How Much Is a Dollar Worth? Tipping versus Equilibrium Coexistence on Competing Online Auction Sites

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Theory models of platform competition predict that prices and buyer-seller ratios should be approximately equal on coexisting auction sites. Using field experiments on eBay and Yahoo Auctions, we find evidence that is inconsistent with equilibrium hypotheses and suggest that the market is tipping. Prices on eBay are consistently 20–70 percent higher than those on Yahoo, and eBay attracts two additional buyers per seller. On Yahoo, prices and bidders counts are unaffected by the auction ending rule. Various differences between the sites cannot account for the magnitude of these disparities. However, a model of imitation dynamics can rationalize our findings.

I. Introduction

With over 83 million active users listing more than 1 billion items per year, eBay dominates the online auction industry (eBay 2008). In 2001,

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it had a 64.3 percent market share in the United States (Nielsen/NetRatings and Harris Interactive 2001). At the time, eBay dwarfed Yahoo, its most notable rival; however, even with a mere 3 percent market share, Yahoo Auctions had hundreds of thousands of listings and members.[1] Both sites brought online users together to buy and sell a wide range of goods, from the unusual to the mundane, in what has been called a "vast electronic garage sale" (Resnick and Zeckhauser 2002, 128).

Competition in global online auction markets has often been winner take all. In 2001, Yahoo overwhelmed eBay in Japan, whereas, in 2002, eBay's dominance forced the closure of Yahoo Auctions in Europe. The two rivals seemed to fight to a draw in the U.S. market. That situation changed in June 2007 when Yahoo Auctions shuttered its North American operations, a move that coincided with a management shake-up that saw the return of Jerry Yang as Yahoo's chief executive officer.

Whereas the pattern of competition between eBay and Yahoo suggests that tipping to a single platform is inevitable, Ellison, Fudenberg, and Möbius (2004) offer a model in which both platforms can coexist in equilibrium.[2] They suggest that the law of one price should hold across competing sites; that is, eBay and Yahoo buyers should pay approximately the same amount for identical items. Furthermore, coexisting sites should have similar ratios of buyers to sellers. When a market is in the process of tipping, there is no reason to expect either similar prices or similar buyer-seller ratios across platforms.

To study tipping and coexistence, we conduct a series of field experiments with collectible coins, comparing prices and buyer-seller ratios across platforms. Field experiments offer several advantages over data from uncontrolled transactions. First, field experiments eliminate the problem of unobserved product and seller heterogeneity. Second, by using experiments, we control for differences in product mix across the sites. Finally, experiments let us isolate the effects of the selling procedure, without the usual endogeneity problems.

We find little evidence of equilibrium coexistence in the U.S. market. The law of one price does not hold: eBay buyers pay 20–70 percent more than Yahoo buyers for identical items. Moreover, buyer-seller ratios are far from equal: an eBay auction attracts, on average, 50 percent more buyers per seller than an identical Yahoo auction. We supplement our experimental results with field data that confirm not only the presence of the price and buyer-seller ratio disparity but also its persistence

[1] Ubid.com and egghead.com had 15 and 4 percent of the online auction market share in 2001, respectively. Both sites differ from eBay and Yahoo: ubid provides business-to-buyer auction services only, whereas egghead auctioned computers and computing accessories before being acquired by Amazon.com in December 2001.

[2] See also Ellison and Fudenberg (2002) for a more general treatment.

over time. Switching costs, vertical differentiation, trust, and liquidity cannot account for the magnitude of the disparity. However, a model in which platform choice is driven by imitation dynamics can rationalize our results.

Our empirical work examines one specific category of products, yet the tipping phenomenon has widespread relevance. First, Yahoo's persistent presence in the U.S. market may have provided a check on eBay's market power; Yahoo's exit has obvious antitrust implications. Our findings also have important policy implications for China, India, and other developing markets in which competition among online auction platforms is still in flux. Indeed, in these areas, Yahoo and eBay are rapidly acquiring smaller auction platforms. We believe our results suggest that competition authorities in these countries must scrutinize these transactions if they wish to prevent a single player from exerting considerable market power.

Online auctions are not unique in their tipping potential. Our work has implications for other "two-sided markets" (see Rochet and Tirole 2003). For instance, the online dating industry shares many of the features of online auctions. Will dating end up as winner take all, or can sites like Yahoo Personals and Match.com continue to coexist?

We also use the field experiment data to test the effect of ending rules and reserve prices on auction revenues. By allowing the seller to choose either a fixed or a variable ending time, Yahoo offers an ideal venue for reexamining the observations about ending-rule effects first made by Roth and Ockenfels (2002). They observed that hard-close auctions on eBay led to considerably more late bidding than did soft-close auctions on Amazon. The theory model in Ockenfels and Roth (2006) rationalizes this difference and implies further that expected revenues should be higher in soft-close auctions. Of course, it is difficult to test this hypothesis using field data, owing to the many differences between the two auction platforms. Using controlled laboratory experiments, Ariely, Ockenfels, and Roth (2005) observe higher revenues and earlier bidding in soft-close auctions. To our knowledge, we are the first to use field experiments to study the effects of ending rules. Somewhat surprisingly, at least compared to our prior beliefs, we find that the choice of ending rules on the Yahoo site has no effect on bid timing, number of bidders, or auction revenues.

The remainder of this section highlights some additional related work, both theoretical and empirical. Section II presents the relevant theory underlying the experiments. Section III outlines the experiments. Section IV describes key results of the statistical analysis. Section V explores several alternative hypotheses, including a disequilibrium model. Our conclusions appear in Section VI.

The question of when markets will tip dates back to the seminal paper

of Schelling (1972). More recent theoretical studies examining competing markets include, among others, McAfee (1993), Peters and Severinov (1997), Gehrig (1998), van Raalte and Webers (1998), Baye and Morgan (2001), Ellison and Fudenberg (2002, 2003), Caillaud and Jullien (2003), Rochet and Tirole (2003), and Schwartz and Ungo (2003). Whereas there is a burgeoning literature on field experiments using auctions (e.g., Lucking-Reiley 1999, 2000; Katkar and Lucking-Reiley 2000; List and Lucking-Reiley 2000, 2002; Hossain and Morgan 2006; Jin and Kato 2006; as well as Reiley 2005, 2006), to the best of our knowledge, we are the first to use field experiments to examine the question of tipping versus equilibrium coexistence of competing auction sites.

II. Theory

A. *Static Equilibrium Model*

Ellison et al. (2004) characterize the set of equilibria in a static model of platform competition. Two forces determine buyer and seller location: The "scale effect" leads to concentration since more buyers and sellers on a single site lead to higher surplus for all participants. The countervailing "market impact effect" favors site multiplicity since competition on the same side of the market decreases the surplus of a given participant: both buyers and sellers prefer to locate where they compete with fewer other agents of the same type. Whereas tipping to either platform constitutes an equilibrium, the surprising finding of Ellison et al. (2004) is that these offsetting effects also permit the equilibrium coexistence of auctions with very unequal market shares. Below, we derive two testable hypotheses that arise from their static equilibrium model.

Two auction sites compete in a market with B buyers and S sellers. Each seller wishes to sell one unit of a homogeneous product. Each buyer has unit demand for the good and a willingness to pay of v, where v is drawn from a uniform distribution on the unit interval. The objects are allocated by uniform price auctions on two competing online auction sites $a \in \{e, y\}$, where e and y are mnemonics for eBay and Yahoo. Buyers and sellers simultaneously choose the site a on which they will trade. All agents are assumed to "single-home": they restrict their activities to only one site. Let (s_a, b_a) denote the number of sellers and buyers choosing to participate on site a. After participants have chosen their preferred platform, buyers learn their valuations, and the auctions are conducted.

Given an allocation of buyers and sellers, the payoff to a seller is the price received. When b_a buyers and s_a sellers participate on site a and

$b_a > s_a + 1$ (i.e., there is no excess supply), then the expected price is simply the expected value of the $s_a + 1$st highest of b_a draws from a uniform distribution:

$$u_s(s_a, b_a) = \bar{p}(s_a, b_a) = \frac{b_a - s_a}{b_a + 1}. \tag{1}$$

A buyer's payoff is equal to her expected surplus—the difference between her willingness to pay and the expected price paid times the probability of receiving an item. Conditional on receiving an item, a buyer's expected willingness to pay is $\mathrm{E}(v|v > v^{s_a+1:b_a})$, where $v^{s_a+1:b_a}$ is the realized price:

$$\begin{aligned} w(s_a, b_a) &= \mathrm{E}(v|v > v^{s_a+1:b_a}) \\ &= \int_0^1 \left(\frac{1+x}{2}\right) f^{s_a+1:b_a}(x)\,dx. \end{aligned}$$

Since $f^{s_a+1:b_a}(x)$ is a beta density with parameters $b_a - s_a$ and $s_a + 1$, it follows that

$$w(s_a, b_a) = \frac{1}{2}\left(\frac{2b_a - s_a + 1}{b_a + 1}\right).$$

The buyer's probability of receiving an object is equal to the seller-buyer ratio on the site since buyers are ex ante identical. Thus, the probability that a buyer receives an object is simply s_a/b_a, and her expected payoff is

$$\begin{aligned} u_b(s_a, b_a) &= [w(s_a, b_a) - \bar{p}(s_a, b_a)]\,\Pr\,(v > v^{s_a+1:b_a}) \\ &= \frac{1}{2}\frac{s_a(s_a+1)}{b_a(b_a+1)}. \end{aligned} \tag{2}$$

An equilibrium consists of an allocation of buyers and sellers such that neither type has an incentive to switch platforms. That is, the competitive effect of an additional seller is enough to offset price differences between the platforms. Similarly, the competitive effect of an additional buyer is enough to raise price sufficiently to wipe out any "bargains" on the lower-priced platform.

