

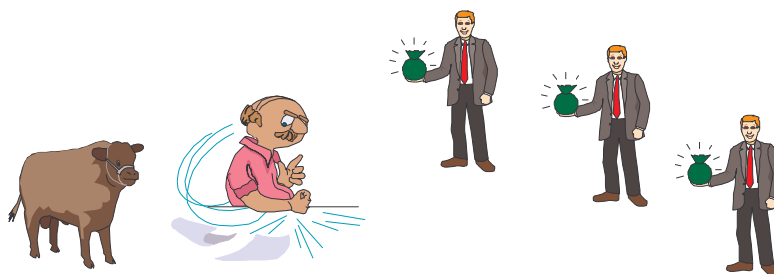
Auctioning one item

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Auctions

- **Methods for allocating goods, tasks, resources...**
- **Participants: auctioneer, bidders**
- **Enforced agreement between auctioneer & winning bidder(s)**
- **Easily implementable e.g. over the Internet**
 - Many existing Internet auction sites
- **Auction (selling item(s))**: One seller, multiple buyers
 - E.g. selling a bull on eBay



- **Reverse auction (buying item(s))**: One buyer, multiple sellers
 - E.g. procurement
- **We will discuss the theory in the context of auctions, but same theory applies to reverse auctions**
 - at least in 1-item settings

Auction settings

- ***Private value*** : value of the good depends only on the agent's own preferences
 - E.g. cake which is not resold or showed off
- ***Common value*** : agent's value of an item determined entirely by others' values
 - E.g. treasury bills
- ***Correlated value*** : agent's value of an item depends partly on its own preferences & partly on others' values for it
 - E.g. auctioning a transportation task when bidders can handle it or reauction it to others

Auction protocols: *All-pay*

- **Protocol**: Each bidder is free to raise his bid. When no bidder is willing to raise, the auction ends, and the highest bidder wins the item. All bidders have to pay their last bid
- **Strategy**: Series of bids as a function of agent's private value, his prior estimates of others' valuations, and past bids
- **Best strategy**: ?
- In private value settings it can be computed (low bids)
- Potentially long bidding process
- **Variations**
 - Each agent pays only part of his highest bid
 - Each agent's payment is a function of the highest bid of all agents
- **E.g. CS application: tool reallocation** [Lenting&Braspenning ECAI-94]

Auction protocols: *English* (*first-price open-cry = ascending*)

- **Protocol**: Each bidder is free to raise his bid. When no bidder is willing to raise, the auction ends, and the highest bidder wins the item at the price of his bid
- **Strategy**: Series of bids as a function of agent's private value, his prior estimates of others' valuations, and past bids
- **Best strategy**: In *private value auctions*, bidder's dominant strategy is to always bid a small amount more than current highest bid, and stop when his private value price is reached
 - No counterspeculation, but long bidding process
- **Variations**
 - In correlated value auctions, auctioneer often increases price at a constant rate or as he thinks is appropriate
 - Open-exit: Bidder has to openly declare exit without re-entering possibility => More info to other bidders about the agent's valuation

Auction protocols:

First-price sealed-bid

- **Protocol**: Each bidder submits one bid without knowing others' bids. The highest bidder wins the item at the price of his bid
 - Single round of bidding
- **Strategy**: Bid as a function of agent's private value and his prior estimates of others' valuations
- **Best strategy**: No dominant strategy in general
 - Strategic underbidding & counterspeculation
 - Can determine Nash equilibrium strategies via common knowledge assumptions about the probability distributions from which valuations are drawn

Strategic underbidding in first-price sealed-bid auction

Example 1

N risk-neutral bidders

Common knowledge that their values are drawn independently, uniformly in $[0, v^{\max}]$

Claim: In symmetric Nash equilibrium, each bidder i bids $b_i = b(v_i) = v_i (N-1) / N$

