and field studies can yield systematically different results because there is something special about the laboratory that induces bidders to take a 'gamblers' mentality - lowering the auction price - whereas in field experiments bidders are much more cautious and time sensitive. Lucking-Reiley (1999) argues that, "Laboratory experiments, which to date have provided the vast majority of data on bidders' behavior in auctions, can be criticized on the grounds that subjects' behavior in an artificial laboratory environment may not be exactly the same as their behavior would be in the "real world." The Magic card market provides an opportunity to run controlled experimental auctions in the field rather than in the laboratory." Consistent and unexplained deviations in laboratory experiments from field observations would challenge the experimental precept of *parallelism* (Smith 1982).[3]

We develop a simple model of auctions with impatient bidders. This theory helps to reconcile prior findings in both the laboratory and the field. We then study Dutch and sealed bid auctions in the laboratory, systematically varying the speed of the Dutch clock, in order to gain insights into the results reported in the literature. We find strong evidence that the clock speed matters.

objects for fixed price. They do this by setting the reservation price equal to the "buy-it-now" amount.

[2] The actual decrement of the clock varied. Bidders were not informed of the exact clock speed. Therefore, an alternative explanation of higher bidding could be a rational response by risk averse bidders to a random clock.

[3] Smith defines parallelism as follows; "Propositions about the behavior of individuals and the performance of institutions that have been tested in laboratory microeconomies apply also to nonlaboratory microeconomies where similar *ceteris paribus* conditions hold."

The Dutch auction received its name from the flower auction in Aalsmeer, Holland that is used to trade flowers and plants with the annual worth of over 2 billion Dutch Guilders (Van den Berg 2001). William Vickrey (1961) showed that the descending price Dutch auction is strategically equivalent to the sealed bid auction. Cox, et al. (1983) propose explanations of lower prices in Dutch auctions in the laboratory that conjectures that participants make systematic errors in the Bayesian updating in Dutch auctions or that they receive some non-monetary enjoyment from participating in the auction. Octavian Carare and Michael Rothkopf (2001) describe a model of a slow Dutch auction and provide a simple game theoretic model allowing bidders to return to a slow Dutch auction at a later date. The Carare and Rothkopf (2001) models provide a theoretical explanation of Lucking-Reiley's results, but not of the Cox et al. results. Adams et al. (1995) combine a Dutch auction with a search model and random arrivals of bidders. They show that under certain conditions a fixed price – clock speed of zero – is optimal.

The paper proceeds as follows. In Section 2, we present a simple model of Dutch auctions where bidders care about timing. Section 3 contains the experimental design. In Section 4, we present the experimental results. Section 5 concludes.

2. A simple theory of Dutch auctions

Let there be N bidders labeled $i = 1, \ldots, N$. Bidders are risk neutral and have independent private values v_i drawn from the common distribution F with support on $[0, \bar{v}]$.[4] Cox et al. (1983) examine a similar auction model except that they assume bidders receive only positive non-monetary payoffs from longer auctions associated with the thrill of the 'waiting game.' They allow bidders to derive some non-monetary enjoyment from participation in the auction. Let

[4] The results here can be easily extended to include risk aversion and affiliation.

$a(t)$ be the level of this added utility at time t. We assume that $a(t) \geq 0$, and $a(t)$ is differentiable. Their model can only lead to lower revenue in the Dutch auction, and does not recognize the fact that time is valuable. We assume that bidders are also impatient. As time passes bidders bare a cost $c(t)$ for participating in the auction. A bidder's profit from participating in an auction that lasts for time t is given by:

$$u_i(v_i, t) = \begin{cases} v_i - b + a(t) - c(t) & \text{if win} \\ a(t) - c(t) & \text{otherwise} \end{cases} \tag{1.1}$$

where b is the price the winning bidder pays. The cost $c(t)$ can be thought of as the cost of monitoring the auction or the opportunity cost associated with the time spent bidding in the auction. A bidder must pay these costs win or lose. In the laboratory, these costs are most likely the bidder's perceived value of ending the auction earlier in order to speed the completion of the experimental session. In practice, they might be the salaries of designated bidders, or the effort of repeatedly returning to the auction website to see if the object is still available. We assume that $c(t) \geq 0$, and $c(t)$ is differentiable. Let $e(t) = a(t) - c(t)$. Assume that either $e'(t) < 0$ for all t or $e'(t) > 0$ for all t.[5]