Using the equilibrium condition for the seller and equation (1), we have

$$\bar{p}(s_y + 1, b_y) \le \bar{p}(s_e, b_e),$$

$$\bar{p}(s_e + 1, b_e) \le \bar{p}(s_y, b_y).$$

Empirically, the addition of a single seller in a relatively thick market is likely to have little effect on price and hence:

HYPOTHESIS 1 (Price equalization). If eBay and Yahoo are coexisting in equilibrium, then the average prices on the two sites for the same item should be approximately equal.

Our second hypothesis comes from the equilibrium condition for buyers and equation (2):

$$\frac{1}{2}\frac{s_y+1}{b_y+1}\frac{s_y}{b_y+2} \leq \frac{1}{2}\frac{s_e+1}{b_e+1}\frac{s_e}{b_e},$$

$$\frac{1}{2}\frac{s_e+1}{b_e+1}\frac{s_e}{b_e+2} \leq \frac{1}{2}\frac{s_y+1}{b_y+1}\frac{s_y}{b_y}.$$

When markets are large, as is the case on eBay and Yahoo, the seller-buyer ratio on site a, γ_a, satisfies $\gamma_a \equiv s_a/b_a \approx (s_a + k)/(b_a + l)$ for all finite k and l, and the above inequalities reduce to

$$(\gamma_y)^2 \leq (\gamma_e)^2,$$

$$(\gamma_e)^2 \leq (\gamma_y)^2,$$

and hence:

HYPOTHESIS 2 (Buyer-seller ratio equalization). If eBay and Yahoo are coexisting in equilibrium, then the average number of buyers per seller on each site should be approximately equal.

B. *Dynamic Disequilibrium Model*

Whereas static equilibrium analysis is appropriate for markets in a steady state, one might worry that "immature" online auction markets have yet to reach equilibrium. In this case, a dynamic model of disequilibrium might prove useful. To examine this possibility, we study behavior in Ellison et al.'s (2004) model when platform choice is characterized by a simple deterministic replicator dynamic. As Gintis (2000) suggests, this dynamic might arise when a fraction of buyers or sellers learn the payoff of another randomly chosen agent of the same type and probabilistically imitate the more successful strategy.

In this framework, there are two types of buyers and sellers—those who go to eBay and those who go to Yahoo. The state of the system at any point in time is summarized by the pair (s, b), the number of sellers and buyers who are eBay types. The remaining $S - s$ sellers and $B - b$ buyers are Yahoo types. Suppose that S and B are large enough that we can neglect integer constraints. Types evolve in proportion to the payoffs

from their strategy relative to the average payoffs in the population. For seller types, this amounts to

$$\dot{s} = s\left[\pi_e - \left(\frac{s}{S}\pi_e + \frac{S-s}{S}\pi_y\right)\right]$$
$$= s\left(\frac{S-s}{S}\right)(\pi_e - \pi_y);$$

whereas for buyer types, we have

$$\dot{b} = b\left(\frac{B-b}{B}\right)(u_e - u_y),$$

where π_a and u_a for $a \in \{e, y\}$ are the expected payoffs to sellers and buyers, respectively, in state (s, b). Using the payoff expressions given in equations (1) and (2), the system becomes

$$\dot{s} = s\left(\frac{S-s}{S}\right)\left[\frac{b-s}{b+1} - \frac{B-b-(S-s)}{B-b+1}\right], \tag{3}$$

$$\dot{b} = \frac{1}{2}b\left(\frac{B-b}{B}\right)\left[\frac{s(s+1)}{b(b+1)} - \frac{(S-s)(S-s+1)}{(B-b)(B-b+1)}\right]. \tag{4}$$

A fixed point of this system is a state (s^*, b^*), where $\dot{s} = \dot{b} = 0$. Equations (3) and (4) reveal states $(0, 0)$ and (S, B) as fixed points. In other words, once the market has tipped, it remains tipped. Perhaps of greater interest are fixed points where the two sites coexist. Whereas there is typically a continuum of interior equilibria in Ellison et al.'s (2004) model, imitation dynamics always produce a unique interior fixed point given by $(S/2, B/2)$. Formally,

PROPOSITION 1. Under imitation dynamics, equilibrium coexistence occurs only when both platforms enjoy equal market shares.

What accounts for the differences between Ellison et al.'s (2004) model and imitation dynamics? In Ellison et al.'s model, market impact effects sustain equilibrium coexistence. Small price differences between platforms do not induce sellers and buyers to switch because increased competition would wipe out any possible gains. Under imitation dynamics, agents may be thought of as boundedly rational. They simply gravitate toward whichever platform offers higher payoffs, not accounting for the competitive impact of their decision. In other words, the disciplining force of the market impact effect vanishes when agents merely imitate more successful strategies.

Next, we study the stability properties of the fixed points. The Hartman-

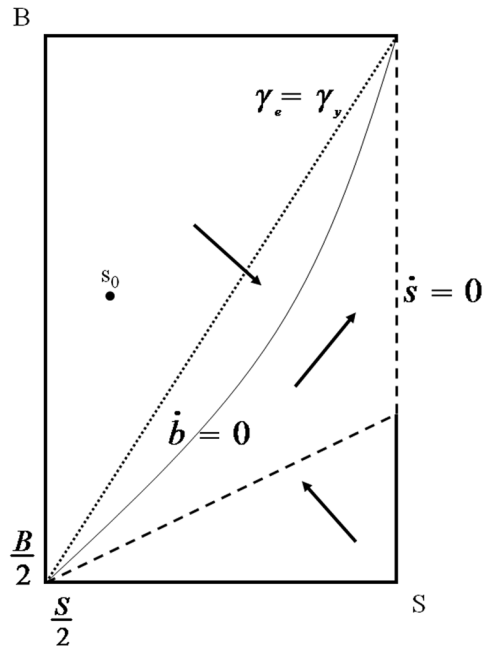

FIG. 1.—Phase diagram for replicator dynamics

Grobman theorem (see Nayfeh and Balachandran 1995, 62–63) states that the stability properties in the neighborhood of a fixed point may be understood by considering the eigenvalues of a linearization of the system evaluated at the fixed point. Performing this analysis, we find

PROPOSITION 2. The interior fixed point ($s_1 = S/2, b_1 = B/2$) is a saddle point, whereas the tipped fixed points ($s = 0, b = 0$) and ($s = S, b = B$) are attractors.

Proposition 2 shows that, for almost all initial states, the system will eventually tip. Figure 1 presents a phase diagram of the system for the region where eBay starts out with the majority of buyers and sellers. The dashed line in the figure, labeled $\dot{s} = 0$, represents the locus of states in which prices on the platforms are equal. The dotted line, labeled $\gamma_e = \gamma_y$, represents the locus of states in which the buyer-seller ratios are equal. Owing to scale effects, as the number of sellers on eBay increases, the buyer-seller ratio must become increasingly uneven for prices to be equal; hence the divergence between the $\dot{s} = 0$ and $\gamma_e = \gamma_y$ lines up to the tipping point. The line labeled $\dot{b} = 0$ represents the locus of states in which buyers enjoy the same surplus on both sites. Again owing to scale effects, this line lies (almost) everywhere below

the line where buyer-seller ratios are equal. The black arrows in the figure indicate the signs of $\dot{s}$ and $\dot{b}$ in each state.

It is interesting to examine the model's market share dynamics. When the state of the system is close to the saddle point, it evolves slowly because prices and surplus are relatively equal across the two sites. The limiting version of this behavior can be seen in trajectories that intersect the saddle point; these take infinite time to converge. In contrast, when market shares are very unequal, there are either large price or surplus differences between the sites, and this results in rapid imitation. Indeed, once the state lies inside the cone formed by the $\dot{b} = 0$ and $\dot{s} = 0$ lines, both buyers and sellers favor eBay, and the system collapses to a single platform in finite time. Thus, while the disequilibrium model does not admit stable coexistence of the sites, it produces behavior qualitatively similar to the static model: two sites can persist for a considerable period of time.