Proof. First divide all bids by v^{\max} so bids were in effect drawn from $[0,1]$. We show that an arbitrary agent, agent 1, is motivated to bid $b_1 = b(v_1) = v_1 (N-1) / N$ given that others bid $b(v_i) = v_i (N-1) / N$

$$\text{Prob}\{b_1 \text{ is highest bid}\} = \Pr\{b_1 > b_2\} \dots \Pr\{b_1 > b_N\}$$

$$= \Pr\{b_1 > v_2 (N-1)/N\} \dots \Pr\{b_1 > v_N (N-1)/N\}$$

$$= \Pr\{b_1 > v_2 (N-1)/N\}^{N-1} = \Pr\{b_1 N / (N-1) > v_2\}^{N-1} = (b_1 N / (N-1))^{N-1}$$

$$E[u_1 | b_1] = (v_1 - b_1) \text{Prob}\{b_1 \text{ is highest bid}\} = (v_1 - b_1) (b_1 N / (N-1))^{N-1}$$

$$dE[u_1 | b_1] / db_1 = (N/(N-1))^{N-1} (-N b_1^{N-1} + v_1 (N-1) b_1^{N-2}) = 0$$

$$\Leftrightarrow N b_1^{N-1} = v_1 (N-1) b_1^{N-2} \quad | \text{ divide both sides by } b_1^{N-2} \neq 0$$

$$N b_1 = v_1 (N-1)$$

$$\Leftrightarrow b_1 = v_1 (N-1) / N \quad \blacksquare$$

Strategic underbidding in first-price sealed-bid auction...

- **Example 2**
 - 2 risk-neutral bidders: A and B
 - A knows that B's value is 0 or 100 with equal probability
 - A's value of 400 is common knowledge
 - In Nash equilibrium, B bids either 0 or 100, and A bids $100 + \varepsilon$ (winning more important than low price)

Auction protocols:

Dutch (descending)

- **Protocol**: Auctioneer continuously lowers the price until a bidder takes the item at the current price
- Strategically equivalent to first-price sealed-bid protocol in all auction settings
- **Strategy**: Bid as a function of agent's private value and his prior estimates of others' valuations
- **Best strategy**: No dominant strategy in general
 - Lying (down-biasing bids) & counterspeculation
 - Possible to determine Nash equilibrium strategies via common knowledge assumptions regarding the probability distributions of others' values
 - Requires multiple rounds of posting current price
- Dutch flower market, Ontario tobacco auction, Filene's basement, Waldenbooks

Dutch (Aalsmeer) flower auction



Auction protocols: *Vickrey* (= *second-price sealed bid*)

- **Protocol**: Each bidder submits one bid without knowing (!) others' bids. Highest bidder wins item at *2nd highest price*
- **Strategy**: Bid as a function of agent's private value & his prior estimates of others' valuations
- **Best strategy**: In a *private value auction with risk neutral bidders*, Vickrey is strategically equivalent to English. In such settings, *dominant strategy is to bid one's true valuation*
 - No counterspeculation
 - Independent of others' bidding plans, operating environments, capabilities...
 - Single round of bidding
- Widely advocated for computational multiagent systems
- Old [Vickrey 1961], but not widely used among humans
- Revelation principle --- proxy bidder agents on www.ebay.com, www.webauction.com, www.onsale.com

Vickrey auction is a special case of Clarke tax mechanism

- Who pays?
 - The bidder who takes the item away from the others (makes the others worse off)
 - Others pay nothing
- How much does the winner pay?
 - The declared value that the good would have had for the others had the winner stayed home
= second highest bid

Results for *private value* auctions

- Dutch strategically equivalent to first-price sealed-bid
- Risk neutral agents => Vickrey strategically equivalent to English
- All four protocols allocate item efficiently
 - (assuming no reservation price for the auctioneer)
- English & Vickrey have dominant strategies => no effort wasted in counterspeculation
- Which of the four auction mechanisms gives highest expected revenue to the seller?
 - Assuming valuations are drawn independently & agents are risk-neutral
- **The four mechanisms have equal expected revenue!**

