# Applicant Auctions for Internet Top-Level Domains: Resolving Conflicts Efficiently

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## Abstract

The prospect of using auctions to resolve conflicts among parties competing for the same top-level internet domains is described. In the auctions investigated, the winner's payment is divided among the losers. For first-price and second-price sealed-bid auctions, we characterize equilibrium bidding strategies and provide examples, assuming bidders' valuations are distributed independently and are either symmetrically or asymmetrically distributed. The qualitative properties of equilibria reveal novel features; for example, in a second-price auction a bidder might bid more than her valuation in order to drive up the winner's payment. Even so, examples indicate that in symmetric cases a bidder's expected profit is the same in the two auction formats. We then test in the experimental lab two auction formats that extent the setting from a single domain to the actual setting with many domains. The first format is a sequential first-price sealed-bid auction; the second format is a simultaneous ascending clock auction. The framing and subjects were chosen to closely match the actual setting. Subjects were PhD students at the University of Maryland with training in game theory and auction theory. Each subject played the role of an actual company (e.g., Google) and bid for domains (e.g., *.book*) consistent with the company's applications. Subjects were given instructions explaining the auction and the equilibrium theory for the single-item case in relevant examples. Both formats achieved auction efficiencies of 98% in the lab. This high level of efficiency is especially remarkable in the case with asymmetric distributions—the format performed better than the simple single-item equilibrium despite the presence of budget constraints in the lab. This experiment together with previous results on the robustness of ascending auctions in general and simultaneous ascending clock auctions in particular suggest that the simultaneous ascending clock auction will perform best in this setting.

## 1 Introduction

The hallmark of market design is its fruitful interaction between theory and practice. This is especially true when theoretical insights guide the development of innovative market designs. A prominent instance was the development of the simultaneous ascending auction, initially for allocation of spectrum licenses and now widely used for other commodities as well. Another application will occur in 2013 when ICANN (Internet Corporation for Assigned Names and Numbers) will use a simultaneous ascending auction, called the last-resort auction, to allocate those new generic top-level domains for which the contending applicants have not reached agreements among themselves to resolve the conflict.

ICANN will retain the winning bidder's payment for each contested domain allocated via the last-resort auction. But a remarkable policy is that ICANN encourages contending applicants to resolve among themselves the competition for each domain.[1] Although competitors might negotiate a resolution of the conflict, or form a consortium to share a domain, for many domains the likely preference will be to choose one among them to be assigned the domain, using some formal process they agreed to be bound by — such as an auction among themselves. In this case the designated applicant is assigned the domain and each of the other applicants receives a refund of 70% of its application fee of $130,000.

Resolving such conflicts is akin to the well-known problem of how to dissolve a partnership efficiently (studied theoretically by Cramton, Gibbons and Klemperer, *Econometrica*, 1987), as when one partner buys the shares of the others at a price determined by an auction. In the ICANN context, however, the matter is slightly different, because rather than a partnership, the applicants (in effect) own *in common* the right to be allocated the domain. It also differs in that each applicant's outside option is, first, to refuse participation in a process to resolve the competition among themselves, and then second, to bid against the others in the subsequent ICANN last-resort auction. A third difference is that many applicants are competing for multiple domains.

The first of these three differences can be resolved only by the applicants for each domain. Here we assume they can agree to some division of the winner's payment among the losers, and we suppose for simplicity that the losers receive equal shares of the winner's payment. Such an agreement largely eliminates the second difference, because the ICANN last-resort auction is surely an inferior outside option for every applicant as compared to an auction among the applicants, for two reasons. One reason is that ICANN keeps the winner's payment in the last-resort auction, but if the applicants auction the domain among themselves then the losers divide the winner's payment among themselves, as in a knockout auction (McAfee and McMillan, *American Economic Review*, 1992). The second reason occurs most clearly in a first-price auction where the winner pays her bid, because each applicant's incentive is to bid somewhat less than she would in ICANN's auction since losing still garners a share of the winner's payment.

We show later that this particular prediction is true in a second-price or ascending auction, where the winner pays the second-highest bid, only for bidders with relatively high valuations of the domain. Thus, even applicants rather confident of winning the ICANN last-resort auction still prefer an auction among all the contending applicants in which the winner's payment is paid to the losers — and the incentive is even stronger for those likely to lose in ICANN's auction. The third difference can be handled either by

[1]"…, cases of contention might be resolved by community priority evaluation or an agreement among the parties. Absent that, the last-resort contention resolution mechanism will be an auction. …Applicants that are identified as being in contention are encouraged to reach a settlement or agreement among themselves that resolves the contention. …Applicants may resolve string contention in a manner whereby one or more applicants withdraw their applications." (ICANN Application Guidebook, Module 4: String Contention, pp. 4-5, 4 June 2012.)

conducting a sequence of applicant auctions for contested domains, or by a simultaneous ascending auction for many contested domains.

There are further technical considerations. For this exposition we ignore the effects of each loser's partial refund of the application fee. Moreover, we assume for simplicity that applicants' valuations of a domain are statistically independent, each drawn randomly according to a specified probability distribution that is commonly known among the applicants. In practice, of course, one expects some correlation among applicants' valuations, as when each applicant has only some estimates of factors that affect all or many of their valuations. We defer to a later exposition our analysis of the more general formulation in which it is assumed only that estimates and valuations are affiliated (i.e., non-negatively correlated everywhere) and we apply the methods of Milgrom and Weber (*Econometrica* 1982).

A primary principle of market design is to promote an efficient outcome to the extent possible. For the case addressed here with independent valuations for a single domain, this requires a design to enable the bidder who most values a domain to win it. This ensures that the gain from trade among the applicants is realized — and, of course, it is more than the ICANN last-resort auction realizes because ICANN keeps the winner's payment. Of course, perfect efficiency cannot be assured if bidders are asymmetric or some are concerned about complementarities and substitution among domains, but the success of simultaneous ascending auctions in similar contexts like spectrum auctions suggests that similarly good outcomes can be obtained for multiple domains.

As a practical matter, it is important to anticipate asymmetries among the bidders. Some of the applicants have much at stake and deep pockets (e.g., Google and Amazon are prominent applicants, and in only a few cases are they contesting the same domain, such as the domain *.talk*). Others have unique motives (e.g., the domain *.swiss* is contested by Swiss International Airlines and the Swiss Confederation, and the domain *.sas* by Scandinavian Airlines System). A single applicant (Donuts) is competing for 68% of the contested domains, and each of four others is competing for over 20% of the 232 contested domains. Thus, in using some theory to predict optimal bidding strategies and auction outcomes, it is important to allow for asymmetries among the bidders. Here we do this chiefly by supposing in the examples that some bidders are more likely than others to have higher valuations.

So, in this preliminary study we report results about equilibrium bidding strategies in sealed-bid auctions for two payment rules, the first-price rule in which the winner pays her bid, and the second-price rule in which the winner pays the second-highest bid. We characterize equilibrium bidding strategies and predicted outcomes for both asymmetric and symmetric distributions of the bidders' valuations, assuming in each case that all bidders have the same interval of possible valuations over which the probability densities of their valuations is positive. The set of bidders for each domain is known to all, since that is a feature of the ICANN situation. Thus, for each bidder the only uncertainty is about others' bids, and thus indirectly, others' valuations.

In practice, of course, one cannot expect that actual behavior conforms to predictions based on equilibrium bidding strategies, not least because the basic assumption is false that the bidders all know the probability distributions of each other's valuations. The further uncertainty about each other's beliefs will be an important factor affecting actual bidding strategies. As a first step, nevertheless, predictions about equilibrium behavior are useful because they reveal the basic motives in devising a good bidding strategy. We compare the behavior of PhD students acting as the bidders in experiments conducted in a laboratory setting with theoretical predictions.

In displaying these preliminary results, our motive is only to indicate that theoretical predictions can provide some insights into the salient features of an auction among the applicants for a single domain. We remark on these features as we proceed. Some are familiar features of first-price auctions, such as the possibility of an inefficient outcome when the bidders are asymmetric, which can occur because a bidder whose valuation is more likely to be low bids higher at each valuation than one whose valuation is likely to be high. For second-price auctions we discover that a bidder who expects to probably lose might nevertheless bid more than its valuation in an attempt to drive up the price paid by the winner. Even so, when the bidders are symmetric, the outcome is efficient in either auction format.

Before beginning the formal analysis of equilibrium bidding strategies, we recall the two payment rules. In either case the winner is the bidder offering the highest bid, and the winner's payment is distributed evenly among the losers. In a first-price auction the winner's payment is its bid, and in a second-price auction it is the second-highest bid. In what follows we first characterize bidding strategies for each payment rule when bidders are asymmetric, and provide some examples, then later provide further characterizations and illustrations when the bidders are symmetric.

## 2 Model with independent private value

Consider a sealed-bid auction of a single domain in which the winner's payment is distributed evenly among the losers. Assume that bidder $i$ has a privately known valuation $v_i$ that is independently distributed according to the probability distribution with cumulative $F_i$ and positive density $f_i$ on an interval $[0, \overline{v}]$ that is the same for all $n$ bidders. In a monotone pure-strategy equilibrium, bidder $i$ bids $\beta_i(v_i)$ if her value is $v_i$. Assume throughout that the bidding strategy $\beta_i$ is an increasing and differentiable function, and thus has an increasing and differentiable inverse function $\alpha_i$. That is, bidder $i$ bids $b$ when her valuation is $v_i = \alpha_i(b)$.

We say that two bidders have the same type if the probability distributions of their valuations are the same. Assume that there are $m_i$ bidders of the same type as bidder $i$. We characterize the equilibrium when all bidders of the same type use the same bidding strategy. For bidder $i$, therefore,

$$G_i(b) = F_i(\alpha_i(b))^{m_i - 1} \prod_{j \neq i} F_j(\alpha_j(b))^{m_j}$$

is the probability that others' bids are less than $b$, and thus $i$ wins with probability $G_i(b)$ if she bids $b$. Let $g_i(b)$ be its associated density at the bid $b$, where

$$g_i(b) = F_i(\alpha_i(b))^{m_i-1} \sum_{j \neq i} \left( \prod_{k \neq i,j} F_k(\alpha_k(b))^{m_k} \right) m_j F_j(\alpha_j(b))^{m_j-1} f_j(\alpha_j(b)) \alpha_j'(b)$$
$$+ \left( \prod_{j \neq i} F_j(\alpha_j(b))^{m_j} \right) (m_i - 1) F_i(\alpha_i(b))^{m_i-2} f_i(\alpha_i(b)) \alpha_i'(b).$$

### 2.1 Asymmetric bidders in a first-price auction

In a first-price auction, from the perspective of any one bidder with value $v$ who bids $b$, her payoff is $v-b$ if $b > b'$, where $b'$ is the highest bid among his opponents, and her payoff if she loses is $b'/(n-1)$ if $b < b'$. Her expected profit from the bid $b$ can therefore be written as

$$(v_i - b) G_i(b) + \frac{1}{n-1} \int_b^{\bar{b}} x \, dG_i(x),$$

where $\bar{b}$ is the maximum of others' possible bids.

**Proposition 1.** *In a sealed-bid first-price auction in which the winner's payment is distributed evenly among losers, an equilibrium in which bidders with the same type follow the same bidding strategy, is defined by, for each bidder of the same type as bidder $i$,*

$$-G_i(b) + \left( \alpha_i(b) - \frac{n}{n-1} b \right) g_i(b) = 0.$$

*and boundary conditions $\beta_i(0) = \beta_j(0)$ and $\beta_i(\bar{v}) = \beta_j(\bar{v})$ where $i \neq j$.*[2]

**Example 1.** Suppose there are two bidders, namely strong bidder and weak bidder. The strong and weak bidders' valuations are distributed according to the beta distribution with parameters (2,1) and (1,2), respectively. The triangular-shaped probability densities of their valuations are shown in Figure 1, and their equilibrium bidding strategies are shown in Figure 2. Observe that their bids are the same when their values are 0 or 1, but for intermediate values the weak bidder bids more than the strong bidder with the same valuation.

