Forward-looking bidding

in

online auctions

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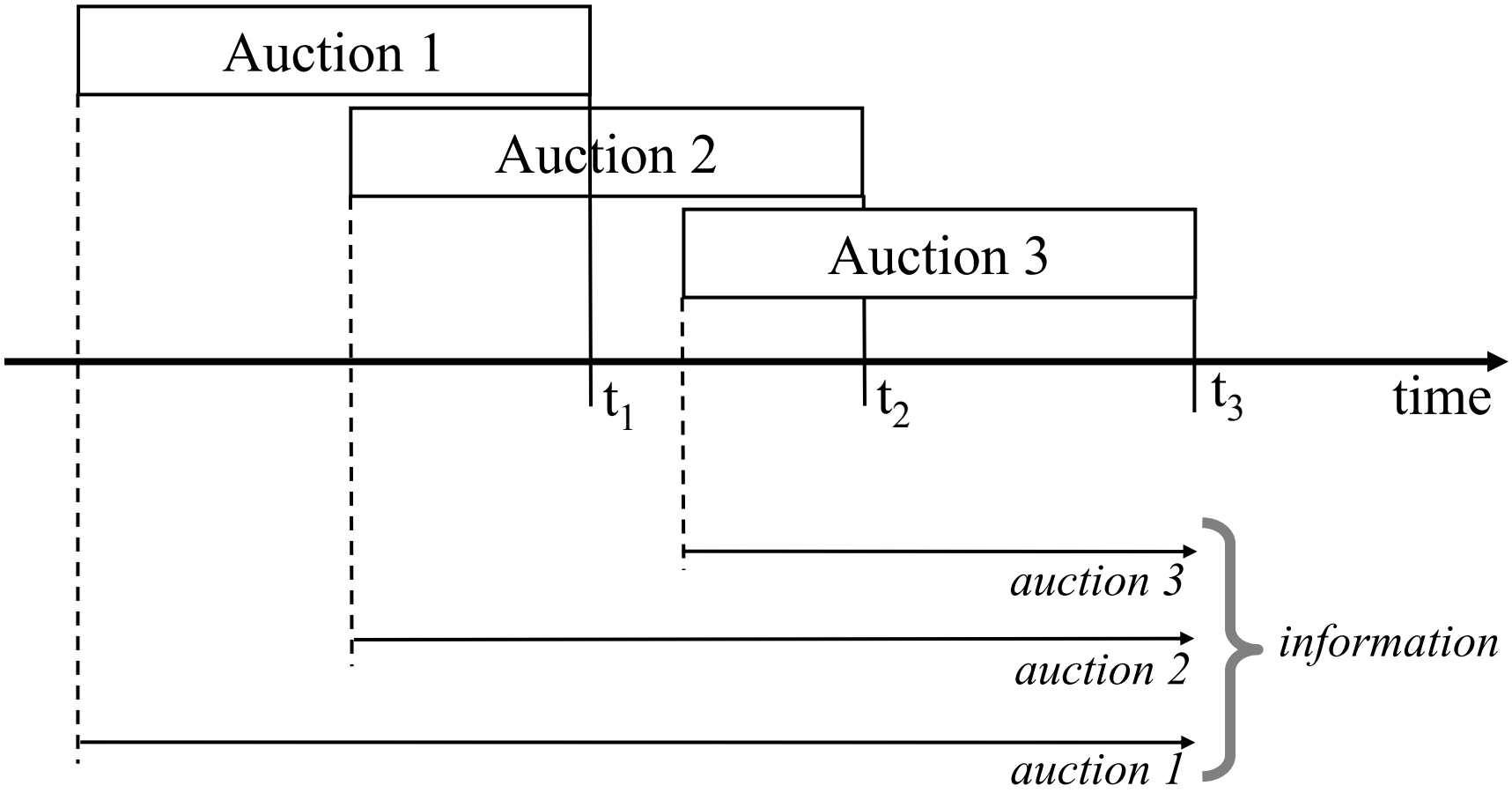
Let's buy a digital camera on eBay...