More generally: Revenue equivalence theorem

• **Thrm.**

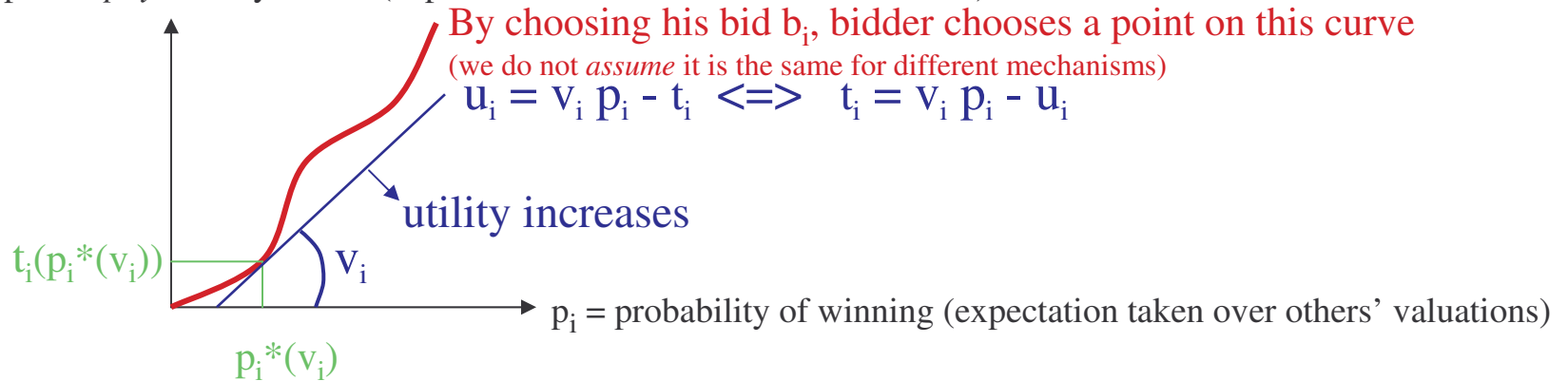
- Assume risk-neutral bidders, valuations drawn independently from potentially different distributions with no gaps
- Consider two Bayes-Nash equilibria of *any* two auction mechanisms
- Assume allocation probabilities $y_i(v_1, \dots, v_{|A|})$ are same in both equilibria
 - Here $v_1, \dots, v_{|A|}$ are true types, not revelations
 - E.g., if the equilibrium is efficient, then $y_i = 1$ for bidder with highest v_i
- Assume that if any agent i draws his lowest possible valuation \underline{v}_i , his expected payoff is same in both equilibria
 - E.g., may want a bidder to lose & pay nothing if bidders' valuations are drawn from same distribution, and the bidder draws the lowest possible valuation
- Then, the two equilibria give the same expected payoffs to the bidders (& thus to the seller)

Proof sketch. [For symbolic proof, see Mas-Colell, Whinston & Green 1995, p. 890-891]

We show that expected payment by an arbitrary bidder i is the same in both equilibria.

By revelation principle, can restrict to Bayes-Nash incentive-compatible direct revelation mechanisms, where others' bids are identical to others' valuations.

t_i = expected *payment* by bidder (expectation taken over others' valuations)



So, for all v_i , we have $dt_i(p_i^*(v_i)) / dp_i^*(v_i) = v_i$

Integrate both sides from $p_i^*(\underline{v}_i)$ to $p_i^*(v_i)$: $t_i(p_i^*(v_i)) - t_i(p_i^*(\underline{v}_i)) = \int_{p_i^*(\underline{v}_i)}^{p_i^*(v_i)} p_i^*(v_i) v_i(p) dp = \int_{\underline{v}_i}^{v_i} v dp_i^*(v)$

Since the two equilibria have the same allocation probabilities $y_i(v_1, \dots, v_{|A|})$ and every bidder reveals his type truthfully, for any realization v_i , $p_i^*(v_i)$ has to be the same in the equilibria. Thus the RHS is the same. Now, since $t_i(p_i^*(\underline{v}_i))$ is same by assumption, $t_i(p_i^*(v_i))$ is the same. ■

Revenue equivalence ceases to hold if agents are not risk-neutral

- **Risk averse bidders:**
 - Dutch, first-price sealed-bid \geq Vickrey, English
- **Risk averse auctioneer:**
 - Dutch, first-price sealed-bid \leq Vickrey, English

Revenue equivalence ceases to hold if agents have budget constraints

- In Vickrey auction, $\text{bid}_i = \min\{v_i, \text{budget}_i\}$
- In 1st-price auction, if there is an equilibrium of the form $\text{bid}_i = \min\{f(v_i), \text{budget}_i\}$, then the expected revenue is higher than in the Vickrey auction

Revenue equivalence ceases to hold between 1st and 2nd-price auctions if distributions are asymmetric

- **Depending on distributions, either can have higher expected revenue (for examples, see Chapter 4.3 of Auction Theory, by Krishna, Academic Press, 2002)**
- **2nd-price auction still efficient, 1st-price auction may not be. Thus the allocation probabilities differ, and thus revenue equivalence theorem doesn't apply**

Optimal auctions (risk-neutral, asymmetric bidders)

- Private-value auction with 2 risk-neutral bidders
 - A's valuation is uniformly distributed on $[0,1]$
 - B's valuation is uniformly distributed on $[1,4]$
- What revenue do the 4 basic auction types give?
- Can the seller get higher expected revenue?
 - Is the allocation Pareto efficient?
 - What is the worst-case revenue for the seller?
 - For the revenue-maximizing auction, see Wolfstetter's survey on class web page