In a first-price sealed bid auction, the bidder does not have a choice over the time the auction will end. Suppose that the sealed bid auction will last time t°. Then, if $e(t^{\circ}) < 0$, the bidders view $e(t^{\circ})$ as a fixed entry fee and select an optimal bid function $b_i^{\circ}(v_i)$ that maximizes their expected utility given that the other bidders are also bidding optimally. While the length of the sealed bid auction may affect a bidder's willingness to participate in the auction (McAfee and McMillan 1987), it will not have any effect on their optimal bid contingent upon participation in

[5] When this is not true, the implication is that some bidders (depending on their value) might want to end the auction sooner and others might want to end it later. Therefore, the effect on the probability of winning given a current price, which is a critical feature of the results presented here, is unclear.

the auction. If $e(t^{\circ}) > 0$, then existing bidder strategies are unaffected, but new bidders might be attracted to the auction.[6] Let $H_i(b_i)$ be the probability that a bid of b_i is maximal. A bidder's expected utility is given by:

$$U_i(v_i) = (v_i - b_i) H_i(b_i) + e(t^{\circ}). \qquad (1.2)$$

Following Maskin and Riley (1993), under the assumption that $f(v) > 0$, there exists a unique, symmetric Bayes Nash equilibrium. For each v_i, the equilibrium bid function must satisfy the following first order condition:

$$(v_i - b_i^{\circ}) H_i'(b_i^{\circ}) - H_i(b_i^{\circ}) = 0. \qquad (1.3)$$

The Dutch auction is characterized in the following manner. The auction begins at a high value, v^S and price decreases at a constant rate $1/d$ per unit time.[7] Therefore, at time t the price available for bidders to end the auction at is given by $b(t) = v^S - (1/d)t$. The auction ends - price equals zero - at time $T = dv^S$. Note that $b'(t) = -(1/d)$.

A bidder's strategy consists of a choice of a stopping function $t(v)$ given the particular Dutch auction presented (d and v^s). In contrast to the sealed bid auction, bidders in a Dutch auction have some control over the amount of monitoring costs they incur. Assuming that the auction has progressed to time t, the bidder must decide whether to allow the auction to continue or to stop the clock. If the auction continues, the bidder increases her (non-monitoring) profit in the event that she wins the auction. However, continuing the auction also decreases the chance that she will win the auction and increases the monitoring costs incurred. Following closely the

[6] We do not allow endogenous entry or exit in our models. While the ex ante decision to participate in an auction might be an important consideration in many real world auctions, we did not allow such choices in the experiment.

[7] In the laboratory experiments presented here $v^S = \overline{v}$, but, depending on the sign of $e'(t)$, the auctioneer may want to select the clock starting point so as to maximize revenue.

arguments in Cox et al. (1983), when the incremental monitoring costs exceed non-monetary benefits or $e'(t) < 0$, it is easy to show that the equilibrium stopping function t^* must be such that $b(t^*) > b_i^\circ$ for all values. This, of course, implies that the auction ends sooner than it would have with patient bidders and yields higher revenue for the auctioneer. When $e'(t) > 0$, the opposite result is true. At the equilibrium stopping rule, the following first order condition must be satisfied for all values:

$$b'(t^*)\{(v_i - b(t^*))(G_i\,'(b(t^*))/G_i(b(t))) - 1\} + e'(t) = 0\,. \qquad (1.4)$$

Using a first order stochastic dominance argument, it follows that this equation implies that the first order condition for the sealed bid auction (1.3) cannot also be satisfied at $b(t^*)$ unless $e'(t) = 0$. Depending on the sign of $e'(t)$, the equilibrium bid in the Dutch auction must be either above or below that of the sealed bid auction.