[2] This is a system of simultaneous first-order ordinary differential equations, one for each type. A general procedure is to make the substitutions $\gamma_i(v_1) = \alpha_i(\beta_1(v_1))$ for types $i$ other than type 1, and use the properties that the derivatives are $\alpha'_1 = 1/\beta'_1$ and $\alpha'_i = \gamma'_i / \beta'_1$. Thus $\gamma_i(v_1)$ is $i$'s valuation such that she bids the same as a bidder of type 1 does when her value is $v_1$. Thus $v_1$ becomes the variable in the differential equations for the function $\beta_1(v_1)$ and the functions $\gamma_i(v_1)$ for types $i$ different than type 1. The boundary conditions are then that each $\gamma_i(0) = 0$ and $\gamma_i(\bar{v}) = \bar{v}$.

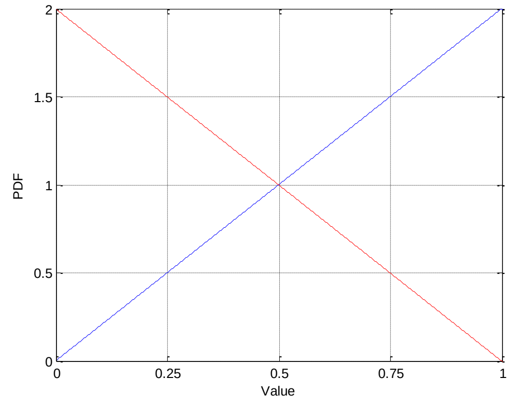



**Figure 1. Probability densities of beta distribution with parameters (2,1) and (1,2), shown in blue and red lines, respectively**

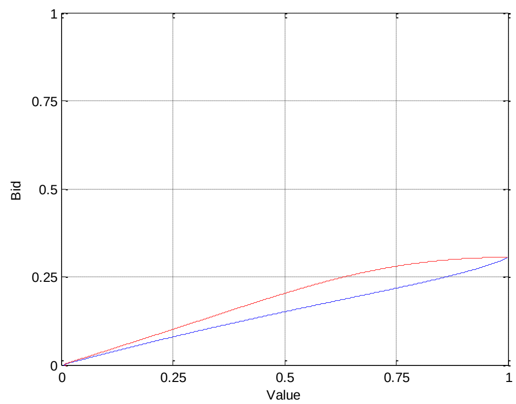



**Figure 2. Bid functions of strong (blue) and weak (red) bidders in asymmetric first-price auction**

## 2.2 Symmetric bidders in a first-price auction

Now we specialize to the case that the bidders have the same distribution of valuations, and each bidder uses the same bidding strategy $\beta(v)$ as a function of her valuation $v$.

From the perspective of any one bidder with value $v$ who bids $b = \beta(v)$, her payoff if she wins is $v - b$ and her payoff if she loses is $\beta(u)/(n-1)$, where $u$ is the random variable that is the maximum of $n-1$ independent draws from the distribution $F$ (hence has the cumulative $G = F^{n-1}$), and she wins if $b(v) > b(u)$. Therefore her expected profit when her value is $v$ and she bids $b$ is

$$(v-b)G(\alpha(b)) + \int_{\alpha(b)}^{\bar{v}} \frac{\beta(u)}{n-1} dG(u).$$

**Proposition 2.** *In a symmetric-bidder sealed-bid first-price auction in which the winner's payment is distributed evenly among losers, a symmetric equilibrium strategy is given by*

$$\beta(v) = \frac{n-1}{nF(v)^n} \int_0^v x dF(x)^n = \frac{n-1}{n}\left(v - \int_0^v F(x)^n \, dx\right)$$

That is, the bid is the fraction $(n-1)/n$ of the expectation of the maximum of $n$ draws from the distribution $F$ conditional on the maximum being less than $v$.

**Example 2.** Suppose $F(v)=v$. Then the equilibrium bidding strategy is

$$\beta(v)=\frac{n-1}{n+1}v,$$

which yields a bidder with value $v$ the expected net profit

$$\pi(v)=\frac{1}{n}\left(v^n+\frac{n-1}{n+1}\right).$$

The expected winning bid, averaged over all possible valuations, is

$$\bar{p}=\frac{n(n-1)}{(n+1)^2}.$$

The expected gain from trade is $n/(n+1)$, of which each bidder's share *ex ante* averaged over all possible valuations is $E[\pi(v)]=1/(n+1)$.

**Example 3.** Suppose each of two bidders has the beta distribution with parameters (2,2). The density of their valuations is shown in Figure 3, and the equilibrium bidding strategy in Figure 4. The formula for the equilibrium bidding strategy is

$$\beta(v)=\frac{v^5(126+5v(12v-35))}{35(3(1-v)v^2+v^3)^2}.$$

The expected profit of a bidder with valuation $v$ is

$$\pi(v)=\frac{13}{70}+v^3-\frac{1}{2}v^4.$$

We will see later that the winner's expected payment of 0.248 is less than the expected payment of 0.263 in a second-price auction with the same distribution of the bidders' valuations; nevertheless, each bidder's expected profit $\pi(v)$ is the same in the two auction formats.

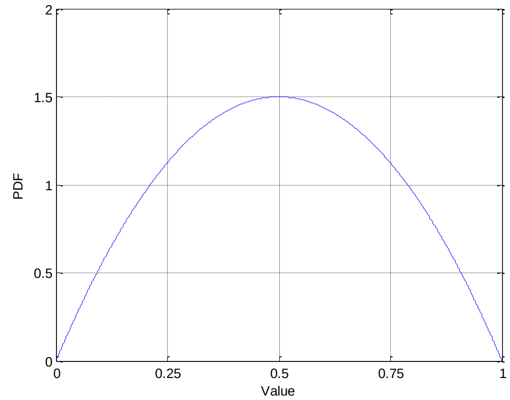



Figure 3. Probability density function of Beta distribution with parameters (2,2)

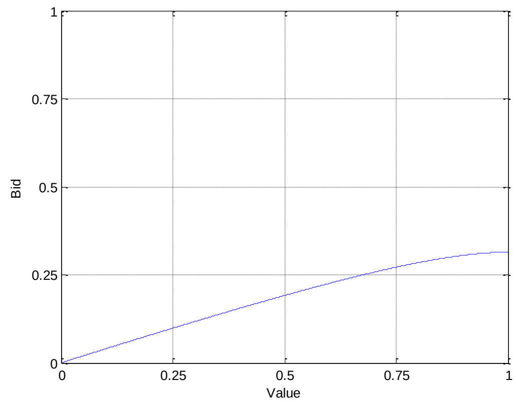



Figure 4. Bid function of a bidder with Beta distribution with parameter (2,2)

## 2.3 Asymmetric bidders in a second-price auction

In a second-price auction, from the perspective of any one bidder with value $v$ who bids $b$, her payoff is $v-b'$ if $b>b'$, where $b'$ is the highest bid among his opponents, and her payoff if she loses is $\max\{b,b''\}/(n-1)$ if $b<b'$, where $b''$ is the second-highest bid among his opponents.

Due to the long formulas that result, for simplicity here we address only the case of two types. Let $G_{ij}(b)=F_1(\alpha_1(b))^{m_1-i}F_2(\alpha_2(b))^{m_2-j}$. Then, the expected payoff of a bidder of type 1 whose value is $v$ and she bids $b\geq\underline{b}$ where $\underline{b}$ is the least bid among his opponents, is

$$\Pi_1(v,b)=\int_{\underline{b}}^{b}(v-b')dG_{10}(b')+\frac{1}{n-1}\int_b^1\left(bG_{20}(b)+\int_b^{b'}x\,dG_{20}(x)\right)(m_1-1)dF_1(\alpha_1(b'))$$
$$+\frac{1}{n-1}\int_b^1\left(bG_{11}(b)+\int_b^{b'}x\,dG_{11}(x)\right)(m_2)\,dF_2(\alpha_2(b'))$$

**Proposition 3.** *In a two-type sealed-bid second-price auction in which the winner's payment is distributed evenly among losers, a symmetric equilibrium is defined by,*

$$0=(\alpha_1-b)\left(m_2F_1f_2\alpha_2'+(m_1-1)F_2f_1\alpha_1'\right)+\frac{m_1-1}{n-1}F_2(1-F_1-bf_1\alpha_1')+\frac{m_2}{n-1}F_1(1-F_2-bf_2\alpha_2').$$

and

$$0=(\alpha_2-b)\big(m_1F_2f_1\alpha_1'+(m_2-1)F_1f_2\alpha_2'\big)+\frac{m_1}{n-1}F_2(1-F_1-bf_1\alpha_1')+\frac{m_2-1}{n-1}F_1(1-F_2-bf_2\alpha_2')$$

*and boundary conditions* $\beta_1(0)=\beta_2(0)$ *and* $\beta_1(\bar{v})=\beta_2(\bar{v})$*. Note that function arguments are omitted to shorten the equations.*

**Example 4.** As in Example 1 for a first-price auction, Suppose there are two bidders, strong and weak bidders. The strong and weak bidders' valuations are distributed according to the beta distribution with parameters (2,1) and (1,2), respectively. Their bidding strategies in a second-price auction are shown in Figure 6.

Note that the strong bidder is more likely to bid lower than the weak bidder, for the same values. Also, each bidder bids more than her value when her value is low. The evident motive is to drive up the price paid by the winning bidder.

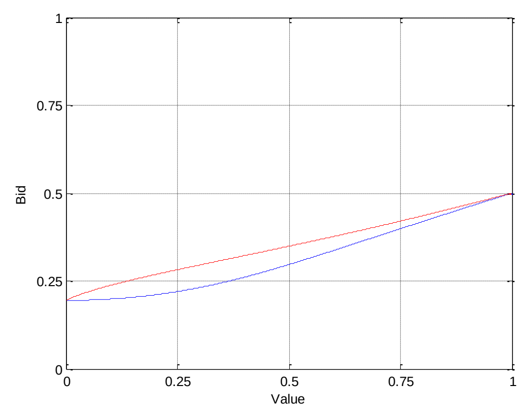



Figure 6. Bid functions of strong (blue) and weak (red) bidders in asymmetric second-price auction

## 2.4 Symmetric bidders in a second-price auction

Now we specialize to the case that the bidders have the same distribution of valuations, and each bidder uses the same bidding strategy $\beta(v)$ as a function of her valuation $v$.

In a second-price auction, from the perspective of any one bidder with value $v$ who bids $b=\beta(v)$, her payoff if she wins is $v-\beta(u)$ and her payoff if she loses is $\max\{b,\beta(w)\}/(n-1)$, where $w$ is the random variable that is the maximum of $n-2$ independent draws from the distribution $F$, and she wins if $b(v)>b(u)$. Hence her expected payoff is

$$\int_0^{\alpha(b)} v-\beta(u)\,dF(u)^{n-1}+(n-1)\int_{\alpha(b)}^{\bar{v}}\left(\int_0^{\alpha(b)}\frac{b}{n-1}dF(w)^{n-2}+\int_{\alpha(b)}^{u}\frac{\beta(w)}{n-1}dF(w)^{n-2}\right)dF(u).$$

**Proposition 4.** *In a symmetric-bidder sealed-bid second-price auction in which the winner's payment is distributed evenly among losers, a symmetric equilibrium strategy is given by*

$$\beta(v) = -\frac{n-1}{n(1-F(v))^n}\int_v^{\bar{v}} x d(1-F(x))^n = \frac{n-1}{n}\left(v + \frac{1}{(1-F(v))^n}\int_v^{\bar{v}} (1-F(x))^n \, dx\right).$$

**Example 6.** Suppose $F(v) = v$. Then

$$\beta(v) = \frac{n-1}{n+1}\left(\frac{1}{n} + v\right),$$

Observe that $\beta(0) = \frac{1}{n+1} \times \frac{n-1}{n}$ and $\beta(1) = \frac{n-1}{n}$, and the strategy is the line between these two extreme points. Note especially that $\beta(v) > v$ if $v < \frac{n-1}{n} \times \frac{1}{2}$. That is, as in the asymmetric case of a second-price auction, one with a low valuation bids more than her value in view of the prospect of raising the price paid by the winner.