Results for *non-private value* auctions

- Dutch strategically equivalent to first-price sealed-bid
- Vickrey not strategically equivalent to English
- All four protocols allocate item efficiently
- *Winner's curse*
 - Common value auctions:

$$\tilde{v}_1 = E[v | \hat{v}_1, b(\hat{v}_2) < b(\hat{v}_1), \dots, b(\hat{v}_N) < b(\hat{v}_1)]$$

- Agent should lie (bid low) even in Vickrey & English
Revelation to proxy bidders?
- Thrm (*revenue non-equivalence*). Let there be at least 2 bidders, let them be *symmetric*, and let their signals be *affiliated* (i.e., if a subset of the signals $X_1 \dots X_N$ is large, then it is more likely that the rest of them are large). The expected revenues are: **English \geq Vickrey \geq Dutch = first-price sealed bid**

Results for *non-private value* auctions...

- **Common knowledge that auctioneer has private info**
 - Q: What info should the auctioneer release ?
- **A: auctioneer is best off releasing all of it**
 - “No news is worst news”
 - Mitigates the winner’s curse

Results for *non-private value* auctions...

- **Asymmetric info among bidders**
 - E.g. 1: auctioning pennies in class
 - E.g. 2: first-price sealed-bid common value auction with bidders A, B, C, D
 - A & B have same good info. C has this & extra signal. D has poor but independent info
 - A & B should not bid; D should sometimes
- => “Bid less if more bidders or your info is worse”
 - Most important in sealed-bid auctions & Dutch

Vulnerability to **bidder collusion**

[even in private-value auctions]

- $v_1 = 20$, $v_i = 18$ for others
- Collusive agreement for English: e.g. 1 bids 6, others bid 5. Self-enforcing
- Collusive agreement for Vickrey: e.g. 1 bids 20, others bid 5. Self-enforcing
- In first-price sealed-bid or Dutch, if 1 bids below 18, others are motivated to break the collusion agreement
- Need to identify coalition parties

Vulnerability to **shills**

- Only a problem in non-private-value settings
- English & all-pay auction protocols are vulnerable
 - Classic analyses ignore the possibility of shills
- Vickrey, first-price sealed-bid, and Dutch are not vulnerable

Vulnerability to a **lying auctioneer**

- Truthful auctioneer classically assumed
- In Vickrey auction, auctioneer can overstate 2nd highest bid to the winning bidder in order to increase revenue



- Bid verification mechanisms, e.g. cryptographic signatures
- Trusted 3rd party auction servers (reveal highest bid to seller after closing)
- In English, first-price sealed-bid, Dutch, and all-pay, auctioneer cannot lie because bids are public

Auctioneer's other possibilities

- **Bidding**
 - **Seller may bid more than his reservation price because truth-telling is not dominant for the seller even in the English or Vickrey protocol (because his bid may be 2nd highest & determine the price) => seller may inefficiently get the item**
 - In an expected revenue maximizing auction, seller sets a reservation price strategically like this [Myerson 81]
 - Auctions are not Pareto efficient (not surprising in light of Myerson-Satterthwaite theorem)
- **Setting a minimum price**
- **Refusing to sell after the auction has ended**

Undesirable private information revelation

- **Agents strategic marginal cost information revealed because truthful bidding is a dominant strategy in Vickrey (and English)**
 - **Observed problems with subcontractors**
- **First-price sealed-bid & Dutch may not reveal this info as accurately**
 - **Lying**
 - **No dominant strategy**
 - **Bidding decisions depend on beliefs about others**

Untruthful bidding with local uncertainty even in Vickrey

- Uncertainty (inherent or from computation limitations)
- Many real-world parties are risk averse
- Computational agents take on owners preferences
- *Thrm [Sandholm ICMAS-96]. It is not the case that in a private value Vickrey auction with uncertainty about an agent's own valuation, it is a risk averse agent's best (dominant or equilibrium) strategy to bid its expected value*
- Higher expected utility e.g. by bidding low