While this result provides a potential explanation for differences in revenue from the Dutch and sealed bid auctions, it is not enough to explain the observed switch in ordering of revenue outcomes with different clock speeds. The non-monetary cost and benefits are likely to be affected by the speed of the clock, so the cost and the benefit functions are really the functions of the clock speed d: $a(t,d)$ and $c(t,d)$. A slower clock (bigger d) is expected to result in earlier bidding by impatient bidders. It is reasonable to expect that slower clocks will increase the rate at which monitoring costs accrue. On the other hand, a slower clock might lower bidders' sense of enjoyment from the auction.[8] Formally, this is equivalent to assuming that $\partial a'(t,d)/\partial d < 0$ and $\partial c'(t,d)/\partial d > 0$ for all t. Therefore, even if the bids from the Dutch auction start off below those of the sealed bid auction for fast clock speeds, there will be a sufficiently slow clock speed such that $e'(t) < 0$. The previous studies are consistent with this model. In the laboratory studies, the relatively fast clock might have made the non-monetary benefits dominate the monitoring costs. In the field experiment, the length of the auction might have limited the sense of thrill from the waiting game and made monitoring costs salient.

An example with uniform value draws

Let v_i be drawn from the uniform distribution on $[0,1]$ for each of the bidders. In this case the risk neutral bidder's equilibrium bid strategy in the sealed bid auction is the following:

$$b(v) = \frac{N-1}{N}v. \tag{1.5}$$

In order to provide some intuitive results, we assume a fairly simple model of non-monetary compensation. We assume that $a()$ and $c()$ are both linear in t. The bidder's non-monetary enjoyment declines with slower clocks yielding $a(t,d) = (a/d)t$, and monitoring costs are unaffected by the clock speed: $c(t) = ct$. Then $e'(t) = et$ where $e = (a/d) - c$. Using the first order condition from (1.4) the equilibrium stopping strategy in the Dutch auction can easily be calculated to be

$$t(v) = d\left(1 - \frac{N-1}{N}v + \frac{de}{N}v\right).^{9} \tag{1.6}$$

Using the fact that the standing bid at time t is given by $b(t) = 1-(1/d)t$, the equilibrium stopping rule translate to stopping the clock at the bid:

$$b(v) = \frac{N-1}{N}v - \frac{ed}{N}v \tag{1.7}$$

When $e<0$, the Dutch auction will cause bidders to increase their bids whereas when $e>0$ bids will decrease.

[8] Slow auctions in the experimental lab could be perceived as boring by subjects.

[9] This solution is only valid if $d \leq a/c - 1$ since slower clocks will lead to high valuing bidders wanting to stop the clock at $t = 0$.

The expected value of the highest valuation - the winner in both auction formats - is $N/N+1$. Therefore, the expected revenue for the seller in the sealed bid auction is $ER_{Sealed} = N-1/N+1$. The expected revenue from the Dutch auction is given by

$$ER_{Dutch} = \frac{N-1}{N+1} - \frac{ed}{N+1}, \tag{1.8}$$

yielding an expected difference in revenue of

$$ER_{Dutch} - ER_{Sealed} = \frac{c}{N+1}d - \frac{a}{N+1}. \tag{1.9}$$

The expected revenue differences depend on the clock speed d. If $d = a/c$, we can expect the sealed bid and the Dutch mechanisms to yield the same revenue. Any slower clock speed - $d > a/c$ - will result in greater revenue from the Dutch auction and any faster clock speed - $d < a/c$ - will result in lower revenue from the Dutch auction.