III. Experiments

We test directly the price equalization and buyer-seller ratio hypotheses using eBay and Yahoo Auctions. At the time of our experiments, Yahoo was one-tenth the size of eBay, and its coin market was thick and active; searches for "Morgan Dollars (1878–1921)" on eBay and Yahoo, performed November 5, 2004, revealed 12,559 and 1,209 items for sale, respectively.[3]

Online auctions provide platforms on which individuals and firms can trade a wide variety of items. Listings can be searched by keywords, broad categories, and price ranges. Visitors may search without logging in, whereas bidders and sellers must register a user name and password. Sellers may post product descriptions, digital images, and other information on the product page. Sellers pay fees for their listings.[4] Neither

[3] EBay lists many items not available on Yahoo. Moreover, the Yahoo-eBay listing ratio for collectible coins does not hold across all common item categories; on March 12, 2005, Yahoo-eBay ratios were approximately 1 : 3, 1 : 6, and 1 : 20 for antique books, antique firearms, and collectible beanie babies, respectively. The quality of many collectibles is not established systematically as it is with graded coins, making direct product and price comparisons between the sites difficult. While suggesting that relative market thickness is not consistent across product categories, these overall differences between the sites do not detract from the remarkable results outlined below.

[4] Throughout the experiments, Yahoo's fees were two-part: listing fees were based on the starting price of the sale item, ranging from \$0.05 for low-value items to \$0.75 for prices over \$50, and the final value fee was 2 percent of the final value up to \$25 and 1 percent of the remaining closing price. Reserve fees were \$0.40 or \$0.75, depending on chosen value. EBay's fees were higher than Yahoo's fees. EBay's listing fees ranged from \$0.30 to \$4.80, and the final value fee was 5.75 percent of the initial \$25 and 2.75 percent of the remaining value up to \$1,000. Reserve fees were \$1 or \$2, depending on the chosen reserve. EBay also charged for displaying more than one photo (\$0.15 each), highlights, borders, and other display options. To compare site fees, consider the sale of a \$100 coin

TABLE 1
AUCTIONED COINS

Item	Item Description	PCGS Book Value ($)	Dealer Price ($)
1	1878-S Morgan Dollar NGC Slab MS-64	105	73
2	1885-O Morgan Dollar NGC Slab MS-63	42	35
3	1898-O Morgan Dollar NGC Slab MS-65	145	89
4	1902-O Morgan Dollar NGC Slab MS-65	145	98
5	1904-O Morgan Dollar NGC Slab MS-64	60	41
6	1922-P Peace Dollar NGC Slab MS-63	32	25
7	1923-P Peace Dollar NGC Slab MS-64	55	30
8	1923-P Peace Dollar NGC Slab MS-65	165	79

NOTE.—NGC = Numismatic Guaranty Corporation of America. Professional Coin Grading Service (PCGS) book values were available at http://pcgs.com, August 1, 2004. Dealer price was our cost from a coin dealer in southern California.

site charges bidders for participation. Both sites use a proxy bidding system: buyers submit their maximum bid, and, as price increases, bids are submitted automatically on their behalf up to their indicated maximum. The current price is set at the second-highest bidder's maximum bid plus some small increment and is updated as new high bids are received.[5] All eBay auctions have a fixed ending time, whereas Yahoo auctions allow sellers to choose between two ending rules: a hard-close rule that specifies an exact ending time and a soft-close rule for which the auction is extended by 5 minutes if a bid is placed close to the auction end. A small ending-rule indicator appears on the Yahoo item description screen.[6]

Experiments on eBay and Yahoo, conducted between August 2003 and November 2004, address the hypotheses in Section II. Eight types of Morgan and Peace Dollar series coins, described in table 1, were purchased from a dealer in California. Before purchase, the coins were professionally graded and sealed by the Numismatic Guaranty Corporation of America. Each encapsulated coin was marked with the date, denomination, grade, and an identification number. Table 1 lists the prices that we paid the dealer, as well as the book value posted by the Professional Coin Grading Service (PCGS) on August 1, 2004. Book value is an estimate of a coin's retail price, compiled from trade paper advertisements, dealer fixed price lists, significant auctions, and activity at major coin shows. Note that the book values of our coins are higher than our purchase prices.

with three photos, no reserve, and a $50 starting price. Yahoo's fees would amount to $2, whereas eBay would collect $6.08 from the sale.

[5] On both sites, increments depend on current price, ranging from less than $1 for items valued below $100 to $100 for items valued over $5,000.

[6] For the hard-close ending rule, the text states, "This auction does not get automatically extended." For the soft-close rule, the text states, "Auction may get automatically extended."

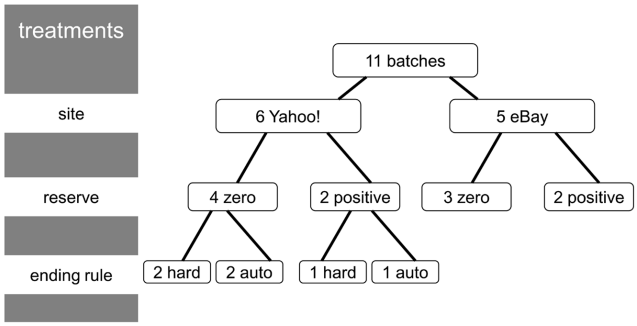

FIG. 2.—Experimental design

We chose coins that are popular yet not particularly rare. Furthermore, the market is thick enough to limit our effect on market prices and to conceal the experimental nature of our auctions.[7] All coins were sold with nearly identical descriptions, varying only by coin age and rating, with three digital photographs.[8] All auctions were 7 days. We varied the reserve price through the opening bid amount rather than using the secret reserve option. We offered free shipping and handling in all auctions.

We divided the coins into batches of eight different Morgan and Peace silver dollars identified in table 1. In total, we conducted 88 auctions (11 batches). All the coins in a batch were auctioned using the same site, ending rule, and reserve. Our treatments consist of varying the identity of the site, the ending rule, and the reserve price. The paired design, depicted in figure 2, allows for comparison between sites holding reserve price and ending rule constant and within sites varying reserve price and ending rule. The complete experimental design is summarized below.

Baseline.—We test the predictions of hypotheses 1 and 2 in the simplest possible fashion. We auctioned two batches of coins on Yahoo and three batches on eBay, specifying a zero reserve and a hard close.[9]

High reserve.—We conducted auctions with positive reserve values to examine hypotheses 1 and 2 in the presence of a significant reserve price. Starting prices in positive-reserve auctions were equal to 70 per-

[7] This mitigates any behavior changes that could arise as a consequence of bidders' awareness of the experimental aspect of the auctions.

[8] The text below the photographs was, "The coin shown is the exact coin you will receive. Sealed in NGC slab. Free shipping and handling with USPS first class. Picture cannot capture all details, please go with grading. Payments can be made via paydirect, paypal, cash and money order only."

[9] The no-reserve treatment used a reserve of $1, a trivial price relative to the coins' actual values.

cent of the purchase price of the coins from the dealer. Two batches of coins were auctioned on each site under this treatment.[10]

Ending rule.—Ockenfels and Roth (2006) suggest that an auction's ending rule may affect revenue. Yahoo offers sellers the choice of a hard or soft close, whereas eBay offers only a hard close. To investigate ending-rule effects, we auctioned fours batches of coins on Yahoo with a zero reserve: two batches used the hard-close rule, and two used the soft-close rule. We also sold two batches on Yahoo with a 70 percent reserve price: one with the hard close and one with the soft close.

Yahoo and eBay maintain reputation ratings for users. Reputation values reflect users' reviews from previous transactions; positive feedback increases a user's rating by one point, whereas negative feedback reduces the rating by one point. Since previous studies have identified reputation effects on sales (Resnick and Zeckhauser 2002), the seller's name and reputation rating were identical for all items auctioned on each site. Our reputation values were reasonably high: 87 and 245 for Yahoo and eBay, respectively.

The auctions were posted on Tuesday, Wednesday, or Thursday evenings. We scheduled these auctions in advance, so that all auctions in a batch were posted at approximately the same time. The field experiments were monitored only through the seller's portal, to ensure that page view counts were not affected. Upon auction completion, the product and bidding history pages were saved electronically. All items were shipped promptly to the winners, and payments were received in full. Whereas field data suffer from unobserved heterogeneities, our field experiments hold constant product quality, product description, shipping fees, auction length, and seller identity.

IV. Results

Table 2 presents descriptive statistics for the experiments, pooled by site. Five Yahoo auctions finished without a sale and were dropped from the data.[11] The average revenues and numbers of bidders were higher on eBay compared to Yahoo under all treatments. Consistent with auction theory, the presence of a reserve price raises revenues and reduces the average number of bidders. Bidders typically placed one or two bids in a given auction, with slightly more multiple bidding on eBay. Winning

[10] For the Yahoo auctions, one batch was auctioned with a hard close and one with a soft close. Ending rules have no effect on auction revenues. Thus, we pool these two batches for the high-reserve tests.