Canon S30, ***15 mins left***
Canon S40, *33 mins left*
Olympus D40, *45 mins left*
Canon S30, ***47 mins left***
Olympus D40, *53 mins left*

- Electronics, movies, computers ... each buyer only wants one unit
- Population heterogeneity in preferences (I am shopping for Canon S30)
- Simultaneous? No, sequential, implicitly organized by end time
- Interlaced sequences of auctions for essentially identical objects

eBay: sequential auctions with overlapping information

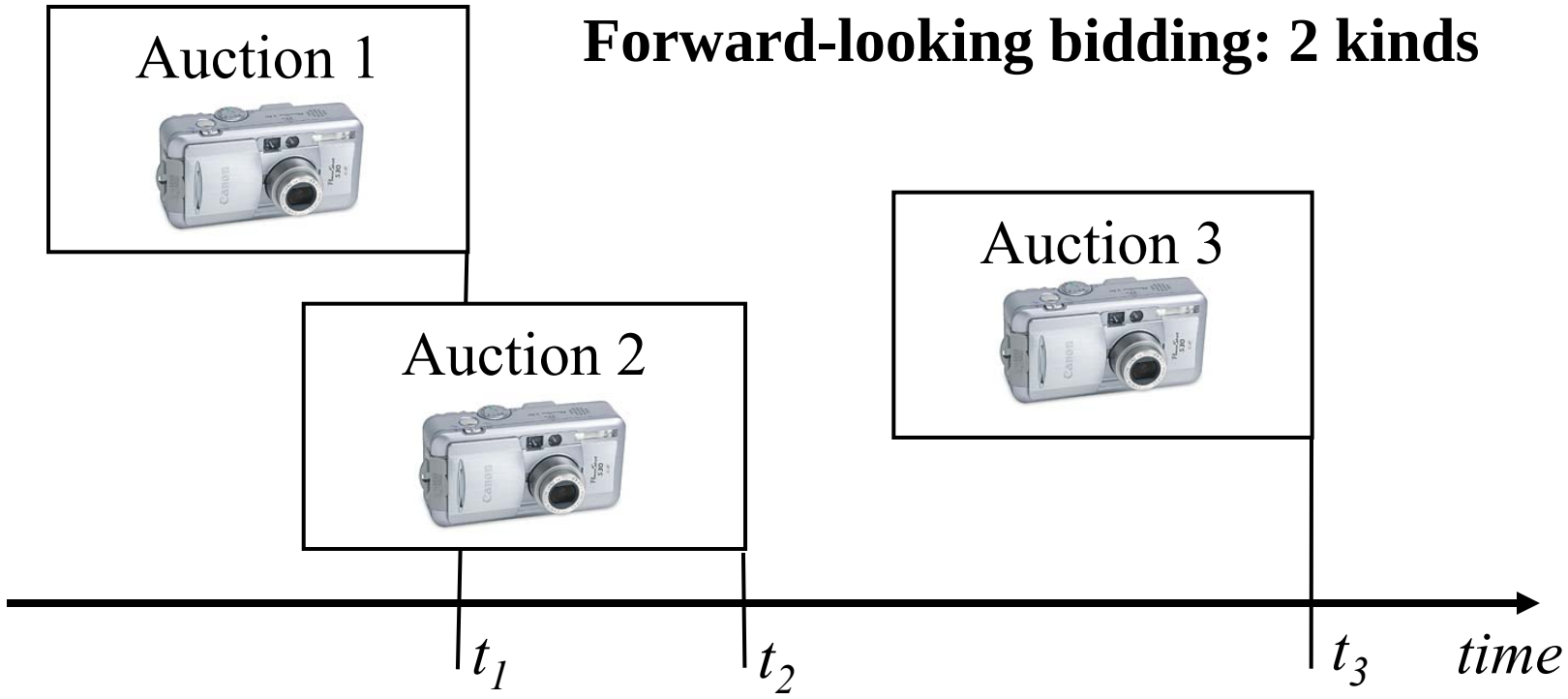


Research questions:

1) How to bid while incorporating the available information?

2) Do eBay bidders bid consistently with the theory?

Forward-looking bidding: 2 kinds



unit-demand → **option-value of losing** → bid-shading (below isolated auction)

How to bid in auction 1?