A final observation about the difference in behavior in the Dutch and sealed bid auctions is that as the number of bidders grows, $N \to \infty$, the difference in revenue declines regardless of the level of e. While we do not vary the number of bidders in our experiments, one would expect that large auctions would lead to little difference in expected revenue.[10]

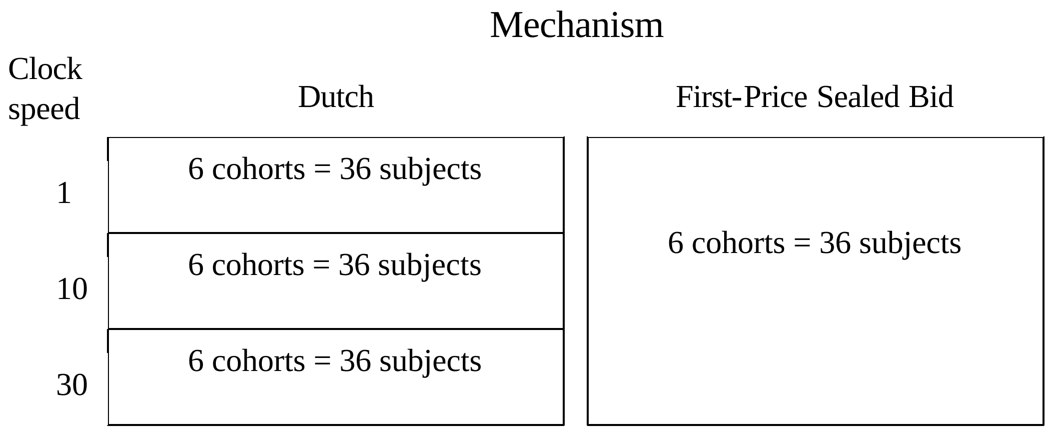
3. Design of the Experiment

Our design manipulates two factors: the auction mechanism, which is either the first-price sealed bid, or the reverse-clock Dutch, and the speed of the Dutch clock. In all auctions three bidders compete for one unit of an artificial commodity, with the value of the commodity drawn from a uniform distribution of 1 to 100. The sealed bid mechanism was a standard first-price sealed bid auction with a zero reserve price. Bidders were required to place integer bids between 0 and 100 tokens.[11] In all Dutch treatments, the price starts at 100 tokens, and goes down by 5 tokens every *d* seconds, where *d* (= 1, 10, and 30 seconds) is the clock speed. Therefore, *d*=1 represents the fastest rate (per second) and *d*=10 and 30 are slower rates. In the Cox et al. studies, the Dutch clock speed varied along with the number of bidders, and all speed levels were fairly fast: the clock decreased by between 1.5% and 4% every 2 seconds. In our study we held the number of bidders at 3 and the clock increment at 5, which is 5% of the maximum artificial commodity value of 100. So all Cox et al. clocks are between our 1 and 10 second treatments, and our 30 second treatment has a significantly slower clock. While it was unrealistic to run controlled laboratory experiments with a clock speed comparable to the Lucking-Reiley study, it was our hope that a 30 second clock would be sufficient to make monitoring costs salient. In order to give bidders time to reflect on their values, a 5 second value observation period was added to the *d*=1 treatment.[12] Figure 1 summarizes our experimental design.

[10] This might explain why Aalsmeer runs fast Dutch auctions since the potential losses in revenue due the fast speed might be mitigated by the large number of bidders.

[11] The bid increments were different in sealed bid treatments (1) than in Dutch treatments (5). Restricting the bidding to integers was a natural choice in the sealed bid treatment. The different bid increments cannot explain the treatment effect.

[12] We were concerned that bidders might not have sufficient time to determine a strategy before the clock started its speedy descent. In the other treatments, bidders had at least 10 seconds before the first decrements.



Each treatment consisted of 21 auctions. In each auction three bidders competed for one unit of an artificial commodity. Values were drawn from a uniform distribution between 0 and 100. Participants were matched in six-person cohorts, and randomly re-matched within the cohort each round. Each treatment consisted of six cohorts (36 participants).

Figure 1: Experimental design.

During each session participants are matched in groups of 6 (we call each group of 6 a *cohort*). Each cohort participates in a sequence of 21 auctions, with two separate groups of three bidders bidding in each round. After each round the participants are randomly re-matched within the cohort, in a way that no participant is matched with the same two participants for two consecutive auctions. The participants are told this. New values were drawn for each of the 21 auction rounds. The value draws were the same for all of the treatments. Within a treatment, 3 cohorts shared the same value draws.