## 2.5 Comparison of first- and second-price auctions

For first-price and second-price auctions, Figure 7 compares the equilibrium bidding strategies and Figure 8 compares expected profits for various numbers of bidders, $n = 2, 4, 8, 16$.

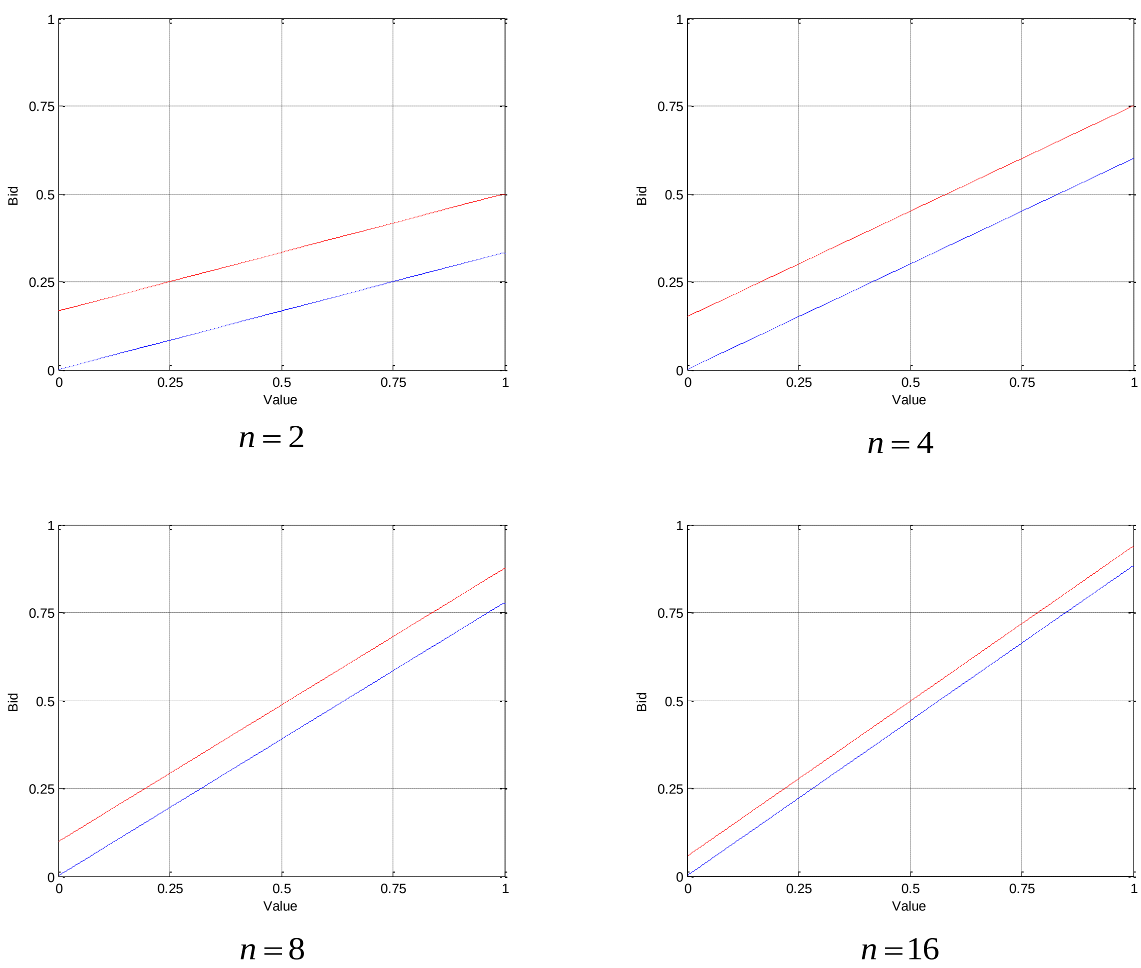



Figure 7. Bid functions of strong (blue) and weak (red) bidders in uniform first- and second-price auctions [[4 lines?]]

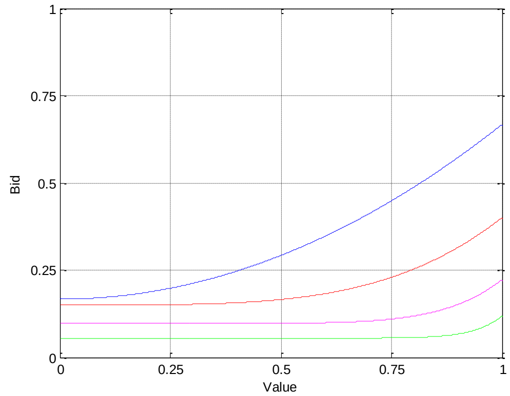



Figure 8. Expected profits in uniform auctions with 2 (blue), 4 (red), 8 (purple) and 16 (green) bidders

Although the bidding strategies for first-price and second-price auctions differ (the latter being higher), and also the expected payment of the winner differs (again, higher for a second-price auction), the expected profit of a bidder is the same in the two auction formats, namely

$$\pi(v) = \frac{(n-1)+(n+1)v^n}{n(n+1)}.$$

**Example 7.** As in Example 3, suppose each of two bidders has the beta distribution with parameters (2,2). The equilibrium bidding strategy in this case is

$$\beta(v) = \frac{13+2v(26+65v+60v^2)}{70(1+2v)^2},$$

as shown in Figure 9. Again, a bidder's expected profit is the same as in a first-price auction, namely

$$\pi(v) = \frac{13}{70} + v^3 - \frac{1}{2}v^4.$$

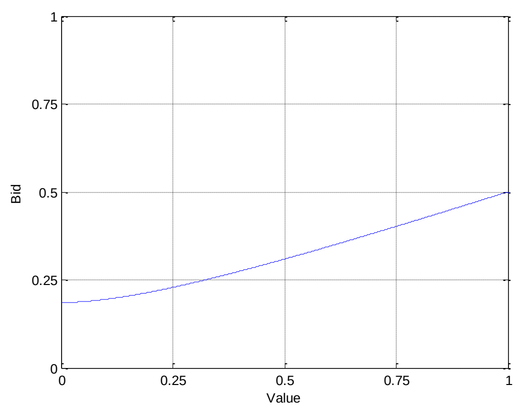



Figure 9. Bid function in asymmetric second-price auction

To summarize we have the following results.

**Proposition 5.** *Suppose (1) each bidder's value is drawn independently from the uniform distribution on* $[0,\bar{v}]$*, (2) each bidder seeks to maximize dollar profit, and (3) the high bidder wins and non-high bidders share the winner's payment equally. Then under either the first-price or second-price pricing rules there is a unique equilibrium, the outcome is ex post efficient, and each bidder's profit is invariant to the pricing rule (revenue equivalence).*

**Proof of Proposition 5.** Direct calculation results in a unique increasing equilibrium. Efficiency then is obvious. Revenue equivalence holds because the interim payment of the lowest-value bidder is invariant to the pricing rule. □

**Theorem 1.** *Suppose (1) each bidder's value is drawn independently from the same distribution F with positive density f on* $[0,\bar{v}]$*, (2) each bidder seeks to maximize dollar profit, and (3) the high bidder wins and non-high bidders share the winner's payment equally. Consider any pricing rule that results in a strictly increasing equilibrium bid function. Then the outcome is ex post efficient. However, the expected buyer payment depends on the pricing rule (revenue equivalence fails).*

**Proof of Theorem 1.** Efficiency is obvious from symmetry, the high-bid-wins rule, and the strictly increasing equilibrium bid function. Revenue equivalence does not hold because the interim payment of the lowest-value bidder is non-zero and depends on the pricing rule. This is shown from direct calculation. For example, consider an auction with three bidders whose values are distributed according to the distribution $F(v) = v^2$. The expected profits of a bidder with zero value differ in first- and second-price auctions as shown in Figure 10. □

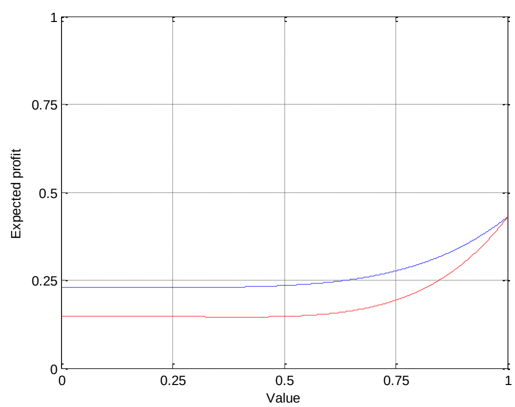



**Figure 10. Expected profit for a bidder with $F(v) = v^2$, three bidders, and first-price (blue) or second-price (red)**

## 3 Model with affiliated value

We consider the general symmetric model of a first-price applicant auction with affiliated signals and values, as in Milgrom and Weber (1982).

Let $F(y\,|\,x)$ be the distribution function of a signal $y$ given a bidder's signal $x$ and let $f(y\,|\,x)$ be its associated density function. Let $v(x,t)$ be the conditional expectation of the value obtained by the winner given his signal $x$ and the highest signal $t$ among the $n-1$ other bidders. Also, let $G(t\,|\,x)$ be the conditional distribution function of the highest signal $t$ among the $n-1$ other bidders given a signal $x$, and let $g(t|x)$ be its associated density. In addition, let $H(s|x,t)$ be the conditional distribution function of the second-highest signal $s$ among the $n-1$ other bidders given signals $x$ and $t$ and let $h(s|x,t)$ be its associated density.

If $\beta$ is the bidding strategy used by all bidders, and $\beta$ is increasing and differentiable with inverse function $\alpha$, then for any one bidder with signal $x$ his bid $b=\beta(x)$ must maximize the bidder's expected profit.

## 3.1 General symmetric first-price auction

A bidder's expected profit is defined as follows.

$$\int_0^{\alpha(b)} \big(v(x,t)-b\big)\, g(t|x)\,dt + \frac{1}{n-1}\int_{\alpha(b)}^{\infty} \beta(t) g(t|x)\,dt.$$

**Proposition 6.** *In a general sealed-bid first-price auction in which the winner's payment is distributed evenly among losers, a symmetric equilibrium strategy when the boundary condition is* $\beta(0)=v(0,0)=0$*, is defined by,*

$$\beta(x)=\frac{n-1}{n}\int_0^x v(t,t)d\theta(t|x)=\frac{n-1}{n}v(x,x)-\frac{n-1}{n}\int_0^x \theta(t|x)\,dv(t,t),$$

*and*

$$\theta(t|x)=\exp\left\{-\int_t^x \frac{n}{n-1}\frac{g(t|t)}{G(t|t)}\,dt\right\}.$$

**Example 4.** Suppose that the realized value is $V=\sum_{i=1}^{n} x_i / n$, the same for all $n$ bidders. Assume that the signals $x_i$ are uniformly, independently and identically distributed on $[0,1]$. Then,

$$\beta(x)=\left(\frac{1}{2}-\frac{1}{n(n+1)}\right)x.$$

Thus, $\beta(x)=\frac{20}{60}x, \frac{25}{60}x, \frac{27}{60}x, \ldots$ , when *n* = 2, 3, 4, … and $\beta(x)$ converges to $x/2$ as $n$ goes to infinity. Figure 5 shows bid functions with 2, 4, 8 and 16 bidders.