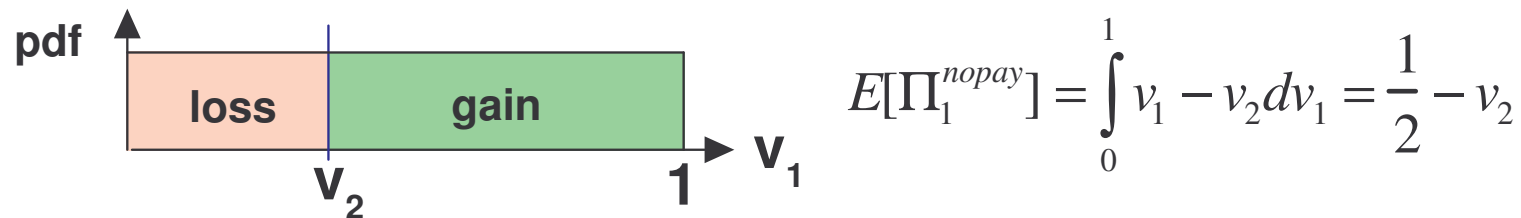
Wasteful counterspeculation

Thrm [Sandholm ICMAS-96]. In a private value Vickrey auction with uncertainty about an agent's own valuation, a risk neutral agent's best (deliberation or information gathering) action can depend on others.

E.g. two bidders (1 and 2) bid for a good.

v_1 uniform between 0 and 1; v_2 deterministic, $0 \leq v_2 \leq 0.5$

Agent 1 bids 0.5 and gets item at price v_2 :



Say agent 1 has the choice of paying c to find out v_1 . Then agent 1 will bid v_1 and get the item iff $v_1 \geq v_2$ (no loss possibility, but c invested)

$$E[\Pi_1^{pay}] = -c + \int_{v_2}^1 v_1 - v_2 dv_1 \quad E[\Pi_1^{pay}] \geq E[\Pi_1^{nopay}] \Leftrightarrow v_2 \geq \sqrt{2c}$$

Sniping

= bidding very late in the auction in the hopes that other bidders do not have time to respond

Especially an issue in electronic auctions with network lag and lossy communication links

	Hypotheses	Predicted contribution to late bidding
Strategic hypotheses	<ul style="list-style-type: none"> • <i>Rational response to naïve English auction behavior or to shill bidders</i>: bidders bid late to avoid bidding wars with incremental bidders. • <i>Collusive equilibrium</i>: bidders bid late to avoid bidding wars with other like-minded bidders. • <i>Informed bidders protecting their information</i>: e.g. late bidding by experts/dealers. 	<p>All three strategic hypotheses suggest more late bidding on eBay than on Amazon, with a bigger effect for more experienced bidders.</p> <p>Plus (via the third point) more late bidding in categories in which expertise is important than in categories in which it is not.</p>
Non-strategic hypotheses	<p>Bidders bid late because ...</p> <ul style="list-style-type: none"> • of procrastination; • search engines present soon-to-expire auctions first; • of a desire to retain flexibility to bid on other auctions offering the same item; • they remain unaware of the proxy bidding system; • of an increase in the willingness to pay over time caused by, e.g., an endowment effect; or because • bidders don't like to leave bids "hanging." 	<p>No difference between eBay and Amazon.</p>

Table 1–Hypotheses about the causes of late bidding

[from Roth & Ockenfels]

Sniping...

Amazon auctions give automatic extensions, eBay does not
Antiques auctions have experts