All sessions were conducted at the Harvard Business School's Computer Laboratory for Experimental Research (CLER) between February 2001 and October 2001. Participants were recruited through flyers posted on billboards. Cash was the only incentive offered. Participants were paid their total individual earnings from the 21 auctions plus a $10 show-up fee at the end of the session. The software was built using the zTree system. Sessions lasted between 60 and

100 minutes (the d=30 sessions were the longest and the sealed bid sessions were the shortest) and average earnings were $25. All subjects participated only once.

4. Results

Sealed Bid

Under the assumption of risk neutrality, the expected value of the high bid is 50. Average revenue (high bid) under the sealed bid treatment was 64.9 tokens, which is consistent with previous experimental findings that bidders bid as if they were risk averse (Kagel 1995). Further, a simple linear regression of bid on value and a constant term yields coefficients of 7.74 (constant) and .746 (value). Table 1 reports the observed average revenue for each independent cohort. Average allocative efficiency was .984 pooled across all cohorts. Table 2 reports the observed efficiency for each independent cohort. On average, it took bidders 19 seconds to complete bidding in a sealed bid auction period.

Cohort	Dutch d =1	Dutch d =10	Dutch d =30	Sealed
1	57.74	63.21	66.31	64.24
2	60.00	62.14	64.52	64.26
3	59.05	60.36	65.95	65.50
4	61.31	64.52	67.38	64.00
5	58.81	63.93	67.38	67.69
6	56.43	63.33	68.10	63.60
Average	58.89	62.92	66.61	64.88

Table 1. Average revenue (high bids) in six independent cohorts.

Cohort	Dutch d=1	d=10	d=30	Sealed
1	0.989	0.994	1.000	0.990
2	0.987	0.992	0.994	0.969
3	0.987	0.979	0.993	0.992
4	0.977	0.992	0.985	0.985
5	0.979	0.992	0.985	0.994
6	0.979	0.978	0.980	0.977
Average	0.983	0.988	0.989	0.985

Table 2. Average allocative efficiency in six independent cohorts. Allocative efficiency is measured as the value of the winning bidder divided by the value of maximum of value of the three bidders for that period.

Dutch

Under the Dutch treatments the average revenue was 58.85 (*d*=1), 62.92 (*d*=10), and 66.61 (*d*=30). As in the sealed bid treatment, all averages are above the risk neutral prediction. Average allocative efficiency was .983 (*d*=1), .988 (*d*=10), and .989 (*d*=30). We report revenue and efficiency for each independent cohort in Tables 1 and 2. Average auction length varied, as expected, with the speed of the clock: 53 seconds for *d*=1, 94 seconds for *d*=10, and 264 seconds for *d*=30.

Comparing Institutions

We summarize our results in Figure 2.

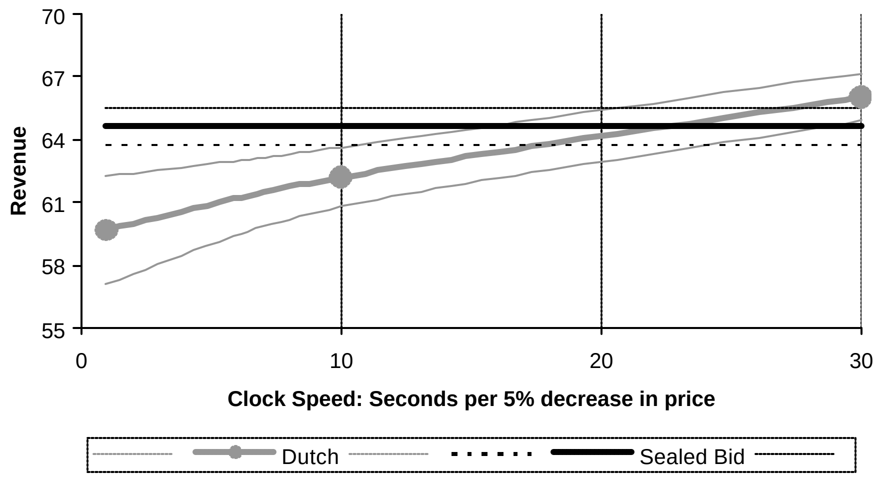


Figure 2. The summary of experimental results. The graph plots average revenue per unit in the 21 auctions, as a function of the speed of the clock. The solid lines represent averages, and the dotted and light gray lines represent ± 2 standard errors.