- given the known ("**forward-seen**") auction 2
- given a potential ("yet unseen") auction 3 (Jofre-Bonet & Pesendorfer 03)

Some related work (all unit-demand bidders)

- **Milgrom & Weber (82b,99)** :
  - finite sequences , identical units
  - no use for information about future auctions (all the same)
  - finite → no bidder-replacement needed → elegant solution
- **Engelbrecht-Wiggans (94)** , **Jofre-Bonet & Pesendorfer (03)** :
  - finite sequences, stochastically equivalent units (different but *iid* units)
  - no information about future auctions → symmetric and independent future
- **Gale & Hausch (94)** :
  - two auctions, different and potentially correlated units
  - $(v_1, v_2) \sim$ continuous F, both (v_1, v_2) known at the start
  - units not necessarily identical → disposal issues
  - very hard to extend to many auctions
  - Contrast: I will only allow $v_i \in \{v, 0\} \approx \{\text{"desired","other"}\}$

Model: One-period look-ahead, 2-type example

Infinite sequence of second-price, sealed-bid auctions

- varying waiting-times ω between individual auctions
- each auction sells one unit of a type-k good, k:{1,2}, Pr(k =1) = ½
- no reserve

N_k bidders present in every period, live until win or exit (Pr(*exit*)=λ per hour)

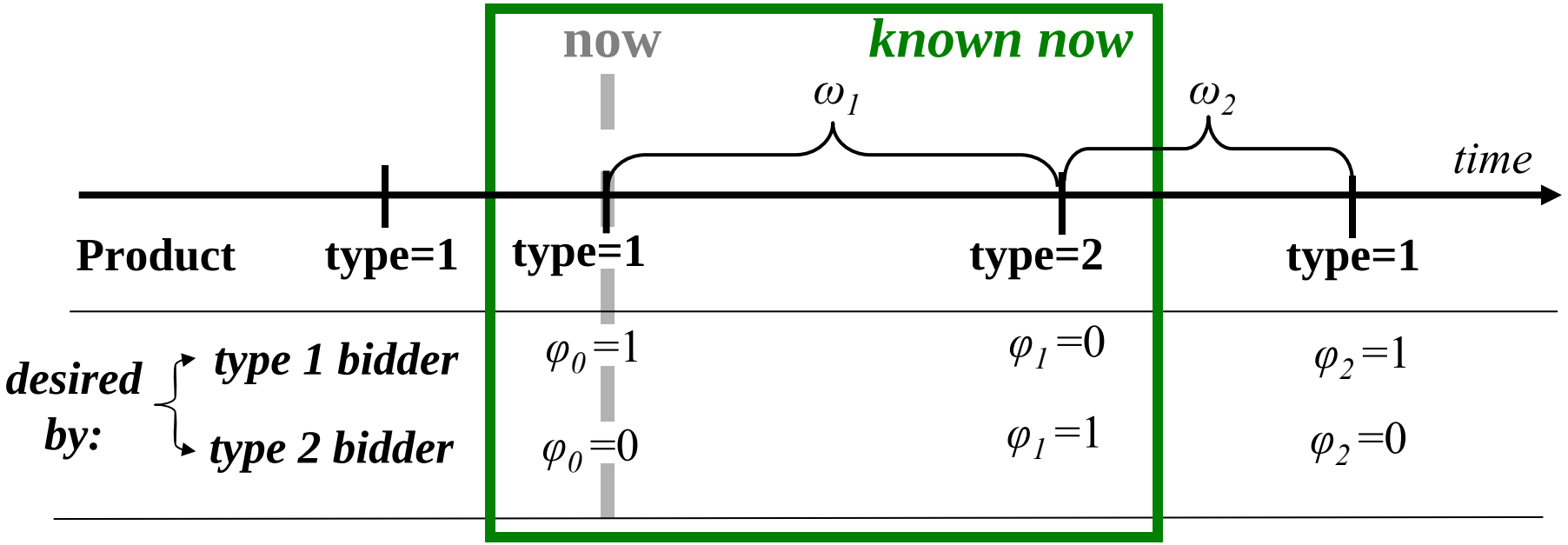
- unit-demand for only one type of good ("desired" type)
- IPV single-unit valuation of desired type, $v \sim F$ continuous
- **Info**: binary desirability of current unit φ_0 and next unit φ_1, waiting-time ω_1