[11] Failure to sell is not simply a case of censoring revenue. While an unsuccessful seller loses the fees paid to the site, he may attempt to sell the item again in a subsequent auction. That is, revenue from a failed posting is not zero; it is simply delayed and eroded by additional fees.

TABLE 2
FIELD EXPERIMENT SUMMARY STATISTICS

	Mean Values	
	eBay	Yahoo
Revenue ($):		
Hard close, no reserve	59.88	46.71
	(30.94)	(25.39)
Hard close, positive reserve	66.41	50.14
	(35.27)	(29.37)
Soft close, no reserve	. . .	49.37
		(23.58)
Soft close, positive reserve	. . .	47.33
		(29.40)
Number of bidders:		
Hard close, no reserve	7.25	5.13
	(2.23)	(3.10)
Hard close, positive reserve	4.38	2.17
	(1.67)	(1.17)
Soft close, no reserve	. . .	5.36
		(2.68)
Soft close, positive reserve	. . .	2.43
		(1.27)
Bids/auction	9.38	7.88
	(4.74)	(6.61)
Bids/bidder	1.56	1.98
	(1.44)	(1.62)
Winning bidder reputation	262.67	232.12
	(692.47)	(420.19)
Minutes from close:		
All bids	2,938.73	3,854.58
	(3,345.79)	(3,404.11)
Winning bid	296.05	1,048.36
	(874.05)	(2,351.53)
Observations:		
Auctions	40	43
Bids	374	368

NOTE.—Standard deviations are in parentheses.

bidders were quite experienced, with average feedback scores of approximately 263 on eBay and 232 on Yahoo. Winning bidders were not "snipers" submitting bids only seconds before the auction close; the last bid by the winning bidder was entered an average of 296 minutes (almost 5 hours) before the close on eBay and 1,050 minutes (17.5 hours) before the close on Yahoo. On average, we received 9.38 and 7.88 bids per auction on eBay and Yahoo, respectively.

Hypotheses 1 and 2 suggest that both revenues and numbers of bidders per auction should be approximately equal across the two sites. As shown in table 3, average Yahoo revenues are lower than average eBay revenues for each coin type: eBay buyers paid between 20 and 70 percent more than Yahoo buyers for identical items. Table 3 also suggests that the average number of unique bidders per auction is lower on Yahoo

TABLE 3
DESCRIPTIVE STATISTICS BY COIN TYPE

	Item							
	1	2	3	4	5	6	7	8
Revenue ($):								
Yahoo	58.66	25.06	77.81	83.33	37.36	16.75	19.66	54.37
	(5.14)	(2.93)	(4.31)	(6.22)	(4.76)	(.96)	(4.27)	(6.23)
eBay	71.54	32.80	97.13	110.52	44.73	23.91	33.33	85.96
	(3.98)	(2.16)	(15.02)	(15.98)	(4.28)	(3.03)	(4.85)	(11.12)
Yahoo-eBay price spread (%)	21.95	30.88	24.83	32.63	19.73	42.72	69.52	58.11
Number of bidders/auction:								
Yahoo	4.17	2.83	5.17	5.50	4.83	2.33	2.67	4.50
	(2.64)	(1.47)	(3.06)	(2.59)	(3.37)	(2.16)	(2.42)	(4.28)
eBay	5.60	4.60	7.20	7.60	6.40	5.20	4.60	7.60
	(2.97)	(2.70)	(1.92)	(2.41)	(3.36)	(1.48)	(1.82)	(1.52)
Yahoo-eBay bidder count spread (%)	34.29	62.54	39.26	38.18	32.51	123.18	72.28	68.89

NOTE.—Standard deviations are in parentheses. Yahoo-eBay price spread is the price difference of eBay and Yahoo as a percentage of the average price on Yahoo. Yahoo-eBay bidder count spread is the difference in the number of bidders on eBay and Yahoo as a percentage of the average price on Yahoo.

than on eBay for each coin type: there were 35–120 percent more bidders per auction on eBay compared to Yahoo.[12]

The summary statistics in table 3 suggest the presence of arbitrage opportunities. For example, a user could buy a 1902 Morgan Dollar (coin 4) on Yahoo for an average price of $83 and sell it on eBay for $110. After eBay and postage fees (totaling $6 and $2, respectively), the arbitrageur would earn a profit of $19 on a single coin.[13]

Table 3 is merely suggestive of significant differences across the sites; we test hypotheses 1 and 2 formally using econometric techniques. Let revenue_{air} denote the revenue obtained from an auction held at site a for coin i under treatment r. Hypothesis 1 suggests the following econometric specification:

$$\text{revenue}_{air} = \beta_0 + \beta_1 \text{site}_{air} + \gamma X_{ir} + \varepsilon_{air}, \tag{5}$$

[12] We construct the bidder count variable by observing the number of unique bidder identification names participating in an auction. To the extent that the same physical bidder places multiple bids under different user IDs, we would be overcounting the number of bidders. However, given the high average "experience level" of our bidders (with feedback ratings of 232.1 on Yahoo and 262.7 on eBay), this does not seem to be a serious issue.

[13] Finance theory has suggested that potential arbitrageurs may be reluctant to exploit some opportunities because of the large fixed costs and capital outlays (Shleifer and Vishny 1997). Moreover, if there is uncertainty about the distribution of returns from arbitrage, price disparities may persist while potential arbitrageurs determine whether expected payoffs cover fixed costs (Mitchell, Pulvino, and Stafford 2002). Here, however, capital requirements are low, and the price disparity is consistent across coins and over time.

where site_{air} is a dummy variable that equals one for eBay auctions and zero for Yahoo, and X_{ir} is a matrix of controls that include coin fixed effects as well as the following variables, depending on the specification.[14]

Reserve.—We use a dummy variable, equal to one under the high-reserve treatment, to reflect the possibility that reserve price affects revenue (see, e.g., Myerson 1981).

Ending rule.—We use an ending-rule dummy variable, equal to one for a hard close, to reflect the possibility that ending rules affect revenue (see Ockenfels and Roth 2006).

Finally, ε_{air} represents an error term. We report robust standard errors to control for heteroskedasticity.[15] Hypothesis 1 states that revenues should be approximately equal across the sites; thus, we expect that the site coefficient should be zero ($\beta_1 = 0$) under specification (5).

Let bidders_{air} be defined as the number of bidders participating in a particular auction. Hypothesis 2 suggests the following econometric specification:

$$\text{bidders}_{air} = \beta_0 + \beta_1 \text{site}_{air} + \gamma X_{ir} + \varepsilon_{air}, \tag{6}$$

where the right-hand-side variables are defined identically to equation (5). Hypothesis 2 predicts that the site coefficient is zero ($\beta_1 = 0$) in this specification.

Equations (5) and (6) assume that any site-specific effect is constant for all coins. Given the variation in coin prices, one might worry that such a specification is overly restrictive. Accordingly, we also examine equations (5) and (6), where the dependent variable is $\ln(\text{revenue}_{air})$ and $\ln(\text{bidders}_{air})$, respectively. For these cases, the site coefficient, β_1, represents the percentage change in revenue or number of bidders per auction. Once again, our hypotheses suggest that $\beta_1 = 0$ in both specifications.

A. *Baseline*

Table 4 displays the results of the regression specifications under the baseline treatment. Model 1 presents the coefficients from equation (5), and model 2 presents the log specification. Models 3 and 4 are the analogues for equation (6).

[14] We also ran specifications replacing item dummies with both the PCGS book value and dealer price to control for variation in retail demand and the cost of acquisition, respectively. Regression coefficients of interest were virtually identical to those reported in the tables. We ran a coin-specific random effect specification; our results are substantially unaffected by the inclusion of random effects.

[15] White's general test for heteroskedasticity was conducted. The null hypothesis of constant variance is rejected in all cases.

TABLE 4
REGRESSION RESULTS UNDER THE BASELINE TREATMENT

	Model			
	Revenue (1)	ln (Revenue) (2)	Number of Bidders (3)	ln (Number of Bidders) (4)
Dependent variable:				
Site dummy (β_1)	13.173**	.268**	2.125**	.498*
	(2.420)	(.036)	(.818)	(.192)
Constant	55.952**	3.988**	5.125**	1.518**
	(2.757)	(.048)	(.675)	(.129)
Item dummies	Yes	Yes	Yes	Yes
Observations	40	40	40	40
R^2	.94	.97	.45	.42

NOTE.—Robust standard errors are in parentheses. Site dummy equals one if auction site was eBay.
* Significance at 5 percent level.
** Significance at 1 percent level.

The results show that eBay auctions yield significantly higher revenues than the equivalent auctions on Yahoo; we reject the hypothesis that $\beta_1 = 0$ at the 1 percent significance level. The economic magnitude of the coefficient estimates is substantial; according to model 2, seller revenues are 26.8 percent higher on eBay. Similarly, examining the number of bidders, we reject the hypothesis that $\beta_1 = 0$ at the 5 percent significance level. Again, the economic magnitude of the coefficients is considerable: an eBay auction attracts more than two additional bidders compared to an equivalent Yahoo auction.