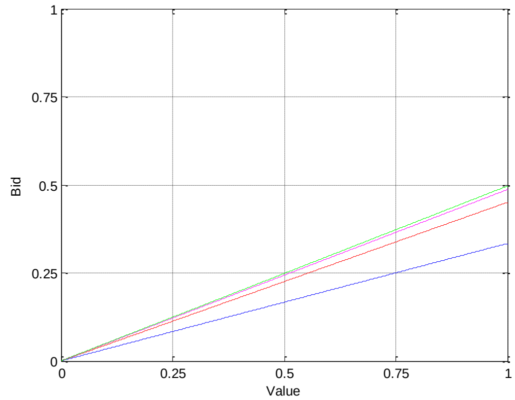



**Figure 5. Bid functions in general symmetric first-price auctions with 2 (blue), 4 (red), 8 (purple) and 16 (green) bidders**

## 3.2 General symmetric second-price auction

A bidder's expected profit is defined as follows.

$$\int_0^{\alpha(b)} (v(x,t)-\beta(t))g(t\,|\,x)dt+(n-1)\int_{\alpha(b)}^{\bar{x}}\left(\int_0^{\alpha(b)}\frac{b}{n-1}h(s\,|\,x,t)ds+\int_{\alpha(b)}^{t}\frac{\beta(s)}{n-1}h(s\,|\,x,t)ds\right)f(t\,|\,x)dt$$

**Proposition 7.** *In a general sealed-bid second-price auction in which the winner's payment is distributed evenly among losers, a symmetric equilibrium strategy is defined by*

$$\beta(x)=\int_x^{\bar{x}} v(t,t)\theta(t\,|\,x)\frac{g(t\,|\,t)}{\bar{H}(t)}dt,$$

*and*

$$\theta(t\,|\,x)=\exp\left\{-\int_x^{s}\frac{g(t\,|\,t)+f(t\,|\,t)H(t\,|\,t,t)}{\bar{H}(t)}dt\right\},$$

where $\bar{H}(x)=\int_x^{\bar{x}} H(x\,|\,x,t)f(t\,|\,x)dt$.

**Example 5.** Suppose that the realized value is $V=\sum_{i=1}^{n} x_i/n$, the same for all $n$ bidders. Assume that the signals $x_i$ are uniformly, independently and identically distributed on $[0,1]$. Then,

$$\beta(x)=\frac{(n+2)(n-1)}{2n(n+1)}(\frac{1}{n}+x)$$

Thus, $\beta(x)=\frac{1}{6}+\frac{1}{3}x,\frac{5}{36}+\frac{1}{12}x,\frac{9}{80}+\frac{1}{20}x,\ldots$ , when *n* = 2, 3, 4, … and $\beta(x)$ converges to $x/2$ as $n$ goes to infinity. Figure 5 shows bid functions with 2, 4, 8 and 16 bidders.

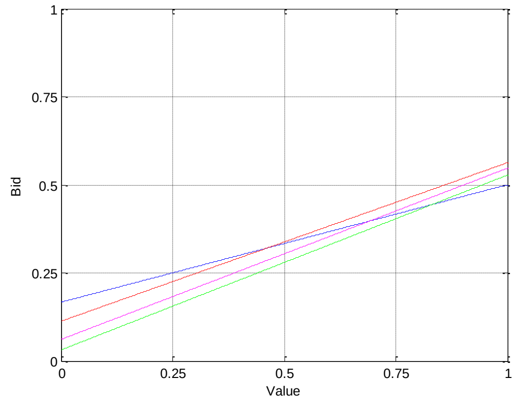



**Figure 5. Bid functions in general symmetric second-price auctions with 2 (blue), 4 (red), 8 (purple) and 16 (green) bidders**

## 4 Proposed auction designs for applicant auction

Our theoretical analysis above has been focused on auctioning a single domain. For the ICANN application, a large number of domains, roughly 145, need to be auctioned. Many bidders are bidding for multiple domains, have budget constraints, and their values depend on the clearing prices of other domains. Therefore, in addition to the pricing rule, other specific details of the auction design matter.

We propose two designs for the Applicant Auction: A first-price auction in which individual domains or batches of domains are sold sequentially, and a simultaneous second-price auction in which all domains are sold simultaneously.

In the *sequential* auction each domain is auctioned in sequence in a sealed-bid first-price auction. The high bidder wins the domain and pays its bid to the losing bidders, with the total payment divided equally among them.[3] After each auction, the auction system reports the high bid. The auction system also presents to each participant its own current winnings and its current settlement balance, which reflects payments for the domains it wins and receipts for domains it lost. The auction schedule is also displayed. For practical reasons, sets of domains may be grouped into batches which are sold simultaneously. This change shortens the auction, with limited impact on results. In the ideal case, in each batch, each company bids on at most one domain. This eliminates a possible exposure problem arising when a budget constrained bidder must bid for two domains at once of which she can only afford one. If such batching is not possible (as is the case in the ICANN setting, due to Donuts bidding on a majority of the contested domains), the next best option is to distribute the number of domains each bidder bids on in each round as evenly as possible.

---

[3] Variations on the division of the payment are certainly possible and will be considered in our analysis. For example, a natural rule would be to divide the winner's payment in proportion to the losing bids; thus, with $n$ bidders and bids $b_1 > b_2 > \ldots > b_n$, the winning bidder 1 pays losing bidder $i$ an amount $b_1 \times b_i / (b_2 + \ldots + b_n)$. The advantage of this approach is that it rewards those with higher values for the domain more. It, however, has a serious disadvantage: it creates an incentive for each bidder to bid more than its true value, and the incentive to bid more is largest for those with low values. This distortion causes the auction to be inefficient. In contrast, the equal-payment approach means that the payment to each loser does not depend on its bid. The outcome is fully efficient in the simplest case described later.

In the *simultaneous* auction, all domains are auctioned simultaneously in an ascending process. This gives the bidders richer possibilities for substituting among domains and bidding for complementary sets of domains. Second, as an ascending price process, the system allows frequent reporting of demand information, and thus facilitates price and allocation discovery through the process. Bidders are provided with relevant information that the bidders can then use when placing subsequent bids. The approach is commonly used for spectrum auctions, but is also used in many other industries, such as diamonds, gas, and electricity. It is particularly applicable in this auction since there is significant uncertainty regarding the overall value of top-level domains.

As mentioned, the simultaneous ascending auction occurs over a sequence of rounds. All domains are auctioned simultaneously. Each has a price associated with it. Before each round, the auctioneer announces a start of round price and an end of round price for each domain for which there is still competition. The end of round price is higher than the start of round price by the bid increment, which is set by the auctioneer in each round based on the level of competition. Each round, bidders who are still in the auction for a domain can update their proxy bid for the domain.

At the end of each round, if the demand for a domain is no greater than one, the highest bidder for that domain wins and pays the second highest price. The winner's payment is split equally among the other applicants for the domain, and all bidders' deposit amounts are updated to reflect the change.

If the demand is two or greater, the auction continues for that domain and another round is scheduled, but bidders whose proxy bid for a domain was lower than the end of round price of a domain are eliminated from the auction for that domain. Before the start of the next round, the auctioneer announces, along with start and end prices for the next round, the excess demand for each domain.

This process continues until all domains have closed.

## 5 Experimental testing of proposed designs

Experiment subjects were PhD students at the University of Maryland in Economics, Computer Science, and Computer Engineering, with training in game theory and auction theory. Subjects were offered a payment of about $200 per session. The actually dollar payment was proportionate to the bidder's total profits, which depends on all the bids and the bidder's values. Actual total payments had a mean of $413, standard deviation of $32, a minimum of $338, and a maximum of $476. Each subject participated in two sessions; each session lasted between 4 and 5.5 hours with a food break in the middle of each session.

The framing and subjects were chosen to closely match the actual setting. Based on ICANN's publicly downloadable data, 16 bidders were selected to allow auctioning 87 domain names for which there was unanimous participation. Of the 16 bidders, the 8 bidders bidding on the fewest domains were simulated using software; that is, these 8 bidders always bid their equilibrium bids. The other 8 bidders were assigned randomly to human experiment subjects, resulting in 198 of the 225 applications being bid on by humans. 3 of the 8 human bidders were given a budget constraint for all auctions; however, it was only binding in the simultaneous case, reflecting the fact that in a sequential auction, bidders do not have to bid on as many domains at once and are thus less likely to face budget constraints (unless they end up winning a large number of domains).

Values for bidders were drawn randomly according to two different probability distributions: For the "symmetric" case, values were drawn from the Uniform distribution, scaled so that the resulting numbers closely matched a realistic estimate for the actual ICANN auction setting. "Asymmetric" values were scaled similarly, but generated by drawing from beta (1,2) or beta (2,1), depending on whether the bidder was marked as weak or strong, respectively. A fixed set of 3 bidders was marked "Strong", the other ones "Weak". To reduce variance across identical treatments and sequential-simultaneous treatments, 4 fixed random data streams were used, in such a way that no individual experiment subject was ever exposed to the same data stream.

Two sets of two 4-hour experiment sessions were run in October 2012 to cover symmetric values and asymmetric values, for the simultaneous and sequential auction design. In each session, two auctions were conducted. Bidders were given their bidding information, including instructions and their bidder's values, four hours prior to the auction.

Both auction designs were implemented in software, using a state of the art commercial web-based auction framework. The user interface was custom written for the auction designs proposed, to allow experiment subjects to focus on the auction. In both cases, subjects were able to enter proxy bids, and the software kept track of the bidder's values to simplify the bidding process and eliminate sources of errors by the bidders.

## 6 Experimental results

Figure 11 shows efficiency measured as ratio of realized value to potential value. Both auction formats, regardless of bidder asymmetry, realize on average 98% of the potential value and thus highly efficient. Efficiency of the sequential auction is not significantly different from that of simultaneous auction.

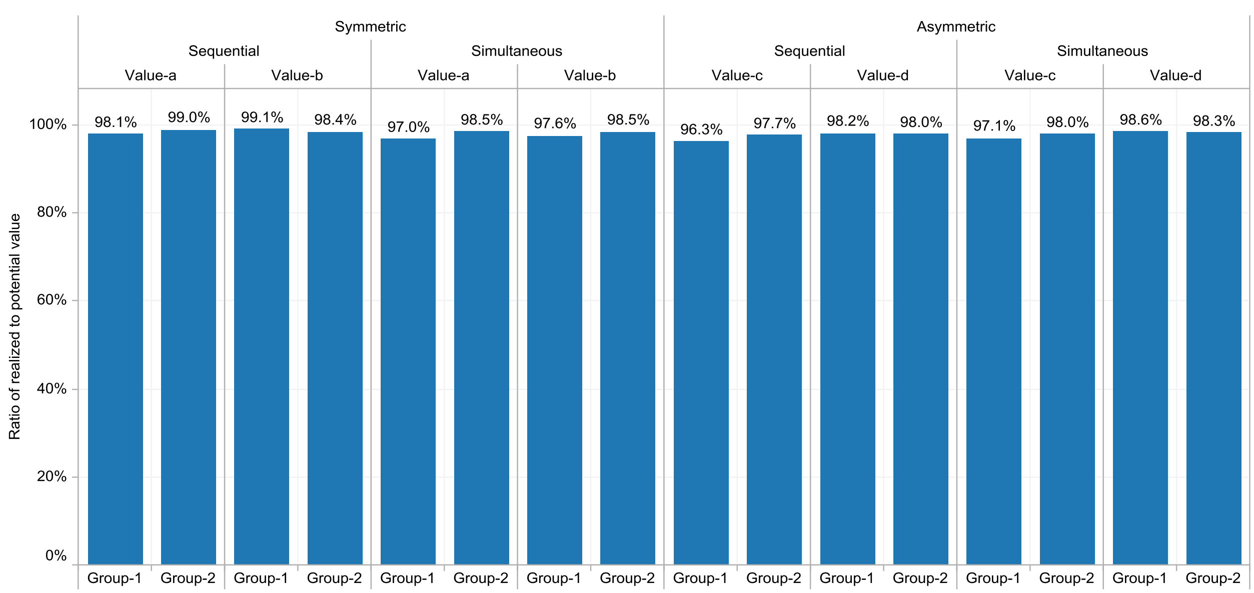



**Figure 11. Efficiency of each treatment**

Figure 12 shows buyer share and seller share—a ratio between buyer and seller's payoffs to realized value, respectively. The split among buyer and sellers is about the same in all cases.