The average revenue in the 1-second Dutch treatment is 9% below the sealed bid revenue. The differences Cox et al. report are in the 3%-5% range, so since our 1-second clock is faster than the Cox et al. clocks, the differences we find are in line with Cox et al. The average revenue in the 30-second Dutch treatment is only 2% above the sealed bid revenue, in contrast to the 23% difference Lucking-Reiley reports. This, however, is consistent with the clock speed explanation, since the Lucking-Reiley price decreased by 5% per day, and the price in our 30-second treatment decreased by 5% every 30 seconds. We compare the average revenue in the Dutch and the sealed bid auctions using a Wilcoxon-Mann-Whitney Rank Sum test, and find that the differences are statistically significant in all treatments (the *p*-value for the 1-second Dutch vs. sealed bid is 0.0011, the *p*-value for the 10-second Dutch vs. sealed bid is 0.0206, and the *p*-

value for the 30-second Dutch vs. sealed bid is 0.0043).[13] The average efficiencies of the auctions are not significantly different.

The Cox et al. explanation of lower revenues in fast Dutch auctions is that bidders derive some pleasure or thrill from the "waiting game." An alternative explanation for the significantly lower prices in our 1-second Dutch clock treatment is that the combination of speed of the clock and slow bidder reaction might consistently bias the bid level downward (bidders are not stopping the clock fast enough). The data suggest that for this explanation to be salient bidder reactions would have to be quite slow--on average 6 seconds elapsed between where the bidders should have stopped the clock if they were bidding consistent with the sealed bid auction and where they actually did stop the clock. Since our 1-second Dutch clock is slightly faster than the fastest Cox. et al. clock, we test the hypothesis that the particularly low revenues in the 1-second auction are due to bidder errors. If it were the case that bidders react too slowly given the clock speed, and the resulting bids are lower than what the bidders intended, we would expect to see some upwards adjustment of bids over time (to correct for these slow reactions). Therefore, we compare the average differences between the 1-second Dutch and sealed bid revenues, over the first 10 vs. the last 10 rounds. The difference is not statistically significant (the one-sided *p*-value is 0.2200).[14]

A final explanation of the Dutch-sealed bid non-isomorphism is that bidders might be failing to Bayesian update properly (Cox et al. 1983). Although Bayesian updating errors might be higher for faster clocks (because there is less time to think), there is no evidence that people do Bayesian updating properly in general (Camerer 1995), and there is no reason to believe that a

[13] Similar *p*-values were also obtained using a *t*-test for samples with unequal variance.

[14] We are not claiming that this is conclusive evidence that there is no bidder error in our 1 second treatment, but we suggest that bidder error, if it is there, is unlikely to be sufficient to explain our data.

few extra seconds would make a difference. Therefore, we would expect errors in Bayesian updating to have a similar effect in all three Dutch treatments.

5. Conclusions

We present an experiment and a simple theory of Dutch auctions with impatient bidders that reconcile the two seemingly inconsistent results about revenue equivalence in first-price sealed bid, and Dutch auctions. We find that the speed of the Dutch clock does have a significant impact on auctioneer's revenue in laboratory experiments: fast clock speeds yield revenues that are significantly below the revenues in the sealed bid auction (consistent with Cox et al. 1982), while the revenue in auctions with a slow clock is higher than that in the sealed bid auction (consistent with Lucking-Reiley 1999). These results cannot be explained by bidder errors. We present a simple theory of Dutch auctions with impatient bidders that is consistent with our data.