B. *High Reserve*

We next investigate whether the zero reserve price in the baseline treatment is responsible for the revenue differences between the sites: perhaps this seller "mistake" has a greater effect on Yahoo than on eBay. We pool the hard-close auctions across the sites and include a dummy variable for auctions with positive reserve prices. Table 5 displays the results. Inclusion of positive reserve auctions has little impact on the magnitude and significance of the site effects; our estimates are similar to those in table 4. We reject the hypothesis that $\beta_1 = 0$ at the 1 percent significance level: eBay auctions generate 29.5 percent higher revenues and attract 2.118 more bidders than their Yahoo equivalents.

Reserve prices also appear to affect auction outcomes. In models 1 and 2, we reject the hypothesis that the positive reserve coefficient is zero at the 5 percent significance level. Setting a positive reserve price increases revenues by approximately 7 percent. The effect of a positive reserve price on the number of bidders is consistent with theoretical

TABLE 5
REGRESSION RESULTS UNDER BASELINE AND HIGH-RESERVE TREATMENTS

	Model			
	Revenue (1)	ln (Revenue) (2)	Number of Bidders (3)	ln (Number of Bidders) (4)
Dependent variable:				
Site dummy (β_1)	14.945**	.295**	2.118**	.570**
	(1.977)	(.028)	(.562)	(.140)
Reserve dummy	4.756*	.071**	−2.868**	−.578**
	(2.042)	(.026)	(.446)	(.108)
Constant	54.332**	3.961**	4.627**	1.307**
	(2.169)	(.034)	(.570)	(.141)
Item dummies	Yes	Yes	Yes	Yes
Observations	62	62	62	62
R^2	.94	.97	.56	.54

NOTE.—Robust standard errors are in parentheses. Site dummy equals one if auction site was eBay. Reserve dummy equals one if reserve is positive.
* Significance at 5 percent level.
** Significance at 1 percent level.

predictions and statistically significant at conventional levels. High-reserve auctions attract nearly 2.9 fewer bidders than low-reserve auctions.

C. *Ending Rule*

Theoretical work by Ockenfels and Roth (2006) implies that revenues in soft-close auctions may be higher than under a hard-close rule.[16] Since Yahoo provides a soft-close option, the revenue differences may be due to our use of the hard-close rule on Yahoo. Table 6 displays results from specifications analogous to equations (5) and (6) for Yahoo auctions only. The ending-rule coefficient is not statistically significantly different from zero in any model. Moreover, the magnitude of the coefficients is small: model 2 of table 6 indicates that revenue increases by 0.5 percent when a seller selects the soft-close over the hard-close rule. In short, there is little evidence that revenues on Yahoo are affected by the ending rule.

We also examined the impact of ending rules on bid timing in Yahoo auctions, using the following specification:

$$\text{bid time}_{ir} = \beta_0 + \beta_1 \text{ending rule}_{ir} + \gamma X_{ir} + \varepsilon_{ir}, \tag{7}$$

where bid time$_{ir}$ is the minutes between the time a bid was placed and the auction end and ending rule is the hard-close dummy variable. The matrix X_{ir} includes coin fixed effects and a dummy for the reserve treat-

[16] Specifically, the revenue-ranking result follows from Ockenfels and Roth's theorems characterizing equilibrium behavior in hard-close auctions (2006, 303) and bidding behavior in soft-close auctions (309).

TABLE 6
REGRESSION RESULTS UNDER ENDING-RULE TREATMENT ON YAHOO

	Model			
	Revenue (1)	ln (Revenue) (2)	Number of Bidders (3)	ln (Number of Bidders) (4)
Dependent variable:				
Ending-rule dummy	.117	.005	−.168	−.115
	(1.495)	(.044)	(.741)	(.171)
Reserve dummy	1.365	.030	−2.714**	−.749**
	(1.546)	(.042)	(.571)	(.142)
Constant	58.143**	4.056**	5.155**	1.587**
	(2.417)	(.051)	(1.109)	(.205)
Item dummies	Yes	Yes	Yes	Yes
Observations	43	43	43	43
R^2	.97	.96	.41	.50

NOTE.—Robust standard errors are in parentheses. Ending-rule dummy equals one if hard-close ending rule. Reserve dummy equals one if reserve is positive.
** Significance at 1 percent level.

ment. Again, we use robust estimation to account for heteroskedasticity. Roth and Ockenfels (2002) report that late bidding occurs more frequently in hard-close auctions, a finding that would be consistent with a negative coefficient on ending rule ($\beta_1 < 0$). In table 7, we report the results of estimating equation (7) using two measures of timing. Model 1 includes the timing of all bids. The sign of β_1 in model 1 is consistent with Roth and Ockenfels' prediction: bidders bid an average of 223 minutes later with a hard close. However, we cannot reject the null hypothesis that $\beta_1 = 0$ at conventional significance levels. Model 2 includes the timing of last bids only, omitting earlier bids posted by the

TABLE 7
BID-TIMING REGRESSION RESULTS FOR YAHOO

	Model 1	Model 2
	Minutes from Close—All Bids	Minutes from Close—Last Bids
Dependent variable:		
Ending-rule dummy (β_1)	−223.327	118.351
	(344.95)	(476.84)
Reserve dummy	−1,828.738**	−1,888.365**
	(485.74)	(551.71)
Constant	5,592.761**	4,397.104**
	(547.05)	(720.68)
Item dummies	Yes	Yes
Observations	375	192
R^2	.11	.19

NOTE.—Robust standard errors are in parentheses. Ending-rule dummy equals one if hard-close ending rule. Reserve dummy equals one if reserve is positive.
** Significance at 1 percent level.

TABLE 8
REGRESSION RESULTS UNDER BASELINE, RESERVE, AND ENDING-RULE TREATMENTS

	Model			
	Revenue (1)	ln (Revenue) (2)	Number of Bidders (3)	ln (Number of Bidders) (4)
Dependent variable:				
Site dummy (β_1)	15.053**	.297**	2.120**	.581**
	(1.855)	(.028)	(.566)	(.139)
Reserve dummy	4.666**	.072**	−2.793**	−.618**
	(1.766)	(.028)	(.379)	(.096)
Ending-rule dummy	.508	.008	−.167	−.106
	(2.012)	(.046)	(.701)	(.166)
Constant	55.602**	3.993**	4.992**	1.452**
	(2.333)	(.049)	(.788)	(.158)
Item dummies	Yes	Yes	Yes	Yes
Observations	83	83	83	83
R^2	.94	.95	.53	.53

NOTE.—Robust standard errors are in parentheses. Site dummy equals one if auction site was eBay. Reserve dummy equals one if reserve is positive. Ending-rule dummy equals one if hard-close ending rule.
** Significance at 1 percent level.

same bidder in a given auction. Here, β_1 reverses sign—bidders bid an average of 118 minutes earlier in hard-close auctions—but the coefficient is not statistically significant at conventional levels. Overall, results appear rather different from the findings contained in Roth and Ockenfels (2002), Ariely et al. (2005), and Ockenfels and Roth (2006).

Interestingly, the presence of a high-reserve price does have a significant effect on bid timing. Using both bid-timing measures, the reserve dummy variable coefficient is negative and significant at the 1 percent level. A positive reserve price delays bids by approximately 30 hours.

D. *Pooled Results*

The results of "pooled" regressions, using all of the data from the field experiments, are displayed in table 8. Again, we reject the hypotheses that site has no effect on revenue or number of bidders at the 1 percent significance level for all models. The results indicate that eBay auctions generate 29.7 percent higher revenues and attract 58.1 percent more bidders than Yahoo auctions.

V. Alternative Hypotheses

Our results are inconsistent with equilibrium coexistence in Ellison et al.'s (2004) model. However, there are a number of factors absent from that model that might explain our findings. Specifically, we examine six alternatives:

1. *Platform differentiation.*—The theory model assumes that sites do not differ in inherent quality. Yet, eBay's platform might offer superior service, and this might lead to the observed revenue differences.
2. *Switching costs.*—There are no switching costs in the theory model. Perhaps the presence of such frictions might account for our results.
3. *Trustworthiness.*—In the theory model, seller reputation is inconsequential to buyers. A large existing literature suggests that reputation does matter. Perhaps sellers on eBay simply have superior reputations relative to Yahoo sellers, and this accounts for the site differences.
4. *Liquidity.*—The theory model does not consider the possibility that a desired item is not available for sale at a given platform. Perhaps the price differences between the two sites reflect an eBay "liquidity premium."[17]
5. *Anomalous data.*—Our study focuses on 88 auctions at a particular point in time. Perhaps with either a larger number of auctions or a different time period, the observed revenue differences would disappear.
6. *Disequilibrium.*—We examine the correspondence between our results and the disequilibrium model presented in Section II.