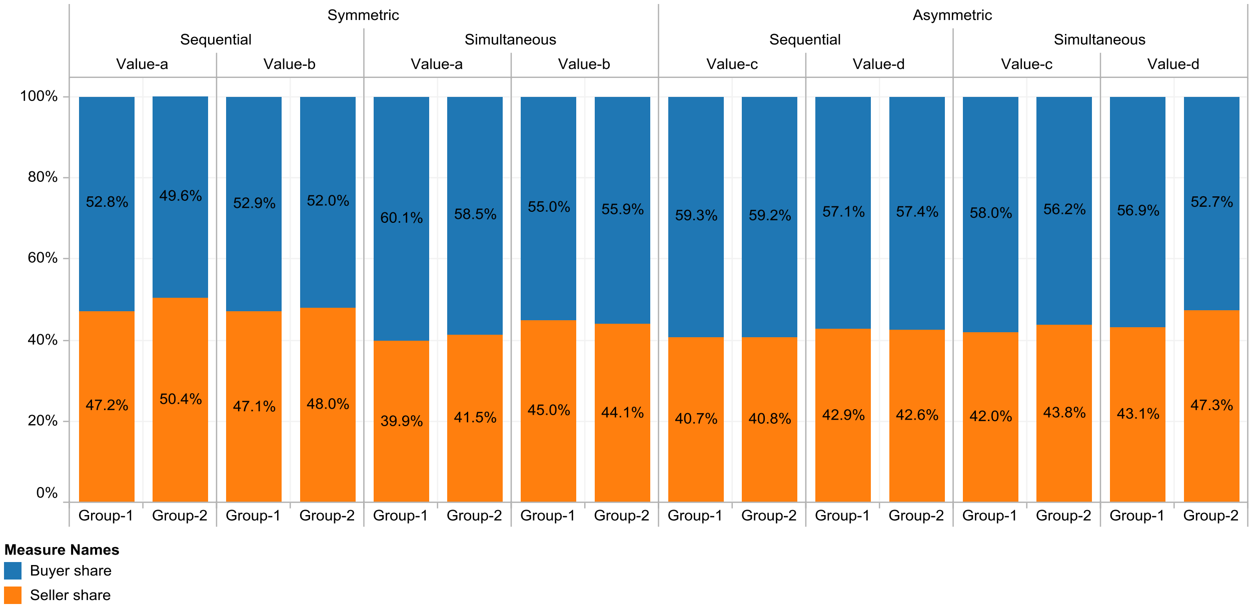



**Figure 12. Buyer and seller's shares**

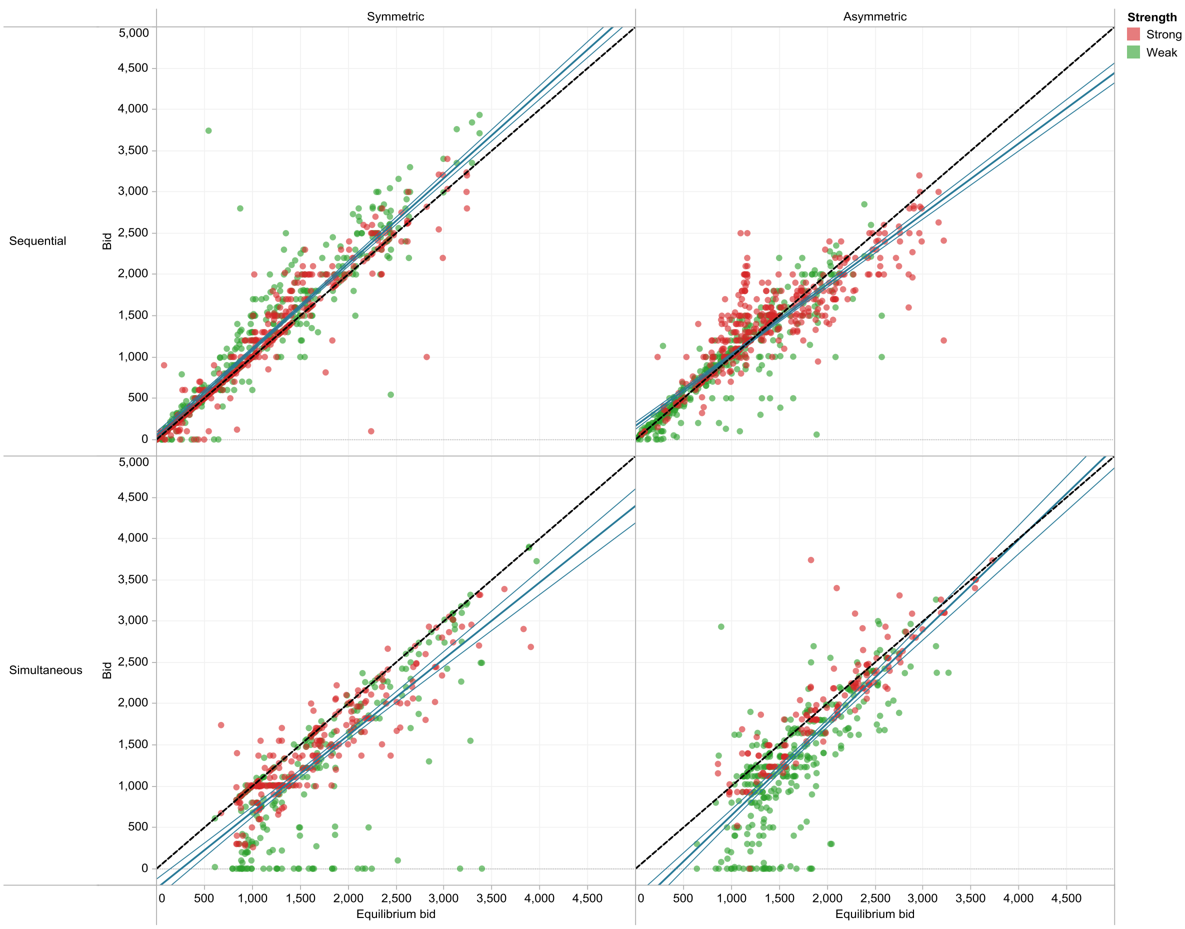



**Figure 13. Actual and equilibrium bids**

Figure 13 plots actual against equilibrium bids. The black dash line is a 45-degree line. The blue lines are trend with 5% confidence band. In sequential auction, bidders tend to overbid in symmetric case and underbid in asymmetric case. In simultaneous auction, bidders tend to underbid in both cases.

## 7 Conclusion

A theme of our results is that the basic tools of auction theory can be used straightforwardly to study applicant auctions in which the winner's payment is divided among the losers. Nevertheless, the qualitative features of the equilibrium bidding strategies include novel aspects. Most dramatic is that in a second-price auction a bidder with a low valuation has an incentive to bid more than her valuation in order to drive up the winner's payment. Nevertheless, when the bidders are symmetric the predicted outcome is efficient and each bidder is indifferent between the two auction formats regardless of her valuation. Even when bidders are symmetric ex ante, the outcome is highly efficient. Our experiments involving PhD students are consistent with the theory.

## References

Cramton, Peter, Robert Gibbons, and Paul Klemperer (1987), "Dissolving a Partnership Efficiently," *Econometrica*, 55, 615-632.

McAfee, R. Preston and John McMillan (1992), "Bidding Rings," *American Economic Review*, 82, 579-599.

Milgrom, Paul and Robert J. Weber (1982), "A Theory of Auctions and Competitive Bidding," *Econometrica*, 50, 1089-1122.

## Appendix A: Proofs

**Proof of Proposition 1.** For $b$ to be optimal it is necessary that the first-order condition is satisfied, for each $i$,

$$-G_i(b)+(v_i-b)g_i(b)-\frac{1}{n-1}bg_i(b)=0.$$

Proposition 1 can be obtained by replacing $v_i=\alpha_i(b)$. □

**Proof of Proposition 2.** For $b=\beta(v)$ to be optimal it is necessary that the first-order condition is satisfied

$$-G(\alpha(b))+(v-b)g(\alpha(b))\alpha'(b)-\frac{\beta(\alpha(b))}{n-1}g(\alpha(b))\alpha'(b)=0,$$

evaluated at $b=\beta(v)$, where $\alpha(b)=v$, $\beta(\alpha(b))=\beta(v)$ and $\alpha'(\beta(v))=1/\beta'(v)$. Thus, the condition reduces to

$$\beta'(v)+\frac{n}{n-1}\cdot\frac{g(v)}{G(v)}\beta(v)=v\frac{g(v)}{G(v)}.$$

With a boundary condition, $\beta(0)=0$, then we can derive the explicit solution as

$$\beta(v)=\frac{n-1}{nF(v)^n}\int_0^v t\,dF(t)^n.$$

Integrating by-part yields the bid function in Proposition 2. □

**Proof of Proposition 3.** For the bid $b$ to be optimal it is necessary that the first-order condition is satisfied, at $\alpha_1(b)=v$,

$$0=(\alpha_1-b)g_{10}+\frac{m_1-1}{n-1}G_{20}(1-F_1-bf_1\alpha_1')+\frac{m_2}{n-1}G_{11}(1-F_2-bf_2\alpha_2'),$$

and, at $\alpha_2(b)=v$,

$$0=(\alpha_2-b)g_{20}+\frac{m_2-1}{n-1}G_{10}(1-F_2-bf_2\alpha_2')+\frac{m_1}{n-1}G_{22}(1-F_1-bf_1\alpha_1').$$

Divide the first and the second conditions by $G_{21}$ and $G_{12}$, respectively, to get the equivalent condition. □

**Proof of Proposition 4.** For the bid $b$ to be optimal it is necessary that the first-order condition is satisfied (after removing a factor $F^{n-3}(\alpha(b))$):

$$
\begin{aligned}
0 &= (v-\beta(\alpha(b)))(n-1)F(\alpha(b))f(\alpha(b))\alpha'(b)+F(\alpha(b))(1-F(\alpha(b))) \\
&+b(n-2)(1-F(\alpha(b)))f(\alpha(b))\alpha'(b)-bF(\alpha(b))f(\alpha(b))\alpha'(b) \\
&-\beta(v)(n-2)(1-F(\alpha(b)))f(\alpha(b))\alpha'(b),
\end{aligned}
$$

where an equilibrium requires that $b=\beta(v)$, $\alpha'=1/\beta'(v)$, and $v$ is the argument of $F$ and $f$. This yields the characterization

$$
\beta'(v)-\frac{nf(v)}{1-F(v)}\beta(v)=-\frac{(n-1)f(v)}{1-F(v)}v.
$$

If we suppose that $\beta(\overline{v})$ is bounded, then we can derive the explicit solution as shown in Proposition 4. □

**Proof of Proposition 6.** The necessary condition for a maximum is

$$
0=-G(\alpha(b)\,|\,x)+\big(v(\alpha(b),t)-b\big)g(\alpha(b)\,|\,x)\alpha'(b)-\frac{1}{n-1}\beta(\alpha(b))g(\alpha(b)\,|\,x)\alpha'(b),
$$

or, since $\beta(\alpha(b))=b$,

$$
\beta'(x)+\frac{n}{n-1}\cdot\frac{g(x\,|\,x)}{G(x\,|\,x)}\beta(x)=v(x,x)\frac{g(x\,|\,x)}{G(x\,|\,x)}.
$$