Why are there fast Dutch auctions? Our theory and experimental results suggest that a patient auctioneer should be willing to commit to a slow Dutch clock in order to force acceptance of a higher standing price. In fact, in the limit, why not commit to offering a fixed price? The auctioneer might have a number of reasons to use a faster clock. First, the auctioneer is likely to pay some cost associated with longer auctions. Aalsmeer, for example, must sell thousands of lots of a highly perishable commodity. If they were to use a slow clock, far fewer lots could be sold. In other settings, such as Filene's Basement (Filene's is a department store well known for running a slow Dutch auction in the basement) or auctions of surplus items, time may be less critical. Second, the laboratory experiments we discussed did not allow the bidders to avoid bidding. If we were to allow for endogenous entry of bidders, we may find that some bidders with low values prefer to avoid the auction altogether rather than pay the exorbitant monitoring costs associated with a slow clock. Just as in sealed bid auctions, bidders with values below a certain cutoff level would choose not to bid. In fact, if $c - a > d$ none of the bidders would participate. Incorporating endogenous entry could lower allocative efficiency and auctioneer revenue.

Finally, time may affect bidder preferences differently. For example, a longer auction might lower a bidder's use value (v_i) for the object. Examples of objects that are likely to exhibit these sorts of preferences are durable goods that might promise a stream of income to the owner (rental apartments or spectrum rights) or items whose usefulness is restricted to a limited time (in style or winter clothing). When use values are declining one can show that the auction will end at a lower prices than a sealed bid auction (assuming the sealed bid auction itself is not too slow). These are probably not the correct sorts of preferences for laboratory experiments discussed here or even Lucking-Reiley's field experiments but might be common in many potential Dutch auction applications. For example, a florist's willingness to pay for a particular lot of flowers is almost definitely related to its freshness. If the auction had lasted a very long time, the flowers would be noticeably less fresh!

The results presented here allow us to make two important conclusions. First, the choice of clock speed in a Dutch auction is an important design variable that must be considered carefully by the auctioneer. While it would be foolish to draw too many actual design lessons from the experimental results presented here, we believe that these results indicate the need for more formal theoretical analysis of specific design parameters in the Dutch auction. The second conclusion is of a methodological nature. The results in Lucking-Reiley are not necessarily due to fundamental differences in field experiments from laboratory experiments. There are simple design changes – a slower clock – that allows one to replicate the qualitative features of this particular field experiment in a laboratory setting.

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Appendix

The base text is for the Dutch mechanism with the 10 second clock. Whenever the numbers are different for the 1 and 30 second treatments, we include them in parenthesis. The parts that are different in the Sealed bid treatment are in *italics*.

Instructions

Introduction

This is an experiment in market decision-making. If you follow the instructions carefully and make good decisions, you can earn a considerable amount of CASH.

The experiment consists of a sequence of 21 auctions. At the end of the session you will receive ten dollars ($10) PLUS your total earnings from all 21 auctions.

It is important that you do not talk or in any way try to communicate with other people during the experiment. If you disobey the rules, we will have to ask you to leave.

Auction Description

In each auction you and two other participants will compete to purchase a fictitious asset. The price of the asset will start at 100 tokens and decrease every 10 seconds (1 second, 30 seconds) by 5 tokens. Any of the bidders can stop the auction and purchase the asset at the price displayed on the screen by clicking the "Submit Bid" button. The first person to click the button wins the asset and pays the price displayed on the screen, and the other two people earn 0 for that auction.

For sealed bid: you submit a bid by entering your bid amount into the text box on the screen, and clicking the "Submit Bid" button. The bidder who submits the highest bid, wins the asset and pays the amount of the bid., and the other two people earn 0 for that auction.

Resale Values and Earnings

If you purchase an asset, your earnings are equal to the difference between your resale value for that asset and the price you paid for the asset. Your resale value will be displayed on your screen at the beginning of each auction.