A. *Platform Differentiation*

Our hypotheses were derived in a model with homogeneous platforms: given the same number of buyers and sellers on the sites, users derive equal payoffs on eBay and Yahoo. In reality, one of the sites may be more attractive than the other. Could differences in price and buyer-seller ratios stem from vertical differentiation? To consider this possibility, suppose that payoffs from Yahoo are unchanged from the original model but that eBay payoffs now reflect its superior service. Specifically, buyer payoffs on eBay are

$$u_b(s_e, b_e) = \frac{1}{2}\frac{s_e(s_e+1)}{b_e(b_e+1)} + q^B,$$

and seller payoffs on eBay are

$$u_s(s_e, b_e) = \frac{b_e - s_e}{b_e + 1} + q^S,$$

where $q^B, q^S > 0$ represents eBay's vertical differentiation advantage.

To study large markets, we fix the seller-buyer ratio in the market at $\gamma < 1$ and examine properties of equilibria as buyers and sellers increase

[17] We are grateful to an anonymous referee for suggesting this alternative.

proportionately. We first show that tipping is inevitable when markets are large.

PROPOSITION 3. In large markets with vertical differentiation, equilibrium coexistence is impossible.

To gain some intuition for proposition 3, suppose that both sites are active in a large market. Here, both the scale and the market impact effects are negligible; however, eBay's vertical differentiation advantage is nonnegligible. Thus, Yahoo buyers and sellers will want to switch sites, destroying the possibility of coexistence. We next show that, even when interior equilibria exist, their properties are inconsistent with our empirical findings.

PROPOSITION 4. In any quasi equilibrium in which the sites coexist and eBay enjoys a vertical differentiation advantage and more than a 50 percent market share, (1) more buyers are attracted to a given Yahoo auction than an eBay auction, and (2) prices are higher on Yahoo than on eBay.

When eBay enjoys greater than a 50 percent market share, it benefits from both scale and differentiation advantages. From the perspective of sellers, coexistence is possible only if Yahoo enjoys some compensating price advantage. This can arise only when Yahoo's buyer-seller ratio is greater than eBay's. Of course, this exactly contradicts the data: eBay sellers enjoy higher prices and more favorable buyer-seller ratios than do Yahoo sellers. Proofs for propositions 3 and 4 are contained in the Appendix.

B. Switching Costs

Our results suggest that, free from other motives or constraints, rational buyers should switch to Yahoo and rational sellers switch to eBay until the gains from moving approach zero. Indeed, hypotheses 1 and 2 assume zero switching costs. In practice, however, the costs of registration, (re)building reputation, and general hassle are nontrivial. Could significant switching costs be driving the observed disparities?

If significant numbers of eBay buyers and Yahoo sellers were unaware of the other service, their effective switching costs would be infinite and could rationalize our findings. This explanation seems unlikely. We conducted searches for "auction," "internet auction," and "online auction" on Yahoo and Google on November 20, 2004. Both engines put Yahoo Auctions and eBay in the top five results for these search terms. Moreover, whereas one might argue that the lesser-known status of Yahoo's auction service makes it invisible to eBay buyers, it seems implausible that Yahoo sellers are unaware of eBay.

The cost of registration itself is low: registration is free and takes approximately 1 minute to complete. For these costs alone to account

for the $15 price disparity shown in table 8, the opportunity cost of time even for a buyer wishing to purchase only one coin would have to exceed $900 per hour. This seems unreasonable.

Resnick and Zeckhauser (2002), among others, show that reputation (feedback rating) is valuable to sellers. To reduce the possibility of fraudulent payments, sellers may also prefer to sell to bidders with positive feedback ratings. For an established Yahoo user, rebuilding her reputation on eBay is a switching cost. In practice, however, the reputation-rebuilding costs cannot account for the 20–60 percent price disparity between sites. A seller with 100 feedback points on Yahoo could rebuild his reputation on eBay for as little as $100, simply by purchasing 100 items for $1 each.[18] Such a seller would fully recoup the cost of this investment after only seven coin sales.

C. *Trustworthiness of the Sites*

Neither eBay nor Yahoo endorses its sellers' reliability. If Yahoo sellers have a reputation for failing to deliver products or selling damaged or counterfeit goods, then perhaps potential buyers simply view Yahoo as a less trustworthy platform. EBay bidders might be willing to pay a premium to avoid this. Several online reviews characterized Yahoo sellers as fraudulent, blaming Yahoo's perceived inaction on abuse claims, yet searches for eBay complaints yield similar results.[19]

To examine whether trust differences between the sites can explain our results, consider the following worst-case scenario. Suppose that a Yahoo buyer does not receive the item and loses her entire bid with probability λ, whereas an eBay buyer always receives the product. Using our data, we calculate the implied default rate λ needed to deter switching. An individual is indifferent between eBay and Yahoo purchases when

$$(1 - \lambda)U_g + \lambda U_b = U_e, \tag{8}$$

where U_g is the utility associated with a successful Yahoo transaction, U_b is the utility from a Yahoo transaction that results in total loss, and U_e

[18] Reputation building of this sort is not a mere theoretical possibility. Brown and Morgan (2006) identify markets on eBay whose sole purpose is the "manufacture" of a reputation for users. By trading seemingly valueless items for pennies, users routinely enhance (or rebuild) their eBay reputations at small cost.

[19] For an example of Yahoo's perceived inaction, see eBay.co.uk and Yahoo Auctions UK reviews on Ciao (http://www.ciao.co.uk). Google searches for "eBay rip off" (omitting the term "Yahoo") and "Yahoo auction rip off" (omitting the term "eBay") revealed 725,000 and 234,000 results, respectively (July 26, 2005).

is the utility from a (always) successful eBay transaction.[20] Solving (8) yields

$$\lambda = \frac{U_e - U_g}{U_b - U_g}.$$

Suppose, as in Cox, Smith, and Walker (1988), that consumer utility exhibits constant relative risk aversion; then

$$U(w) = \frac{1}{1-\rho} w^{1-\rho},$$

where $\rho \in [0, 1)$ is the coefficient of relative risk aversion and w is total wealth. With this specification, we have

$$U_g = \frac{1}{1-\rho}(W + V - P_y)^{1-\rho},$$

$$U_b = \frac{1}{1-\rho}(W - P_e)^{1-\rho},$$

$$U_e = \frac{1}{1-\rho}(W + V - P_y)^{1-\rho},$$

where W is wealth, V is the value of the item, and P_a is the price on auction site a.

To calibrate the model, we fix W at \$55,000, the median household wealth level in the United States in 2000 (U.S. Census Bureau 2005). This (likely) underestimates the wealth of coin collectors and hence biases the results in favor of conservative implied default rates. We estimate V as the PCGS book value for the coins and P_e and P_y as the average revenue by coin by site (table 3). We then vary the risk aversion parameter and compute the default rate solving equation (8). For reasonable parameter values of ρ, the implied default rates range from 12 ($\rho = 0.9$, coin 1) to 19 percent ($\rho = 0.1$, coin 8). To be indifferent, a buyer must believe that at least one of eight transactions on Yahoo would result in total loss. This seems implausibly high.[21]

D. *Liquidity*

Whereas items in general product categories, such as coins, are always available on both platforms, specific items, such as a 1902 Morgan Dollar

[20] Suppose that vertical differentiation between the sites leads to the sorting of bidders by risk preferences. Interpreting the indifference expression for the marginal bidder implies that the risk preferences must be identical across the two platforms.

[21] Of course, this is not an equilibrium explanation. Since no credible signal exists for reliable sellers, both good and bad sellers will switch to eBay.

MS-65, may not be. Since the "inventory" of products depends on the size of a platform, it seems intuitive that "stock-outs" are more likely on Yahoo than on eBay. Perhaps the observed price differences are attributable to an eBay liquidity advantage: consumers pay higher prices on eBay to avoid the cost of unsuccessful searches.

To investigate this possibility, suppose that it costs c per platform for a consumer to search for her desired product. The product is always available on eBay but available only with probability $\lambda < 1$ on Yahoo. Let V denote the value of the item to the consumer, and suppose that the expected surplus from acquiring the item is sufficient to induce a consumer to continue to search until it is found. A consumer has two possible search strategies: (1) go directly to eBay or (2) first visit Yahoo in search of a "bargain" and proceed to eBay if the Yahoo search fails. In competitive markets, prices on the two platforms will adjust until consumers are indifferent between the competing search strategies. Thus, in equilibrium,

$$V - P_e - c = \lambda(V - P_y - c) + (1 - \lambda)(V - P_e - 2c). \tag{9}$$

Rearranging equation (9) yields the following expression for the probability of a stock-out on Yahoo:

$$1 - \lambda = \frac{P_e - P_y}{P_e - P_y + c}. \tag{10}$$

We observe the price premium in our data but do not observe the cost of the search or the stock-out probability. Hong and Shum (2006) structurally estimate the value of the search cost parameter for online textbook markets. We use their estimates to calibrate c and infer the stock-out probability implied by equation (10). Using table 2 of Hong and Shum, each coin is matched with a cost estimate (Δ_1 in their notation) for a textbook with the most similar price. We use the average price difference between eBay and Yahoo to obtain $P_e - P_y$ for each coin. Table 9 presents the results. The implied stock-out rates are extremely high, ranging from 76 to over 90 percent. Whereas liquidity may account for some of the price differences between the two platforms, the eBay premium seems to be too great to be explained solely by liquidity.