This is analogous to the necessary condition for an ordinary first-price auction except that the hazard rate in the second term is inflated by the factor $n/(n-1)$, which reflect the effect of dividing the winner's payment among the losers. Solving the differential equation and integrating by-part, together with the boundary condition, yield the equilibrium strategy. □

**Proof of Proposition 7.** The necessary condition for a maximum is

$$
\begin{aligned}
0 &= (v(x,x)-\beta(x))\frac{g(x\,|\,x)}{\beta'(x)}-(n-1)\left(\int_0^x\frac{b}{n-1}h(s\,|\,x,x)ds+\int_x^x\frac{\beta(s)}{n-1}h(s\,|\,x,x)dt\right)\frac{f(x\,|\,x)}{\beta'(x)} \\
&+(n-1)\int_x^{\overline{x}}\left(\int_0^x\frac{1}{n-1}h(s\,|\,x,t)ds+\frac{\beta(x)}{n-1}\frac{h(x\,|\,x,t)}{\beta'(x)}-\frac{\beta(x)}{n-1}\frac{h(x\,|\,x,t)}{\beta'(x)}\right)f(t\,|\,x)dt,
\end{aligned}
$$

or, since $\beta(\alpha(b))=b$,

$$
0=(v(x,x)-\beta(x))\frac{g(x\,|\,x)}{\beta'(x)}-\beta(x)H(x\,|\,x,x)\frac{f(x\,|\,x)}{\beta'(x)}+\overline{H}(x\,|\,x).
$$

Suppose $\beta(\overline{x})$ is bounded, solving the differential equation yields the equilibrium bidding strategy. □

## Appendix B: Bidder Instructions

### 1. Sequential First-Price Sealed-Bid Auction: Instructions to Bidders (Symmetric distribution)

Welcome to the Applicant Auction Experiment. In this experiment, you will participate in domain auctions as a bidder. The precise rules and procedures that govern the auctions are explained below.

Various foundations have provided funds for this research. The instructions are simple, and if you follow them carefully and make good decisions you can finish the experiment with a considerable amount of money, which will be paid to you in cash at the end of the experiment. Participants completing the session do not risk losing any money. The experiment will last about four hours.

Currency used in this experiment is Experimental Dollars (ED) in thousands. Throughout the experiment the dollar figures refer to this currency with "thousands" suppressed. At the end of the experiment your earnings will be converted into US Dollars using the conversion rates given below. You will be paid in cash at the end of the experiment. The more ED you earn, the more US Dollars you earn.

#### Auction setting

You are a bidder in four domain auctions that will be conducted in this experiment. In each auction, there are 16 bidders competing for 87 domains. Each bidder will be assigned: (i) a set of domains that the bidder has applied for, and (ii) their *private values* for these domains.

Bidders differ in the set of domains that they applied for and have different values for the same domains. The domains for each bidder are shown in the bidding tool discussed at the end of this instruction. Bidders cannot bid for domains they did not apply for.

In the experiment about eight bidders are played by human bidders, while the remaining bidders are played by computer bidders. You will be randomly assigned to one of the human bidders. The computer bidders follow an equilibrium bidding strategy for a simplified setting, as described below.

#### Values

Two auctions are conducted in this session. Both auctions are identical in structure, although the values are independent.

Each bidder's value for each domain is randomly and independently drawn from a *uniform distribution* on the interval [0, 5000], rounded to the nearest integer. These values are private—each bidder will know only her own value.

#### Auction rules

A Sequential First-Price Sealed-Bid Auction will be used throughout this session. All 87 domains will be sold in a sequence of first-price sealed-bid rounds. In each round, a small batch of domains will be auctioned simultaneously using the first-price sealed-bid format: for each domain, the high bidder wins and pays her bid. The winner's payment is split equally among the losing bidders. Ties are broken randomly.

The batching of domains, as well as the auction schedule for each round will be announced before the first round takes place.

You will be able to make bids on each of the domains you applied for. At the time you place your bid you will know the set of domains you applied for (and therefore can bid on) and the set of domains each of the other bidders applied for. Thus, you will know both the number of bidders and the other companies that applied for each domain. If you fail to place a bid in the time available—either before or during the round in which the particular domain is auctioned—a bid of zero is assumed.

After a round has ended, the winning bid amount will be disclosed, but not the identity of the winner.

## Profits

A bidder's total profit is the sum of the profits from all domains of interest. Due to the payment rule in this auction, along with the usual profit from the domains you have won, you also profit from the domains that you have lost.

- Profit from domain won:

$$\text{Profit}_{won} = \text{value} - \text{price}$$

- Profit from domain lost, where *n* is the initial number of bidders for the domain:

$$\text{Profit}_{lost} = \frac{\text{winner's payment}}{\text{n} - 1}$$

### *Examples*

Suppose that your valuation for the domain is 4,500 and you win it at a price of 4,000. Then your profit from this domain is equal to 4,500 – 4,000 = 500 ED.

Suppose that you lose the domain, the initial number of bidders for that domain is 5, and the winner pays 4,000. Then your profit from this domain is equal to 4,000 / 4 = 1,000 ED.

## Deposit

Each bidder has an initial deposit. The size of the deposit determines the maximum bidding commitment the bidder can make. The total of active bids and winning payments cannot exceed five times the current deposit. As domains are sold, the payment received by the loser is added to the deposit amount.

The auction system will prevent a bidder from placing bids on a collection of domains that would cause the bidder's total commitment to exceed five times the bidder's current deposit.

## Bidding strategy

The sequential first-price sealed-bid auction allows the bidders to adopt complex bidding strategies. Below are some results from auction theory about single item auctions that may be relevant when devising your bidding strategy.

Before stating the results, here is some notation. There are $n$ bidders with bidder $i$ assigning a value of $V_i$ to the object. Each $V_i$ is drawn independently on the interval $[0, \bar{v}]$ according to the cumulative distribution function $F_i$ with a positive density $f_i$. ( $\bar{v} = 5000$ in the experiment.)

Recall that in the standard private-value setting where winning payments are retained by the auctioneer, the first-price auction has a unique symmetric equilibrium when each bidder's value is drawn from the same distribution *F* with positive density *f*. It is

$$b(v) = v - F(v)^{-(n-1)} \int_0^v F(u)^{n-1} du.$$

For the uniform distribution on the interval $[0, \bar{v}]$, this reduces to $b(v) = \frac{n-1}{n} v$. Thus with two bidders you bid one-half of your value.

Bidder incentives change in our setting where the winner's payment is shared equally among the losers. Notice that losing is made more attractive in this case, relative to the standard auction—the loser receives a share of the winner's payment, rather than 0.

With symmetric bidders with values independently drawn from the uniform distribution, there is a unique symmetric equilibrium for the first-price domain auction. It is

$$b(v) = \frac{n-1}{n+1} v.$$

### Bidding tool

In addition to the auction system, you will have a bidding tool, applicant-auction-tool-sequential.xlsx. All bidders have the same tool. The tool allows you to explore alternative bidding strategies. It includes all the information that is common knowledge: the domains, the bidders and which domains each can bid for, the equilibrium bid functions wherever the equilibrium is known (as described above). Note that there is a separate sheet for each auction. Be sure you are using the correct sheet for the particular auction.

To use the tool, you will need to go to the appropriate sheet. Each of the two auctions has a separate sheet—Symmetric1 and Symmetric2. Then sort the sheet by your bidder name and then by domain, so that all the domains you can bid for are listed first and in alphabetical order. Then you can paste your values into the sheet from the auction system by clicking on the Bidder Info button, selecting all domains and values in the window toward the bottom of the screen, then Ctrl-C to copy. Of course this step must be repeated for each auction. Be sure to save the Workbook once your values are pasted in. Also save your workbook at the end of each auction.

You can then use the tool to explore various bidding strategies. Once you are happy with your bids, you can enter them directly in the auction system, or if you have many bids, you can upload your bids. To upload bids, you must first create a bid upload file in .csv format. Then go to the auction system and click the Upload button on the Bidding screen to upload the bids. Be sure to check your uploaded bids carefully. Any errors can be corrected directly or through another upload.

Please note that you initially may not have sufficient money on deposit to bid as high as you would like on all of your domains. You may need to limit some bids early on in order to satisfy the limitation on bids coming from your limited deposit. You commitments from active bids and domains won can be at most five times your current deposit.

### Payment conversion

Your profits in each auction in ED currency is converted to the US Dollars by the formula

$$\text{Payment in US dollars} = \text{Profit in ED} \times \text{rate for role}$$

The payout rate for each role is given below:

| Bidder | Rate |
|---|---|
| Donuts | 0.12% |
| Minds+Machine | 0.27% |
| Google | 0.32% |
| Famous Four | 0.29% |
| Uniregistry | 0.27% |
| Afilias | 0.97% |
| Amazon | 0.44% |
| Radix | 0.92% |

At the end of the session you will receive your total US dollar payoff in cash. The conversion rates have been set so that each subject receives a payment of approximately US$400, regardless of role. The actual payment will be more or less than US$400 depending on the bids of the bidders in the auctions.

## 2. Simultaneous Ascending Clock Auction: Instructions to Bidders (Symmetric distribution)

Welcome to the Applicant Auction Experiment. In this experiment, you will participate in domain auctions as a bidder. The precise rules and procedures that govern the auctions are explained below.

Various foundations have provided funds for this research. The instructions are simple, and if you follow them carefully and make good decisions you can finish the experiment with a considerable amount of money, which will be paid to you in cash at the end of the experiment. Participants completing the session do not risk losing any money. The experiment will last about four hours.

Currency used in this experiment is Experimental Dollars (ED) in thousands. Throughout the experiment the dollar figures refer to this currency with “thousands” suppressed. At the end of the experiment your earnings will be converted into US Dollars using the conversion rates given below. You will be paid in cash at the end of the experiment. The more ED you earn, the more US Dollars you earn.

## Auction setting

You are a bidder in four domain auctions that will be conducted in this experiment. In each auction, there are 16 bidders competing for 87 domains. Each bidder will be assigned: (i) a set of domains that the bidder has applied for, and (ii) their *private values* for these domains.

Bidders differ in the set of domains that they applied for and have different values for the same domains. The domains for each bidder are shown in the bidding tool discussed at the end of this instruction. Bidders cannot bid for domains they did not apply for.

In the experiment about eight bidders are played by human bidders, while the remaining bidders are played by computer bidders. You will be randomly assigned to one of the human bidders. The computer bidders follow an equilibrium bidding strategy for a simplified setting, as described below.

## Values

Two auctions are conducted in this session. Both auctions are identical in structure, although the values are independent.

Each bidder's value for each domain is randomly and independently drawn from a *uniform distribution* on the interval [0, 5000], rounded to the nearest integer. These values are private—each bidder will know only her own value.

## Auction rules

A Simultaneous Ascending Clock Auction will be used throughout this session.

All 87 domains will be sold simultaneously in multiple rounds. In each round, for each domain, the number of active bidders is announced together with two prices: (i) the *minimum price to bid,* and (ii) the *minimum price to continue*. The *minimum price to bid* is where the auction has reached at the end of the last round (or $0 in the first round). You are already committed to a bid of at least this amount, which is why this is the lowest bid you may place. The *minimum price to continue* is the smallest bid that you may place in the current round in order to be given the opportunity to bid in the next round. Thus, for each domain of interest, the submitted bid indicates your decision to either exit in the current round with a bid that is between the *minimum price to bid* and the *minimum price to continue*, or continue with a bid that is at or above the *minimum bid to continue*, in which case you will be given the opportunity to continue bidding on the domain in the next round. In other words you may:

- *Exit* from a domain by choosing a bid that is less than the announced *minimum price to continue* for that round. A bidder cannot bid for a domain for which she has submitted an exit bid.
- You may *continue* to bid on a domain of interest by choosing a bid that is greater than or equal to the announced *minimum price to continue* for that round.