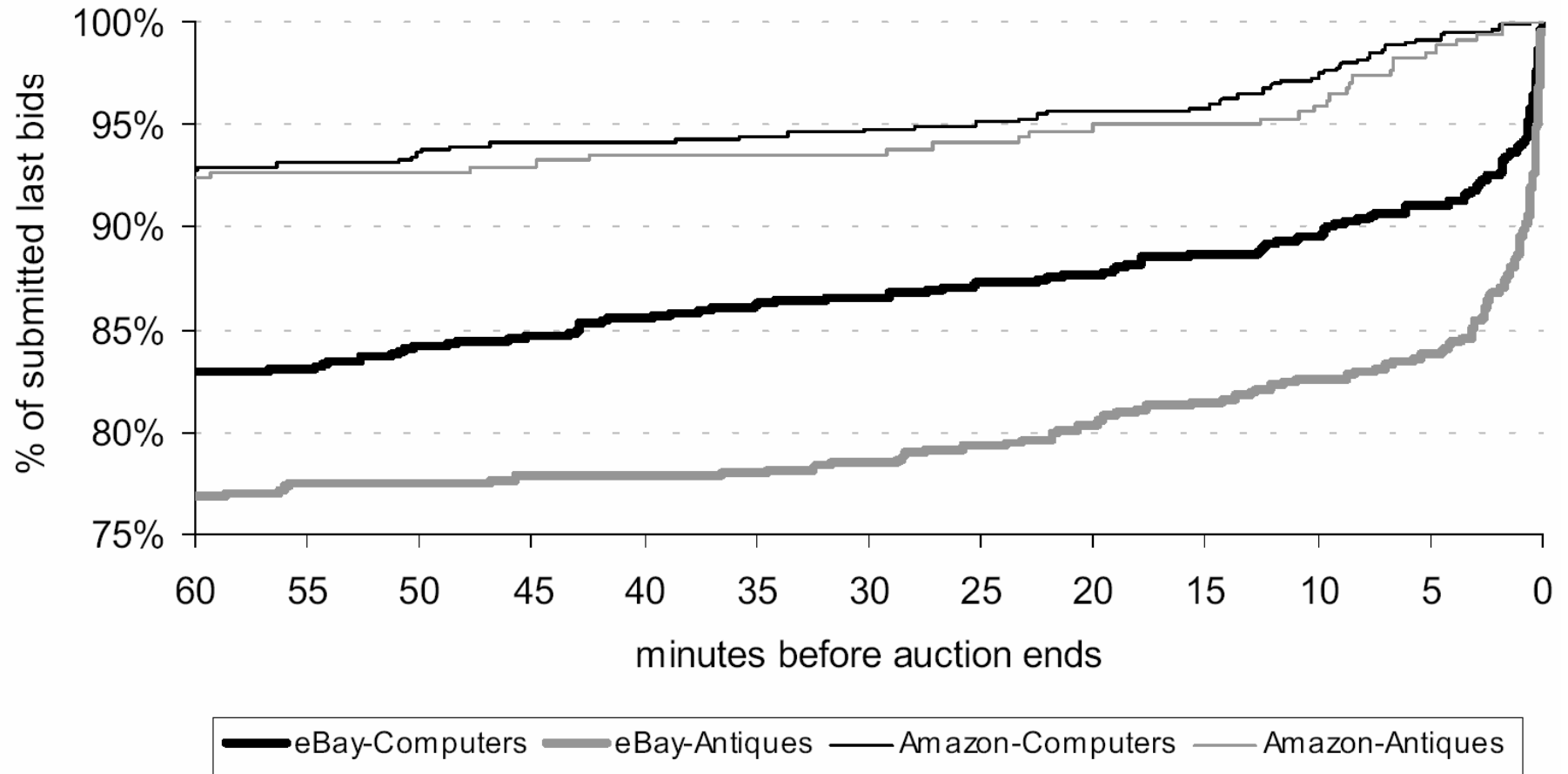


Figure 1a—Cumulative distributions over time of bidders' last bids

[from Roth & Ockenfels]

Sniping...