E. Anomalous Data

Are the observed disparities artifacts of the experimental design? Do they persist beyond the time of the experiment? To examine these possibilities, we gathered data from over 25,000 Morgan and Peace series coin auctions on eBay and Yahoo in April, May, June, and August 2006.

TABLE 9
IMPLIED STOCK-OUT RATE BY COIN

Coin	Price Difference ($P_e - P_y$; \$)	Search Cost (\$)	Implied Stock-Out Rate (%)
1	12.88	2.40	84
2	7.74	1.30	86
3	19.32	2.90	87
4	27.19	2.90	90
5	7.37	2.30	76
6	7.16	1.30	85
7	13.67	1.30	91
8	31.59	2.90	92

NOTE.—Search costs were gathered from Hong and Shum (2006). Coins were matched with products of similar value. For example, a coin with an average eBay price of \$97 was matched with the search cost associated with a \$100 item in their study.

TABLE 10
FIELD DATA SUMMARY STATISTICS

	MEAN VALUES	
	eBay	Yahoo
Revenue (\$)	59.900	54.179
	(40.455)	(32.012)
Number of bids	7.064	4.509
	(4.726)	(5.850)
Observations	1,281	371

NOTE.—Standard deviations are in parentheses.

To compare the experimental and field data, we identified items with descriptions and grades similar to the coins used in our experiments. For example, for 1898 Morgan Dollar coins, we selected only those coins graded MS-64. As we found during our experiments, the market for Morgan and Peace series coins on eBay was substantially larger than on Yahoo.

Table 10 presents summary statistics for the field data, including 1,652 auctions in total—371 coins on Yahoo and 1,281 coins on eBay. Pooling the eight coin types, the mean price on eBay is \$60, whereas the average price on Yahoo is only \$54. EBay auctions also continue to attract more bidders: on average, eBay auctions attract seven bids, whereas Yahoo auctions attract only five. Table 11 presents the results from regressions similar to equations (5) and (6) for this data set. Coefficients are all statistically significant and confirm the persistence of the revenue and bid count disparities. Controlling for other auction features, eBay yields an \$11, or 15 percent, revenue premium relative to Yahoo. Examining the number of bids per auction, we conclude that eBay auctions attracted approximately two more bidders per seller than comparable Yahoo auctions—equivalent to approximately 70 percent more bids per

TABLE 11
REGRESSION RESULTS WITH FIELD DATA

	Model			
	Revenue (1)	ln (Revenue) (2)	Number of Bidders (3)	ln (Number of Bidders) (4)
Dependent variable:				
Site dummy (β_1)	11.605**	.148**	2.002**	.691**
	(1.869)	(.028)	(.300)	(.053)
Reserve (opening price)	.456**	.006**	−.083**	−.018**
	(.027)	(.001)	(.004)	(.001)
Constant	46.366**	3.797**	7.890**	1.513**
	(2.164)	(.035)	(.352)	(.060)
Item dummies	Yes	Yes	Yes	Yes
Observations	1,652	1,650	1,614	1,587
R^2	.31	.31	.35	.51

NOTE.—Robust standard errors are in parentheses. Site dummy equals one if auction site was eBay.
** Significance at 1 percent level.

seller on eBay relative to Yahoo.[22] In short, the field data suggest that the observed revenue and bid count differences were not an artifact of our particular experimental design or the time at which the experiments were conducted.

F. *Disequilibrium*

Can the disequilibrium model presented in Section II rationalize these results? Returning to figure 1, consider the initial state labeled s_0, which roughly corresponds to the situation of the two firms at the time of our experiments. At this point, both price and buyer-seller ratio are higher on eBay than on Yahoo. Sellers are attracted to higher prices and gravitate toward the eBay platform. Buyers, however, head toward the better bargains available on Yahoo. This process continues until buyers are indifferent between the two platforms. At that point, sellers continue to switch to eBay and, owing to scale effects, the flow of buyers reverses: buyers now start deserting Yahoo in favor of eBay. Thereafter, eBay's market share grows monotonically until there is complete tipping.[23] This model is capable of rationalizing the qualitative results we observe in

[22] In our field experiments, the number of bidders per seller was the variable of interest. Since unique bidder counts per auction are not available for our field data, we use the number of bids per auction to proxy for the buyer-seller ratio. To alleviate concerns about potential bias, consider this: in our field experiments, the average numbers of bids per bidder on eBay and Yahoo are 1.56 and 1.98, respectively (see table 2). Were bids-per-bidder statistics equal, total bid count would be simply a transformation of total bidder count. Because Yahoo bidders tend to submit fewer bids, our total bid counts actually underestimate the difference in buyer-seller ratios on eBay and Yahoo.

[23] Once the system reaches a state (s, b) such that $\dot{s} \geq 0$ and $\dot{b} \geq 0$ with at least one strict inequality, then all future states of the system are such that $\dot{s} \geq 0$ and $\dot{b} \geq 0$.

the data. For initial conditions such as s_0, the system dynamics have the property that eBay's price is always higher than Yahoo's. Furthermore, for a portion of this path, the buyer-seller ratio favors eBay as well.

Finally, we turn to the speed of tipping. Whereas the model itself says nothing about the length of a path in real time, we use data from the field experiments to simulate the dynamic process. Formally, the discrete approximation

$$s(t + \Delta t) = s(t)\left\{1 + \left[\frac{S - s(t)}{S}\right][\pi_e(t) - \pi_y(t)]\Delta t\right\},$$

$$b(t + \Delta t) = b(t)\left\{1 + \left[\frac{B - b(t)}{B}\right][u_e(t) - u_y(t)]\Delta t\right\}$$

converges to equations (3) and (4) as $\Delta t \to 0$. In our simulations, we let $\Delta t = 1$ and interpret this as 1 day. In terms of imitation and learning, this implies that each day all of the buyers and sellers learn another agent's payoffs and switch platforms in proportion to the difference in these payoffs. Using the experimental and field data from November 2004, we estimate that the Morgan and Peace silver dollar market consists of about 14,000 sellers and 81,500 buyers. Of these amounts, about 89 percent of sellers and 93 percent of buyers were on eBay. We used these values as our initial condition and then simulated the dynamic process.

The dynamic process produces tipping to the eBay platform but is quite slow. If we say that the market has tipped once eBay commands a 99 percent market share of both buyers and sellers, then the simulation indicates that it takes about 245 years to tip. Lowering the tipping point to a 95 percent market share reduces this time to 96 years. If we treat Δt as representing 1 hour instead of 1 day, the simulation suggests that tipping takes about 4 years. The process is so slow because, as Yahoo agents become increasingly rare, fewer agents choose to switch each period. Of course, we do not mean for these simulations to be taken too literally; the model is quite abstract and no doubt inaccurate in many respects. Still, if imitation dynamics are a reasonable approximation of platform choice, then eBay and Yahoo might well coexist for a considerable period of time, despite persistent price disparity.

VI. Conclusion

The relationship between eBay and Yahoo evolved since the time of our field experiments. On May 25, 2006, Yahoo and eBay announced a U.S. advertising alliance (eBay 2006) in an apparent bid to dampen Google's Internet dominance. EBay and Yahoo Auctions also planned to collab-

orate in search-based advertising. In July 2007, Yahoo announced that it was closing its auction site. The market had tipped.

During their coexistence, we identified significant differences in revenues and the number of bidders per seller for identical items on eBay and Yahoo. Switching costs, vertical differentiation, trustworthiness, liquidity, and anomalous data could not reconcile our results with a theory of equilibrium coexistence. Yet, a simple replicator dynamic, in which agents imitate successful strategies, plausibly rationalizes our results and the eventual shuttering of Yahoo Auctions in the United States.

It may be too early to detect anticompetitive effects of Yahoo's exit from the U.S. auction market. However, about 6 months after Yahoo's exit, eBay did announce significant changes to its fee structure. While it reduced most listing fees, it raised final value fees collected for successful auctions, in some cases by as much as 67 percent. The changes provoked a boycott of eBay by many sellers, and, indeed, a third-party Web site noted a 17 percent decline in eBay's listings during the boycott period.[24] The combined evidence of platform competition in online auctions in Europe, Japan, Taiwan, and the United States suggests a strong tendency for these markets to tip and, consequently, the need for careful scrutiny by competition authorities. This is particularly true for emerging markets like China and India, where competition among the major players in the online auction space is still in flux.

Appendix

Proofs of Propositions

PROPOSITION 1. Under imitation dynamics, equilibrium coexistence occurs only when both platforms enjoy equal market shares.