Everyone discounts future δ per hour, no memory

Discussion of the assumptions

- Interlaced sequences of identical-goods auctions with non-overlapping pop.
- Some bidder-replacement essential (otherwise steady-state survivors v =0)
- Innovation: bids depend on forward-seen information (ω_1,φ_1)

Model: One-period look-ahead, 2-type example



$S(\varphi_0,\varphi_1,\omega_1,v_i \mid c_0)$:expected surplus given loss to current competitive bid $c_0 \sim G$

$$b(\varphi_0,\varphi_1,\omega_1,v) = \arg\max_{\beta} \int_{\beta}^{\beta} (\varphi_0 v - c_0)\, dG(c_0) + (\delta\lambda)^{\omega_1} \int_{\beta}^{\beta} S(\varphi_0,\varphi_1,\omega_1,v \mid c_0)\, dG(c_0)$$

1(current desired)

1(next desired)

time till next

valuation of desired

surplus if win now & pay c_0

key tradeoff

surplus if lose now to a bid c_0

Optimal Forward-Seeing Bidding

$$b(\varphi_0,\varphi_1,\omega_1,v)=\arg\max_{\beta\geq 0}\int_0^{\beta}(\varphi_0 v-c_0)\,dG(c_0)+(\delta\lambda)^{\omega_1}\int_{\beta}^{\beta}S(\varphi_0,\varphi_1,\omega_1,v\,|\,c_0)\,dG(c_0)$$

FOC: $b(1,\varphi_1,\omega_1,v)=v-(\delta\lambda)^{\omega_1}\,S\left(1,\varphi_1,\omega_1,v\,|\,c_0=b(1,\varphi_1,\omega_1,v)\right)<v$

$b(0,\varphi_1,\omega_1,v)=0$

SOC: $\dfrac{\partial S(1,\varphi_1,\omega_1,v\,|\,c_0)}{\partial c_0}>-\dfrac{1}{(\lambda\delta)^{\omega_1}}$

Properties:

- can show FOC has a unique solution, and that SOC satisfied
- bid-shading (a benefit to losing compared to isolated 2PSB)
- “pivotal thinking” : bid as if about to lose in a tie to a bidder like you

Equilibrium

Bellman condition: In a symmetric pure-strategy Markov-Perfect equilibrium, the expected surplus function must be "correct":

$$S\left(\varphi_{0,1},\omega_1,v\mid c_0\right)=E_{\varphi_2,\omega_2}\left[\int^{b\left(\varphi_{1,2},\omega_2,v\right)}\left(v-c_1\right)dG\left(c_1\mid c_0,\varphi_{0,1,2},\omega_{1,2}\right)+\left(\delta\lambda\right)^{\omega_2}\int_{b\left(\varphi_{1,2},\omega_2,v\right)}S\left(\varphi_{1,2},\omega_2,v\mid c_1\right)dG\left(c_1\mid c_0,\varphi_{0,1,2},\omega_{1,2}\right)\right]$$

S exists when F has a continuous density on a compact interval.

For a given F, S can be obtained by value-function iteration. Could this be a basis for a structural approach?

Bidders are not price-takers, take into account evolution of the pool of competitors.

Properties of equilibrium bidding

$b(\varphi_0, \varphi_1, \omega_1, v)$

Empirical strategy:

- positive only on desired type: $b = 0 \leftrightarrow \varphi_0 = 0$ — *assume (identification)*
- increase in waiting time ω_1 — *test*
- decrease in desirability of the forward-seen type φ_1 (1 vs. 0) — *test*
- increasing in v on desired type — *look at order stats given N*

Reduced-form test of model predictions

1) K+1 types, multi-period look-ahead with timing (**type-independent**) information Ω and product (**type-specific**) information Φ
   - eBay bidders usually see about a week ahead, could be many periods
   - Ω : auctions ending within the next hour marked in **red**, easy to see

2) Focus on a particular subset x of the state-variables (Ω,Φ) and integrate out the rest of the state, i.e. generate "on average" predictions given x:

   $\bar{b}(x,v) = E\left[b(1,\Phi,\Omega,v) \mid x\right]$ (example: x = # auctions ending within next hour)

3) If something is true for every valuation v, it will be true for the order-statistics of the valuations within each auction (keeping N constant)

4) Note that the first and second highest bids are observed in eBay data. => Regress bid order-statistics $b_{(j)}(x)$ on x (control for varying N)

Reduced-form test of forward-seeing bidding

Forward-seeing variables considered:

type-independent Ω :

- number of category auctions ending in the next hour

type-specific Φ :

1) time until next auction of the same type
2) 1(current type offered at least once within next five auctions)
3) {1(current type offered 1,2,3,4,5 auctions from now)}

} considered one at a time

Regression specification:

$$\overline{b}_{(m),i} = \underbrace{\alpha_{m,type(i)}}_{\substack{type/order\\ fixed\text{-}effect}} + \underbrace{\beta_m \Omega_i}_{\substack{type\text{-}indep.\\ forward\text{-}seeing}} + \underbrace{\gamma_m \Phi_{i,type(i)}}_{\substack{type\text{-}specific\\ forward\text{-}seeing}} + \underbrace{\theta_m z_i}_{\substack{controls:\\ \bullet\ number\ of\ unique\ bidders\\ \bullet\ seller\ reputation\\ \bullet\ new\ vs.\ used\ dummy\\ \bullet\ listing\ features\ (photo\ldots)}} + \varepsilon_{m,i}$$

i: observation (listing) uction *i* sells type

m: order of the order-statistic (either 1 or 2)

Two different datasets from eBay

2 datasets

• 1 month of top 30 movies on DVD in 2002 (**type** = title), 3113 listings

• 4 months of MP3 players in 2001 (**type** = brand X model)
further split because prices vary a lot:

- 15 Low-priced players (~$70, +/- $20), 1693 listings
- 15 High-priced players (~$180, +/- $60), 2451 listings

Weaknesses of the data

- only seller-provided descriptions to identify types
- number of unique bidders not perfectly observed

→ 3 (datasets) x 2 (order-stats) x 3 (type-spec variables) = 18 regressions

Preliminary evidence for predicted behavior

- Most eventual winners won only one unit within the data-period (93% in MP3-players and 87% in movies).

- A substantial number of bidders participated in more than one auction (43% in MP3-players and 33% in movies) and those who did mostly stuck to bidding on one product-type.

- It does not seem that the multi-auction bidders simply submitted a very low bid initially to learn about the auction process or their true valuation, and only later raised their bid to their "full" willingness to pay. (Of the multi-bidders, 49% in movies and 59% in MP3 players submitted a higher second bid).

Regression results

Predicted effects : Number within category in next hour ↓, Time until next identical ↑, Identical in next 5 auctions ↓, More distant future options gradually less effect.

DVD movies

type-independent: mostly not significant, predicted sign

type-specific : all as predicted:

- Average price ~$10 → effect size on price: 3-7%

MP 3 players

type-independent: as predicted, but small (double number of auctions in next hour ~ 2 % ↓)

type-specific :

- Low-price players: not significant, predicted sign
- High-priced players : all as predicted
- Average price ~$180 → effect size on price: 4-6% when the same type is available in the next 5 auctions, 1% when next delayed by 1 hour.

Regularity: 2nd highest bid (price) exhibits bigger effects than 1st highest bid. (?)