> That is: YOUR EARNINGS = RESALE VALUE - PURCHASE PRICE.
>
> For example if you pay 30 for the asset and your resale value is 64, your earnings are
>
> EARNINGS FROM THE ASSET = 64 - 30 = 34 tokens.

Resale values will differ among individuals and auctions. For each bidder the resale value for the asset will be between 1 and 100. Each number from 1 to 100 has an equal chance of being chosen. It is as if the numbers from were stamped on 100 balls, one number on each ball, and placed in an urn. A random draw from the urn determines the resale value of an asset for an individual. Your chance of drawing a resale value between 1 and 10 is 10%, between 11 and 20 is 10%, between 21 and 30 is 10%, and so on. You are not to reveal your resale values to anyone. It is your own private information

At the end of each auction, all bidders will see the auction's outcome on their screens. If you won the auction, you will be informed of your earnings. If you did not win, you will be told that you did not trade, and your earnings for that auction are 0.

Your earnings from all previous auctions, along with your values, the winning prices, and the amounts you paid, will be displayed on your screen during each auction.

Example 1 Suppose that, in a given period the bidders have these resale values:
Bidder 1 has the resale value of 85
Bidder 2 has the resale value of 80
Bidder 3 has the resale value of 63

Suppose the market price changes as follows:

Beginning of the round:	price = 100
After 10 (1, 30) seconds:	price = 95
After 20 (2, 60) seconds:	price = 90
After 30 (3, 90) seconds:	price = 85
After 40 (4, 120) seconds:	price = 80
After 50 (5, 150) seconds:	price = 75

After 50 seconds Bidder 1 stops the auction.

For sealed bid: suppose Bidder 1 bids 75, bidder 2 bids 60, and bidder 3 bids 55.

Bidder 1 earns 85 – 75 = 10 tokens for this period, and bidders 2 and 3 earn 0 tokens for this trading period.

Matching

You will not be matched with the same two participants for two consecutive auctions. You will not be told which of the other participants in the room you are matched with, and they will not be told that you matched with them. What happens in any auction has no effect on what happens in any other auction.

Ending the experiment

At the end of the experiment, your earnings from all 21 auctions will be totaled and converted to dollars at the rate of ten (10) cents for each token. You will be paid this amount plus an additional $10, in private and in cash. The total payment will be displayed on your computer screen at the end of the session.

Now, please complete the quiz on the next page. If you have any questions raise your hand and I will come to where you are sitting and answer them. When everyone has completed the quiz I will go over the answers, show you a brief demo of the computer interface you will be using, and we will begin the decision making part of the experiment.

QUIZ

Question 1 Suppose the bidders' resale values are: 70 experimental dollars (bidder 1), 40 experimental dollars (bidder 2), 45 experimental dollars (bidder 3). The price changes as follows:

Beginning of the round:	price = 100
After 10 (1, 30) seconds:	price = 95
After 20 (2, 60) seconds:	price = 90
After 30 (3, 90) seconds:	price = 85
After 40 (4, 120) seconds:	price = 80
After 50 (5, 150) seconds:	price = 75

And after 50 seconds Bidder 1 stops the auction.

For sealed bid: suppose Bidder 1 bids 75, bidder 2 bids 30, and bidder 3 bids 25.

1. Who wins the auction? ____________________

2. What are the earnings of

bidder 1__________,

bidder 2__________ and

bidder 3__________?

Question 2 Suppose the bidders' resale values are the same as in Exercise 1: 70 experimental dollars (bidder 1), 40 experimental dollars (bidder 2), 95 experimental dollars (bidder 3). The price changes as follows:

Beginning of the round:	price = 100
After 10 (1, 30) seconds:	price = 95
After 20 (2, 60) seconds:	price = 90
After 30 (3, 90) seconds:	price = 85
After 40 (4, 120) seconds:	price = 80

And after 40 seconds Bidder 3 stops the auction.

For sealed bid: suppose Bidder 1 bids 60, bidder 2 bids 30, and bidder 3 bids 80.

1. Who wins the auction? ___________________

2. What are the earnings of

bidder 1__________,

bidder 2__________ and

bidder 3__________?