At the end of the round, the auction system will identify if the domain received multiple bids that are greater than or equal to the *minimum price to continue*. If so, the auction for that domain will proceed to the next round. The price for the domain will be increased by a percentage increment in the next round.

If there is only one or no bid that is greater than or equal to the *minimum price to continue* for a domain, the domain is won by the highest bidder. Ties are broken randomly.

The auction continues until there is no domain for which multiple bidders are active; that is, there is no excess demand, since all or all-but-one bidder has placed an exit bid for the domain at a price less than the *minimum price to continue*.

Pricing is based on a second-price rule: Each domain then is awarded to the highest bidder, who will pay the highest losing bid. Each losing bidder will receive an equal share of the winner's payment; that is, each loser receives the winner's payment divided by the number of losing bidders for the particular domain.

In each round, bidders need to submit their bids within the time allowed. If no action is taken for a domain, it will be assumed that the bidder has chosen to exit from that domain.

### Profits

A bidder's total profit is the sum of the profits from all domains of interest. Due to the payment rule in this auction, along with the usual profit from the domains you have won, you also profit from the domains that you have lost.

- Profit from domain won:

$$\text{Profit}_{won} = \text{value} - \text{price}$$

- Profit from domain lost, where *n* is the initial number of bidders for the domain:

$$\text{Profit}_{lost} = \frac{\text{winner's payment}}{\text{n} - 1}$$

#### *Examples*

Suppose that your valuation for the domain is 4,500 and you win it at a price of 4,000. Then your profit from this domain is equal to 4,500 – 4,000 = 500 ED.

Suppose that you lose the domain, the initial number of bidders for that domain is 5, and the winner pays 4,000. Then your profit from this domain is equal to 4,000 / 4 = 1,000 ED.

### Deposit

Each bidder has an initial deposit. The size of the deposit determines the maximum bidding commitment the bidder can make. The total of active bids and winning payments cannot exceed five times the current deposit. As domains are sold, the payment received by the loser is added to the deposit amount. Also for domains that have not yet sold but for which the bidder has exited, the bidder's deposit is credited with the minimum payment that the bidder may receive once the domain is sold—this is the *minimum price to bid* in the current round.

The auction system will prevent a bidder from placing bids on a collection of domains that would cause the bidder's total commitment to exceed five times the bidder's current deposit.

## Bidding strategy

The simultaneous ascending clock auction allows the bidders to adopt complex bidding strategy. Below are some results from auction theory about single item auctions that may be relevant when devising your bidding strategy.

Before stating the results, here is some notation. There are $n$ bidders with bidder $i$ assigning a value of $V_i$ to the object. Each $V_i$ is drawn independently on the interval $[0, \bar{v}]$ according to the cumulative distribution function $F_i$ with a positive density $f_i$. ( $\bar{v} = 5000$ in the experiment.)

Recall that in the standard private-value setting where winning payments are retained by the auctioneer, the second-price and ascending clock auctions both have the same dominant strategy equilibrium: bid (up to) your private value, or $b(v) = v$.

Bidder incentives change in our setting where the winner's payment is shared equally among the losers. Notice that losing is made more attractive in this case, relative to the standard auction—the loser receives a share of the winner's payment, rather than 0.

With symmetric bidders with values independently drawn from the uniform distribution, there is a unique symmetric equilibrium for the second-price domain auction. It is

$$b(v) = \bar{v}\,\frac{(n-1)\left(n\frac{v}{\bar{v}}+1\right)}{n(n+1)}.$$

## Bidding tool

In addition to the auction system, you will have a bidding tool, applicant-auction-tool-simultaneous.xlsx. All bidders have the same tool. The tool allows you to explore alternative bidding strategies. It includes all the information that is common knowledge: the domains, the bidders and which domains each can bid for, the equilibrium bid functions wherever the equilibrium is known (as described above). Note that there is a separate sheet for each auction. Be sure you are using the correct sheet for the particular auction.

To use the tool, you will need to go to the appropriate sheet. Each of the two auctions has a separate sheet—Symmetric1 and Symmetric2. Then sort the sheet by your bidder name and then by domain, so that all the domains you can bid for are listed first and in alphabetical order. Then you can paste your values into the sheet from the auction system by clicking on the Bidder Info button, selecting all domains and values in the window toward the bottom of the screen, then Ctrl-C to copy. Of course this step must be repeated for each auction. Be sure to save the Workbook once your values are pasted in. Also save your workbook at the end of each auction.

You can then use the tool to explore various bidding strategies. Once you are happy with your bids, you can enter them directly in the auction system, or if you have many bids, you can upload your bids. To upload bids, you must first create a bid upload file in .csv format. Then go to the auction system and click the Upload button on the Bidding screen to upload the bids. Be sure to check your uploaded bids carefully. Any errors can be corrected directly or through another upload.

Please note that you initially may not have sufficient money on deposit to bid as high as you would like on all of your domains. You may need to limit some bids early on in order to satisfy the limitation on bids coming from your limited deposit. You commitments from active bids and domains won can be at most five times your current deposit.

### Payment conversion

Your profits in each auction in ED currency is converted to the US Dollars by the formula

$$\text{Payment in US dollars} = \text{Profit in ED} \times \text{rate for role}$$

The payout rate for each role is given below:

| Bidder | Rate |
|---|---|
| Donuts | 0.12% |
| Minds+Machine | 0.27% |
| Google | 0.33% |
| Famous Four | 0.29% |
| Uniregistry | 0.28% |
| Afilias | 0.99% |
| Amazon | 0.44% |
| Radix | 0.93% |

At the end of the session you will receive your total US dollar payoff in cash. The conversion rates have been set so that each subject receives a payment of approximately US$400, regardless of role. The actual payment will be more or less than US$400 depending on the bids of the bidders in the auctions.

## 3. Sequential First-Price Sealed-Bid Auction: Instructions to Bidders (Asymmetric distributions)

Welcome to the Applicant Auction Experiment. In this experiment, you will participate in domain auctions as a bidder. The precise rules and procedures that govern the auctions are explained below.

Various foundations have provided funds for this research. The instructions are simple, and if you follow them carefully and make good decisions you can finish the experiment with a considerable amount of money, which will be paid to you in cash at the end of the experiment. Participants completing the session do not risk losing any money. The experiment will last about four hours.

Currency used in this experiment is Experimental Dollars (ED) in thousands. Throughout the experiment the dollar figures refer to this currency with “thousands” suppressed. At the end of the experiment your earnings will be converted into US Dollars using the conversion rates given below. You will be paid in cash at the end of the experiment. The more ED you earn, the more US Dollars you earn.

## Auction setting

You are a bidder in four domain auctions that will be conducted in this experiment. In each auction, there are 16 bidders competing for 87 domains. Each bidder will be assigned: (i) a set of domains that the bidder has applied for, and (ii) their *private values* for these domains.

Bidders differ in the set of domains that they applied for and have different values for the same domains. The domains for each bidder are shown in the bidding tool discussed at the end of this instruction. Bidders cannot bid for domains they did not apply for.

In the experiment about eight bidders are played by human bidders, while the remaining bidders are played by computer bidders. You will be randomly assigned to one of the human bidders. The computer bidders follow an equilibrium bidding strategy for a simplified setting, as described below.

## Values

Two auctions are conducted in this session. Both auctions are identical in structure, although the values are independent.

Each bidder's value for each domain is randomly and independently drawn from a *triangle distribution* on the interval [0, 5000], rounded to the nearest integer. These values are private—each bidder will know only her own value. Two types of triangle distributions are used depending on whether the bidder is *strong* or *weak*. There are three strong bidders: Donuts, Google and Amazon. The rest of the bidders are weak.

- The value, *v*, of a *strong bidder* for each domain is randomly and independently drawn from a distribution with density $f_s(v) = 2\frac{v}{\bar{v}^2}$, and cumulative $F_s(v) = \left(\frac{v}{\bar{v}}\right)^2$ on the interval [0, 5000], rounded to the nearest integer. The mean value then is 3750 thousand dollars.
- The value *v* of a *weak bidder* for each domain is randomly drawn from a distribution with density $f_w(v) = \frac{2}{\bar{v}}\left(1 - \frac{v}{\bar{v}}\right)$, , and cumulative $F_w(v) = 1 - (1 - \frac{v}{\bar{v}})^2$ on the interval [0, 5000], rounded to the nearest integer. The mean value then is 1250 thousand dollars.

## Auction rules

A Sequential First-Price Sealed-Bid Auction will be used throughout this session. All 87 domains will be sold in a sequence of first-price sealed-bid rounds. In each round, a small batch of domains will be auctioned simultaneously using the first-price sealed-bid format: for each domain, the high bidder wins and pays her bid. The winner's payment is split equally among the losing bidders. Ties are broken randomly.

The batching of domains, as well as the auction schedule for each round will be announced before the first round takes place.

You will be able to make bids on each of the domains you applied for. At the time you place your bid you will know the set of domains you applied for (and therefore can bid on) and the set of domains each of the other bidders applied for. Thus, you will know both the number of bidders and the other companies that applied for each domain. If you fail to place a bid in the time available—either before or during the round in which the particular domain is auctioned—a bid of zero is assumed.

After a round has ended, the winning bid amount will be disclosed, but not the identity of the winner.

## Profits

A bidder's total profit is the sum of the profits from all domains of interest. Due to the payment rule in this auction, along with the usual profit from the domains you have won, you also profit from the domains that you have lost.

- Profit from domain won:

$$\text{Profit}_{won} = \text{ value} - \text{price}$$

- Profit from domain lost, where *n* is the initial number of bidders for the domain:

$$\text{Profit}_{lost} = \frac{\text{winner's payment}}{\text{n} - 1}$$

*Examples*

Suppose that your valuation for the domain is 4,500 and you win it at a price of 4,000. Then your profit from this domain is equal to 4,500 – 4,000 = 500 ED.

Suppose that you lose the domain, the initial number of bidders for that domain is 5, and the winner pays 4,000. Then your profit from this domain is equal to 4,000 / 4 = 1,000 ED.

## Deposit

Each bidder has an initial deposit. The size of the deposit determines the maximum bidding commitment the bidder can make. The total of active bids and winning payments cannot exceed five times the current deposit. As domains are sold, the payment received by the loser is added to the deposit amount.

The auction system will prevent a bidder from placing bids on a collection of domains that would cause the bidder's total commitment to exceed five times the bidder's current deposit.

## Bidding strategy

The sequential first-price sealed-bid auction allows the bidders to adopt complex bidding strategies. Below are some results from auction theory about single-item auctions that may be relevant when devising your bidding strategy.

Before stating the results, here is some notation. There are $n$ bidders with bidder $i$ assigning a value of $V_i$ to the object. Each $V_i$ is drawn independently on the interval $[0, \bar{v}]$ according to the cumulative distribution function $F_i$ with a positive density $f_i$. ( $\bar{v} = 5000$ in the experiment.)

Recall that in the standard private-value setting where winning payments are retained by the auctioneer, the first-price auction has a unique symmetric equilibrium when each bidder's value is drawn from the same distribution *F* with positive density *f*. It is

$$b(v) = v - F(v)^{-(n-1)} \int_0^v F(u)^{n-1} du.$$

For the uniform distribution on the interval $[0, \bar{v}]$, this reduces to $b(v) = \frac{n-1}{n} v$. Thus with two bidders you bid one-half of your value.

Bidder incentives change in our setting where the winner's payment is shared equally among the losers. Notice that losing is made more attractive in this case, relative to the standard auction—the loser receives a share of the winner's payment, rather than 0.

We can calculate the unique symmetric equilibrium when there are two bidders and each bidder's value is independently drawn from a triangle distribution.