Results: movies

	Highest bid		2nd highest bid		Highest bid		2nd highest bid		Highest bid		2nd highest bid	
Variable	Estimate	*(t-stat)*	Estimate	*(t-stat)*	Estimate	*(t-stat)*	Estimate	*(t-stat)*	Estimate	*(t-stat)*	Estimate	*(t-stat)*
α (30 type-specific dummies)	suppressed for parsimony (mean 7.92, standard deviation 1.39, minimum 5.40, maximum 10.9)											
θ (top-seller dummy)	0.645	*(9.30)*	0.575	*(8.51)*	0.637	*(9.33)*	0.561	*(8.41)*	0.628	*(9.18)*	0.553	*(8.31)*
θ (new dummy)	0.756	*(10.63)*	0.826	*(11.87)*	0.747	*(10.70)*	0.817	*(11.93)*	0.748	*(10.71)*	0.825	*(12.05)*
θ (current competition)	0.128	*(8.81)*	0.094	*(6.20)*	0.127	*(8.89)*	0.096	*(6.38)*	0.125	*(8.71)*	0.094	*(6.26)*
β (log (# next hour+1))	-0.045	*-(0.83)*	0.033	*(0.63)*	-0.087	*-(1.74)*	-0.039	*-(0.80)*	-0.084	*-(1.68)*	-0.039	*-(0.81)*
γ (log time until next)	0.06	*(2.35)*	0.108	*(4.07)*								
γ (same type next 5 auctions)					-0.17	*-(1.92)*	-0.313	*-(3.51)*				
γ (same type 1 a. from now)									-0.348	*-(2.52)*	-0.722	*-(5.00)*
γ (same type 2 a. from now)									-0.433	*-(2.10)*	-0.385	*-(1.93)*
γ (same type 3 a. from now)									0.136	*(0.67)*	0.098	*(0.48)*
γ (same type 4 a. from now)									-0.051	*-(0.29)*	-0.182	*-(1.05)*
γ (same type 5 a. from now)									0.07	*(0.31)*	0.025	*(0.12)*
	N=3017	R^2=0.42	N=2356	R^2=0.53	N=3113	R^2=0.42	N=2431	R^2=0.53	N=3113	R^2=0.42	N=2431	R^2=0.53

- All three measures of type-**specific** future information as predicted
  - Time until next identical ↑, Identical in next 5 auctions ↓, More distant future options gradually less effect.
- Type-**independent** future information mostly not significant, predicted sign
- 2nd highest bid exhibits bigger effects than 1st highest bid. (?)
  - Average price ~$10, so effect size on price: 3-7%