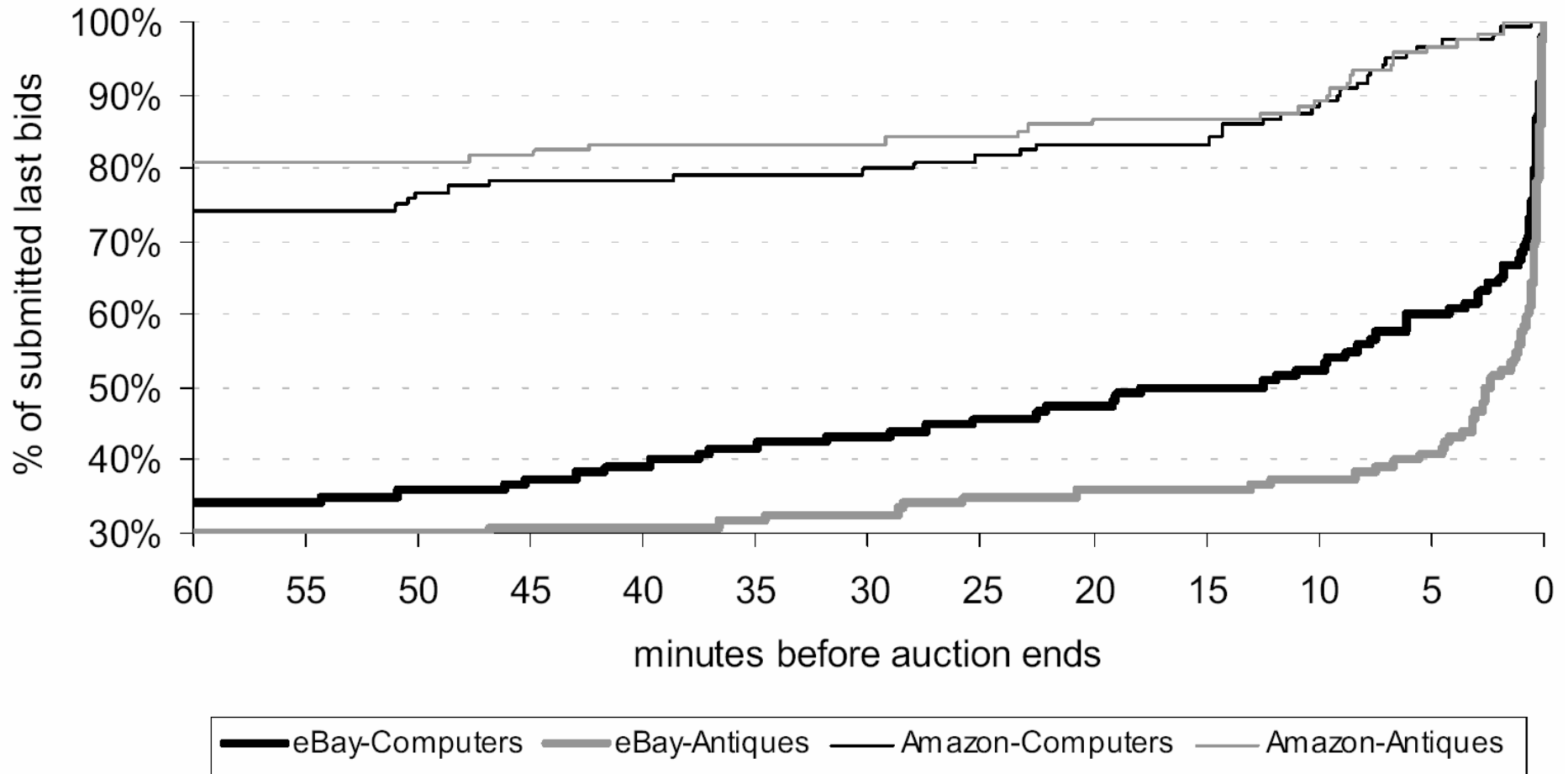


Figure 1b—Cumulative distributions over time of auctions' last bids

[from Roth & Ockenfels]

Sniping...

- Can make sense to both bid through a regular insecure channel and to snipe
- Might end up sniping oneself



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You place bids on eSnipe when it's convenient for you. Then, during the last seconds of the auction, eSnipe bids automatically for you.
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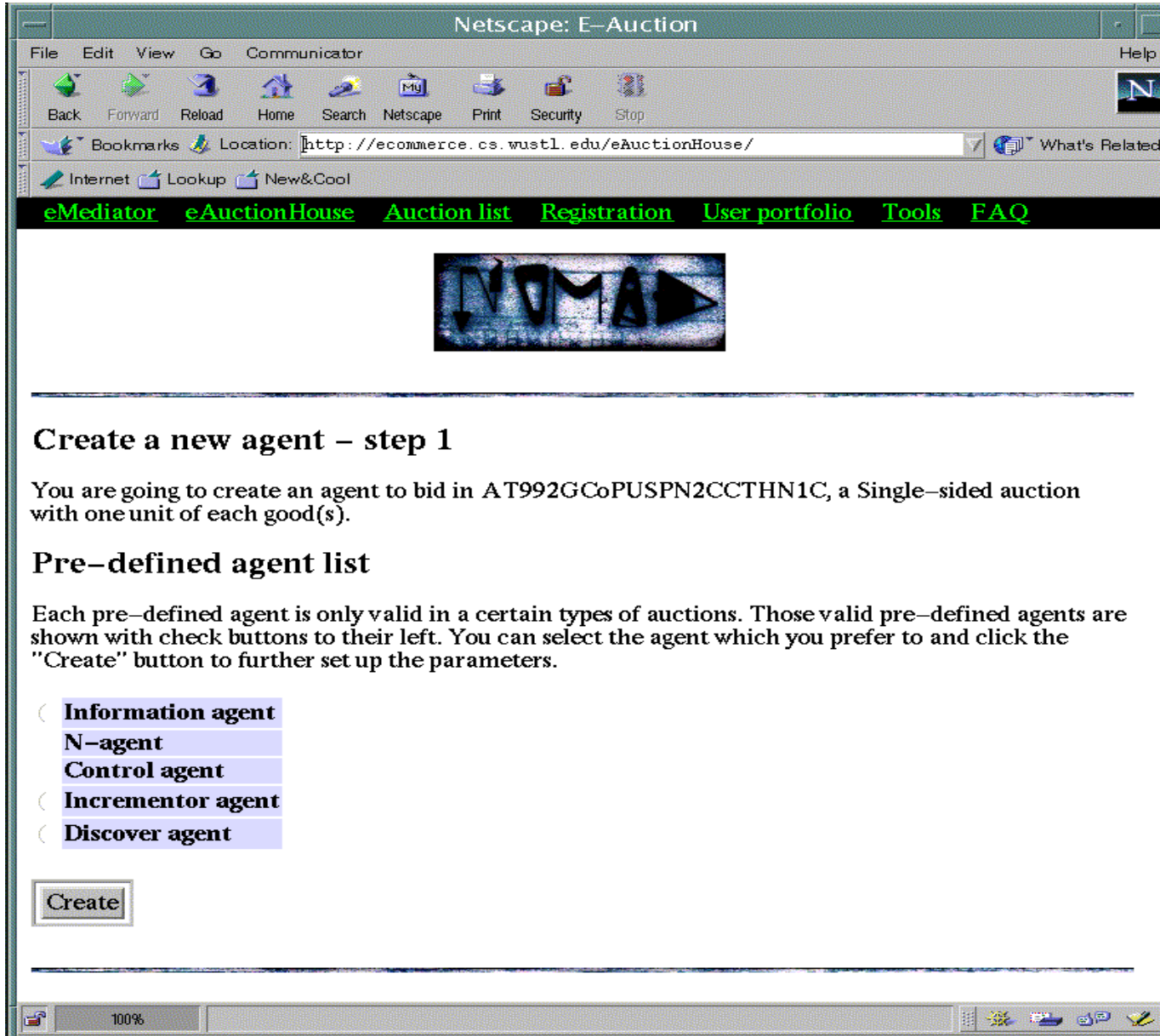
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Mobile bidder agents in eMediator