Proof. From equations (3) and (4), it follows that if $s = S/2$ and $b = B/2$, then $\dot{s} = \dot{b} = 0$. To prove uniqueness, suppose that some interior state (s, b) is a fixed point. Then (s, b) has the property that

$$u_e \equiv \frac{b-s}{b+1} = \frac{B-b-(S-s)}{B-b+1} \equiv u_y,$$

$$\pi_e \equiv \frac{s(s+1)}{b(b+1)} = \frac{(S-s)[(S-s)+1]}{(B-b)[(B-b)+1]} \equiv \pi_y.$$

Solving for s in the first equation yields

$$s = \frac{S-B+2b+Sb}{B+2}.$$

[24] Medved.net tracks and publishes eBay listing counts over time. EBay does not publicly release its listing statistics.

Substituting this into the second equation, we have

$$\frac{[(S-B+2b+Sb)/(B+2)][(S+2b+Sb+2)/(B+2)]}{b(b+1)} =$$

$$\frac{\{S-[(S-B+2b+Sb)/(B+2)]\}\{S-[(S-2B+2b+Sb-2)/(B+2)]\}}{(B-b)[(B-b)+1]},$$

which, after some rearrangement, becomes

$$\frac{(S-B+2b+Sb)(S+2b+Sb+2)}{b(b+1)} =$$

$$\frac{(SB+S+B-2b-Sb)(SB+S+2B-2b-Sb+2)}{(B-b)[(B-b)+1]}. \tag{A1}$$

We claim that the left-hand side of equation (A1) is strictly increasing in b, whereas the right-hand side is decreasing in b. Differentiating the left-hand side of equation (A1) with respect to b, we obtain

$$\frac{\partial \text{LHS}}{\partial b} = \frac{1}{b^2}(B-S)(S+2) > 0$$

since $B > S$.

Differentiating the right-hand side of equation (A1) with respect to b, we obtain

$$\frac{\partial \text{RHS}}{\partial b} = -(B-S)\frac{S+2}{(B-b)^2} < 0.$$

Thus, equation (A1) has a unique solution. QED

PROPOSITION 2. The interior fixed point $(s_1 = S/2, b_1 = B/2)$ is a saddle point, whereas the tipped fixed points $(s = 0, b = 0)$ and $(s = S, b = B)$ are attractors.

Proof. Linearizing the system and evaluating at $(0,0)$ or (S,B) yields eigenvalues of $(-(B-S)/(B+1), -\frac{1}{2}[S(S+1)]/[B(B+1)])$. Since these are real and negative, $(0,0)$ and (S,B) are both hyperbolic fixed points that are attractors. Linearizing the system and evaluating at $(S/2, B/2)$ yields eigenvalues that are both real but with opposite signs. The product of these eigenvalues is $-[(B-S)S(S+2)/B(B+2)^3]$. Thus, $(S/2, B/2)$ is a hyperbolic fixed point that is a saddle point. QED

PROPOSITION 3. In large markets with vertical differentiation, equilibrium coexistence is impossible.

Proof. Fix the ratio of sellers to buyers at $\gamma < 1$ and consider equilibria as the number of buyers becomes infinite. It will be convenient to denote the number of buyers as N (rather than B as we did previously). For a fixed N number of buyers, an equilibrium is described by the number of sellers and buyers on eBay $(s_e(N), b_e(N))$.

Suppose that, contrary to the proposition, there exists a sequence of equilibria $(s_e(N), b_e(N))$ such that both markets are active in the limit. Formally, this amounts

to the condition that, for some sequence of equilibria, $\{s_e(N)\}_{N=1}^{\infty}$, $\{b_e(N)\}_{N=1}^{\infty}$, $\{N\gamma - s_e(N)\}_{N=1}^{\infty}$, and $\{N - b_e(N)\}_{N=1}^{\infty}$ are all divergent.

Define the limit buyer-seller ratios in each market as

$$\rho_y = \lim_{N\to\infty} \frac{(N/\gamma) - s_e(N)}{N - b_e(N)} \quad \text{and} \quad \rho_e = \lim_{N\to\infty} \frac{s_e(N)}{b_e(N)}.$$

Equilibrium requires that the following system of inequalities hold for all N:

$$\frac{b_e(N) - s_e(N)}{b_e(N) + 1} + q^S \geq \frac{N - b_e(N) - [\gamma N - s_e(N) + 1]}{N - b_e(N) + 1},$$

$$\frac{N - b_e(N) - [\gamma N - s_e(N)]}{N - b_e(N) + 1} \geq \frac{b_e(N) - s_e(N) - 1}{b_e(N) + 1} + q^S,$$

$$\frac{s_e(N)[s_e(N) + 1]}{2b_e(N)[b_e(N) + 1]} + q^B \geq \frac{[\gamma N - s_e(N)][\gamma N - s_e(N) + 1]}{2[N - b_e(N) + 1][N - b_e(N) + 2]},$$

$$\frac{[\gamma N - s_e(N)][\gamma N - s_e(N) + 1]}{2[N - b_e(N)][N - b_e(N) + 1]} \geq \frac{s_e(N)[s_e(N) + 1]}{2[b_e(N) + 1][b_e(N) + 2]} + q^B.$$

Taking limits, we obtain

$$1 - \rho_e + q^S \geq 1 - \rho_y,$$

$$1 - \rho_y \geq 1 - \rho_e + q^S,$$

$$\rho_e^2 + q^B \geq \rho_y^2,$$

$$\rho_y^2 \geq \rho_e^2 + q^B.$$

The first two inequalities imply that

$$\rho_y = \rho_e - q^S,$$

whereas the second two inequalities imply that

$$\rho_y = \sqrt{\rho_e^2 + q^B}.$$

Thus, for any such sequence, it must be the case that

$$\rho_e = \frac{1}{2}\left(q^S - \frac{q^B}{q^S}\right),$$

$$\rho_y = -\frac{1}{2}\left(q^S + \frac{q^B}{q^S}\right).$$

Notice that this implies that $\rho_y < 0$, which is a contradiction.

It remains to show that it is not the case that only one of $\{s_y(N)\}_{N=1}^{\infty}$, $\{b_y(N)\}_{N=1}^{\infty}$, $\{N\gamma - s_y(N)\}_{N=1}^{\infty}$, and $\{N - b_y(N)\}_{N=1}^{\infty}$ is convergent while the rest diverge. To confirm this, suppose that $\{s_a(N)\}_{N=1}^{\infty}$ was convergent for one of the sites. In that case, buyers using that site earn zero payoffs in the limit, when they could earn positive payoffs from switching to the other site. This is a contradiction. Similarly, if $\{b_a(N)\}_{N=1}^{\infty}$ is convergent for one of the sites, then sellers

on that site earn zero payoffs in the limit and have a profitable deviation as well. QED

PROPOSITION 4. In any quasi equilibrium in which the sites coexist and eBay enjoys a vertical differentiation advantage and more than a 50 percent market share, (1) more buyers are attracted to a given Yahoo auction than an eBay auction, and (2) prices are higher on Yahoo than on eBay.

Proof. Suppose that there is an interior equilibrium (s_e, b_e) in which eBay enjoys more than a 50 percent market share. Incentive compatibility for Yahoo sellers requires

$$s_e \geq b_e - \frac{b_e + 1}{B + 2}[B - S - q^S(B - b_e + 1)].$$

Let $\mu \geq 1/2$ denote eBay's market share of buyers. To prove part 1 of the proposition, we show that the market share of sellers on eBay must strictly exceed μ. We rewrite the incentive constraint for Yahoo sellers as

$$\begin{aligned} s_e &\geq \mu B - \frac{\mu B + 1}{B + 2}(B - S) + \frac{\mu B + 1}{B + 2} q^S(B - \mu B + 1) \\ &> \mu B - \frac{\mu B + 1}{B + 2}(B - S) = \frac{S - B + B\mu(S + 2)}{B + 2}, \end{aligned}$$

where the strict inequality follows from the fact that $q^s > 0$. We claim that $[S - B + B\mu(S + 2)]/(B + 2) \geq \mu S$ whenever $\mu \geq 1/2$. Notice that

$$\frac{S - B + B\mu(S + 2)}{B + 2} - \mu S = \frac{(2\mu - 1)(B - S)}{B + 2} \geq 0.$$

Thus, we have shown that the seller-buyer ratio on eBay is $\gamma_e > \gamma$. From the adding-up condition on buyer-seller ratios, it then follows that $\gamma_e > \gamma > \gamma_y$.

To establish part 2 of the proposition, recall that the expected price spread between the sites is

$$\bar{p}_y - \bar{p}_e = \frac{(1 - \mu)B - (S - s_e)}{(1 - \mu)B + 1} - \frac{\mu B - s_e}{\mu B + 1},$$

which takes on the same sign as $B - S + (B + 2)s_e - B\mu(S + 2)$. Since $s_e > [S - B + B\mu(S + 2)]/(B + 2)$, it follows that

$$B - S + (B + 2)s_e - B\mu(S + 2) > 0.$$

The Yahoo price always exceeds the eBay price when eBay enjoys more than a 50 percent market share. QED

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