Low-price players:	**Highest bid**		**2nd highest bid**		**Highest bid**		**2nd highest bid**		**Highest bid**		**2nd highest bid**	
Variable	Estimate	*(t-stat)*	Estimate	*(t-stat)*	Estimate	*(t-stat)*	Estimate	*(t-stat)*	Estimate	*(t-stat)*	Estimate	*(t-stat)*
α (15 type-specific dummies)	suppressed for parsimony (mean 65-70, standard deviation 19-20, minimum 40, max 103-108)											
θ (log (Seller Reputation+6))	0.869	*(2.92)*	0.038	*(0.16)*	0.803	*(2.79)*	0.041	*(0.17)*	0.799	*(2.77)*	0.037	*(0.16)*
θ (photo-listing dummy)	1.855	*(1.63)*	0.207	*(0.23)*	2.04	*(1.83)*	0.428	*(0.48)*	2.065	*(1.85)*	0.483	*(0.53)*
θ (bold-listing dummy)	-1.318	*-(0.53)*	-1.673	*-(0.88)*	-0.996	*-(0.41)*	-1.664	*-(0.89)*	-0.996	*-(0.40)*	-1.605	*-(0.86)*
θ (gallery-listing dummy)	4.633	*(3.03)*	4.322	*(3.56)*	4.339	*(2.90)*	4.092	*(3.43)*	4.331	*(2.89)*	4.088	*(3.42)*
θ (new dummy)	2.951	*(3.03)*	4.264	*(5.53)*	3.215	*(3.36)*	4.378	*(5.75)*	3.217	*(3.36)*	4.369	*(5.73)*
θ (current competition)	0.28	*(2.46)*	0.537	*(5.37)*	0.287	*(2.57)*	0.544	*(5.51)*	0.286	*(2.56)*	0.544	*(5.51)*
β (log (# next hour+1))	-2.578	*-(3.48)*	-2.392	*-(4.00)*	-2.587	*-(3.69)*	-2.576	*-(4.55)*	-2.596	*-(3.69)*	-2.596	*-(4.57)*
γ (log time until next)	0.048	*(0.15)*	0.176	*(0.70)*								
γ (same type next 5 auctions)					-0.965	*-(1.00)*	-0.358	*-(0.46)*				
γ (same type 1 a. from now)									-0.454	*-(0.34)*	0.296	*(0.27)*
γ (same type 2 a. from now)									-1.376	*-(0.68)*	-0.359	*-(0.23)*
γ (same type 3 a. from now)									-1.436	*-(0.73)*	-0.221	*-(0.14)*
γ (same type 4 a. from now)									-1.586	*-(0.73)*	-1.914	*-(1.07)*
γ (same type 5 a. from now)									-0.88	*-(0.39)*	-1.046	*-(0.56)*
	N=1645	R^2=0.63	N=1600	R^2=0.73	N=1693	R^2=0.63	N=1646	R^2=0.72	N=1693	R^2=0.63	N=1646	R^2=0.72
High-price players:												
Variable	Estimate	*(t-stat)*	Estimate	*(t-stat)*	Estimate	*(t-stat)*	Estimate	*(t-stat)*	Estimate	*(t-stat)*	Estimate	*(t-stat)*
α (15 type-specific dummies)	suppressed for parsimony (mean 186-171, standard deviation 57-58, minimum 99-114, max 316-334)											
θ (log (Seller Reputation+6))	0.729	*(1.67)*	1.332	*(3.41)*	0.816	*(1.89)*	1.405	*(3.60)*	0.787	*(1.82)*	1.392	*(3.57)*
θ (photo-listing dummy)	0.009	*(0.01)*	0.977	*(0.85)*	-0.162	*-(0.13)*	0.746	*(0.65)*	-0.102	*-(0.08)*	0.852	*(0.74)*
θ (bold-listing dummy)	4.427	*(1.50)*	2.597	*(1.00)*	4.369	*(1.49)*	2.898	*(1.12)*	4.176	*(1.42)*	2.693	*(1.04)*
θ (gallery-listing dummy)	1.088	*(0.45)*	-1.11	*-(0.51)*	0.966	*(0.40)*	-1.228	*-(0.57)*	1.146	*(0.48)*	-1.171	*-(0.54)*
θ (new dummy)	7.112	*(5.07)*	7.131	*(5.65)*	7.259	*(5.21)*	7.112	*(5.62)*	7.117	*(5.10)*	6.918	*(5.47)*
θ (current competition)	0.582	*(3.90)*	0.646	*(4.64)*	0.536	*(3.62)*	0.634	*(4.55)*	0.538	*(3.64)*	0.64	*(4.60)*
β (log (# next hour+1))	-5.057	*-(4.58)*	-3.542	*-(3.61)*	-6.755	*-(6.61)*	-5.783	*-(6.35)*	-6.577	*-(6.41)*	-5.522	*-(6.05)*
γ (log time until next)	2.617	*(5.51)*	3.232	*(7.73)*								
γ (same type next 5 auctions)					-7.441	*-(4.89)*	-8.172	*-(6.07)*				
γ (same type 1 a. from now)									-8.83	*-(4.95)*	-10.248	*-(6.57)*
γ (same type 2 a. from now)									-7.624	*-(3.55)*	-7.696	*-(4.04)*
γ (same type 3 a. from now)									-8.364	*-(3.37)*	-8.959	*-(3.97)*
γ (same type 4 a. from now)									-3.214	*-(1.13)*	-4.832	*-(1.86)*
γ (same type 5 a. from now)									-4.023	*-(1.22)*	-1.389	*-(0.49)*
	N=2317	R^2=0.86	N=2393	R^2=0.88	N=2372	R^2=0.85	N=2451	R^2=0.87	N=1693	R^2=0.85	N=1646	R^2=0.87

Discussion of the empirical findings

- Forward-seeing effects operate on eBay (3-7% price-reduction when the same type available within next 5 auctions, controlling for # bidders)

$\Rightarrow$ Fairly high lower bound on bidder-sophistication

$\Rightarrow$ Direction for specifying future more fine-grained structural models

$\Rightarrow$ Analysts interested in demand-estimation should not interpret eBay auctions as repeated isolated auctions (downward bias)

- There may be forward-looking bid-shading beyond the reaction to already-listed "forward-seen" future auctions.

$\Rightarrow$ Sellers may want to take note: such forward-looking bid-shading is a response to a seller strategy; bidding depends on selling and vice versa.

- Relevance beyond eBay: most sequences have look-ahead preannouncements...