- **Allow user to participate while disconnected**
- **Avoid network lag**
- **Put expert bidders and novices on an equal footing**
- **Full flexibility of Java (Concordia)**
- **Template agents through an HTML page for non-programmers**
 - **Information agent**
 - **Incrementor agent**
 - **N-agent**
 - **Control agent**
 - **Discover agent**

Mobile bidder agents in eMediator



Netscape: E-Auction


File Edit View Go Communicator Help

Back Forward Reload Home Search Netscape Print Security Stop

Bookmarks Location: <http://ecommerce.cs.wustl.edu/eAuctionHouse/> What's Related

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Create a new agent – step 1

You are going to create an agent to bid in AT992GCoPUSPN2CCTHN1C, a Single-sided auction with one unit of each good(s).

Pre-defined agent list

Each pre-defined agent is only valid in a certain types of auctions. Those valid pre-defined agents are shown with check buttons to their left. You can select the agent which you prefer to and click the "Create" button to further set up the parameters.

- Information agent
- N-agent
- Control agent
- Incrementor agent
- Discover agent

Create

100%

Mobile bidder agents in eMediator...

The screenshot shows a Netscape browser window titled "Netscape: E-Auction". The address bar contains "eMediator". The browser's menu bar includes "File", "Edit", "View", "Go", "Communicator", and "Help". The toolbar contains icons for "Back", "Forward", "Reload", "Home", "Search", "Netscape", "Print", "Security", and "Stop". The page content includes a navigation menu with links for "eMediator", "eAuctionHouse", "Auction list", "Registration", "User portfolio", "Tools", and "FAQ".

Create a new agent – step 2

Nomad helps to create an agent according to the parameters you specified. Agent type and the parameters combined together provide bidding strategy. An agent reports any change of the bidding price by sending email to you. An agent dies when the auction that it is bidding closes or its bid is unable to win based on its bidding strategy.

Specifications

Auction ID
AT992GCoPUSPN2CCTHN1C

User ID

Password

Email address for agent reporting

Agent name (optional)

Agent type
Price-agent

Agent itinerary
 Docking at ecommerce.cs.wustl.edu
 Bidding at ecommerce.cs.wustl.edu

Your valuation of the good (\$)

Initial bidding price (\$)

Minimum increment (\$)

Interval (minutes) for checking the highest bid

Conclusions on 1-item auctions

- **Nontrivial, but often analyzable with reasonable effort**
 - **Important to understand merits & limitations**
 - **Unintuitive protocols may have better properties**
 - **Vickrey auction induces truth-telling & avoids counterspeculation (in limited settings)**
- **Choice of a good auction protocol depends on the setting in which the protocol is used**