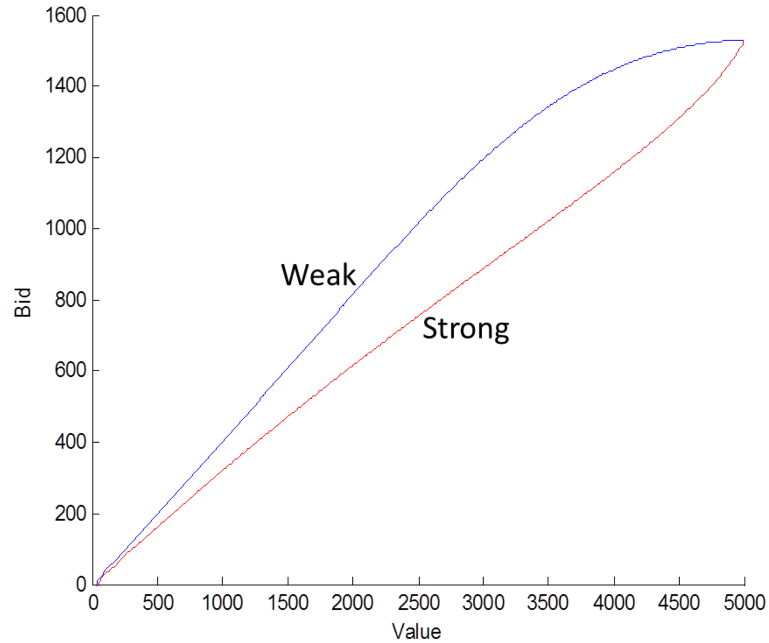
With two strong bidders, the symmetric equilibrium bid function is

$$b_{2strong}(v) = \frac{2v}{5}.$$

With two weak bidders, the symmetric equilibrium bid function is

$$b_{2weak}(v) = \frac{v(40 + 3\frac{v}{\bar{v}}(4\frac{v}{\bar{v}} - 15))}{30(\frac{v}{\bar{v}} - 2)^2}.$$

When the bidders' values are drawn from different distributions then numerical methods must be used to compute the equilibrium. As an example, we present the case with one strong bidder and one weak bidder in the figure below. Notice that the weak bidder bids more aggressively than the strong bidder to compensate for the weakness; similarly the strong bidder bids less aggressively than the weak bidder in recognition of her relative strength.




## Bidding tool

In addition to the auction system, you will have a bidding tool:

bidding-tool-sequential-asymmetric-25oct5pm-xy-role.xlsm.

*Please make a copy of this file and change the name of this tool before you paste your values. In particular, (1) replace "xy" with either an "X" or a "Y" depending on whether you have an X or Y in the URL with your login instructions, and (2) replace "role" with your company name, e.g. Google. Then go to the auction system and copy and paste your values. You may do this in advance of the experiment but be sure to bring you customized file to the lab.*

All bidders have the same tool. The tool allows you to explore alternative bidding strategies. It includes all the information that is common knowledge: the domains, the bidders and which domains each can bid for, the equilibrium bid functions wherever the equilibrium is known (as described above). Note that there is a separate sheet for each auction. Be sure you are using the correct sheet for the particular auction.

To use the tool, you will need to go to the appropriate sheet. Each of the two auctions has a separate sheet—Asymmetric1 and Asymmetric2. Then sort the sheet by your bidder name and then by domain, so that all the domains you can bid for are listed first and in alphabetical order. Then you can paste your values into the sheet from the auction system by clicking on the Bidder Info button, selecting all domains and values in the window toward the bottom of the screen, then Ctrl-C to copy. Of course this step must be repeated for each auction. Be sure to save the Workbook once your values are pasted in. Also save your workbook at the end of each auction.

You can then use the tool to explore various bidding strategies. *You may do this in advance of the experimental session.* Once you are happy with your bids, you can enter them directly in the auction system, or if you have many bids, you can upload your bids. To upload bids, you must first create a bid upload file in .csv format. Then go to the auction system and click the Upload button on the Bidding screen to upload the bids. Be sure to check your uploaded bids carefully. Any errors can be corrected directly or through another upload.

Please note that you initially may not have sufficient money on deposit to bid as high as you would like on all of your domains. You may need to limit some bids early on in order to satisfy the limitation on bids coming from your limited deposit. You commitments from active bids and domains won can be at most five times your current deposit.

### Payment conversion

Your profits in each auction in ED currency is converted to the US Dollars by the formula

$$\text{Payment in US dollars} = \text{Profit in ED} \times \text{rate for role}$$

The payout rate for each role is given below:

| | **Rate** |
|---|---|
| **Bidder** | **Asymmetric** |
| Donuts | 0.10% |
| Minds+Machine | 0.34% |
| Google | 0.26% |
| Famous Four | 0.34% |
| Uniregistry | 0.32% |
| Afilias | 1.04% |
| Amazon | 0.36% |
| Radix | 1.10% |

At the end of the session you will receive your total US dollar payoff in cash. The conversion rates have been set so that each subject receives a payment of approximately US$400, regardless of role. The actual payment will be more or less than US$400 depending on the bids of the bidders in the auctions.

## 4. Simultaneous Ascending Clock Auction: Instructions to Bidders (Asymmetric distributions)

Welcome to the Applicant Auction Experiment. In this experiment, you will participate in domain auctions as a bidder. The precise rules and procedures that govern the auctions are explained below.

Various foundations have provided funds for this research. The instructions are simple, and if you follow them carefully and make good decisions you can finish the experiment with a considerable amount of money, which will be paid to you in cash at the end of the experiment. Participants completing the session do not risk losing any money. The experiment will last about four hours.

Currency used in this experiment is Experimental Dollars (ED) in thousands. Throughout the experiment the dollar figures refer to this currency with "thousands" suppressed. At the end of the experiment your earnings will be converted into US Dollars using the conversion rates given below. You will be paid in cash at the end of the experiment. The more ED you earn, the more US Dollars you earn.

### Auction setting

You are a bidder in four domain auctions that will be conducted in this experiment. In each auction, there are 16 bidders competing for 87 domains. Each bidder will be assigned: (i) a set of domains that the bidder has applied for, and (ii) their *private values* for these domains.

Bidders differ in the set of domains that they applied for and have different values for the same domains. The domains for each bidder are shown in the bidding tool discussed at the end of this instruction. Bidders cannot bid for domains they did not apply for.

In the experiment about eight bidders are played by human bidders, while the remaining bidders are played by computer bidders. You will be randomly assigned to one of the human bidders. The computer bidders follow an equilibrium bidding strategy for a simplified setting, as described below.

### Values

Two auctions are conducted in this session. Both auctions are identical in structure, although the values are independent.

Each bidder's value for each domain is randomly and independently drawn from a *triangle distribution* on the interval [0, 5000], rounded to the nearest integer. These values are private—each bidder will know only her own value. Two types of triangle distributions are used depending on whether the bidder is *strong* or *weak*. There are three strong bidders: Donuts, Google and Amazon. The rest of the bidders are weak.

- The value, *v*, of a *strong bidder* for each domain is randomly and independently drawn from a distribution with density $f_s(v) = 2\frac{v}{\overline{v}^2}$, and cumulative $F_s(v) = \left(\frac{v}{\overline{v}}\right)^2$ on the interval [0, 5000], rounded to the nearest integer. The mean value then is 3750 thousand dollars.
- The value *v* of a *weak bidder* for each domain is randomly drawn from a distribution with density $f_w(v) = \frac{2}{\overline{v}}\left(1 - \frac{v}{\overline{v}}\right)$, , and cumulative $F_w(v) = 1 - (1 - \frac{v}{\overline{v}})^2$ on the interval [0, 5000], rounded to the nearest integer. The mean value then is 1250 thousand dollars.

### Auction rules

A Simultaneous Ascending Clock Auction will be used throughout this session.

All 87 domains will be sold simultaneously in multiple rounds. In each round, for each domain, the number of active bidders is announced together with two prices: (i) the *minimum price to bid,* and (ii) the *minimum price to continue*. The *minimum price to bid* is where the auction has reached at the end of the last round (or \$0 in the first round). You are already committed to a bid of at least this amount, which is why this is the lowest bid you may place. The *minimum price to continue* is the smallest bid that you may place in the current round in order to be given the opportunity to bid in the next round. Thus, for each domain of interest, the submitted bid indicates your decision to either exit in the current round with a bid that is between the *minimum price to bid* and the *minimum price to continue*, or continue with a bid that is at or above the *minimum bid to continue*, in which case you will be given the opportunity to continue bidding on the domain in the next round. In other words you may:

- *Exit* from a domain by choosing a bid that is less than the announced *minimum price to continue* for that round. A bidder cannot bid for a domain for which she has submitted an exit bid.

- You may *continue* to bid on a domain of interest by choosing a bid that is greater than or equal to the announced *minimum price to continue* for that round.

At the end of the round, the auction system will identify if the domain received multiple bids that are greater than or equal to the *minimum price to continue*. If so, the auction for that domain will proceed to the next round. The price for the domain will be increased by a percentage increment in the next round.

If there is only one or no bid that is greater than or equal to the *minimum price to continue* for a domain, the domain is won by the highest bidder. Ties are broken randomly.

The auction continues until there is no domain for which multiple bidders are active; that is, there is no excess demand, since all or all-but-one bidder has placed an exit bid for the domain at a price less than the *minimum price to continue*.

Pricing is based on a second-price rule: Each domain then is awarded to the highest bidder, who will pay the highest losing bid. Each losing bidder will receive an equal share of the winner's payment; that is, each loser receives the winner's payment divided by the number of losing bidders for the particular domain.

In each round, bidders need to submit their bids within the time allowed. If no action is taken for a domain, it will be assumed that the bidder has chosen to exit from that domain.

### Profits

A bidder's total profit is the sum of the profits from all domains of interest. Due to the payment rule in this auction, along with the usual profit from the domains you have won, you also profit from the domains that you have lost.

- Profit from domain won:

$$\text{Profit}_{won} = \text{value} - \text{price}$$

- Profit from domain lost, where *n* is the initial number of bidders for the domain:

$$\text{Profit}_{lost} = \frac{\text{winner's payment}}{\text{n} - 1}$$

### *Examples*

Suppose that your valuation for the domain is 4,500 and you win it at a price of 4,000. Then your profit from this domain is equal to 4,500 – 4,000 = 500 ED.

Suppose that you lose the domain, the initial number of bidders for that domain is 5, and the winner pays 4,000. Then your profit from this domain is equal to 4,000 / 4 = 1,000 ED.

## Deposit

Each bidder has an initial deposit. The size of the deposit determines the maximum bidding commitment the bidder can make. The total of active bids and winning payments cannot exceed five times the current deposit. As domains are sold, the payment received by the loser is added to the deposit amount. Also for domains that have not yet sold but for which the bidder has exited, the bidder's deposit is credited with the minimum payment that the bidder may receive once the domain is sold—this is the *minimum price to bid* in the current round.

The auction system will prevent a bidder from placing bids on a collection of domains that would cause the bidder's total commitment to exceed five times the bidder's current deposit.

## Bidding strategy

The simultaneous ascending clock auction allows the bidders to adopt complex bidding strategies. Below are some results from auction theory about single-item auctions that may be relevant when devising your bidding strategy.

Before stating the results, here is some notation. There are $n$ bidders with bidder $i$ assigning a value of $V_i$ to the object. Each $V_i$ is drawn independently on the interval $[0, \bar{v}]$ according to the cumulative distribution function $F_i$ with a positive density $f_i$. ( $\bar{v} = 5000$ in the experiment.)

Recall that in the standard private-value setting where winning payments are retained by the auctioneer, the second-price and ascending clock auctions both have the same dominant strategy equilibrium: bid (up to) your private value, or $b(v) = v$.

Bidder incentives change in our setting where the winner's payment is shared equally among the losers. Notice that losing is made more attractive in this case, relative to the standard auction—the loser receives a share of the winner's payment, rather than 0.

We can calculate the unique symmetric equilibrium when there are two bidders and each bidder's value is independently drawn from a triangle distribution.

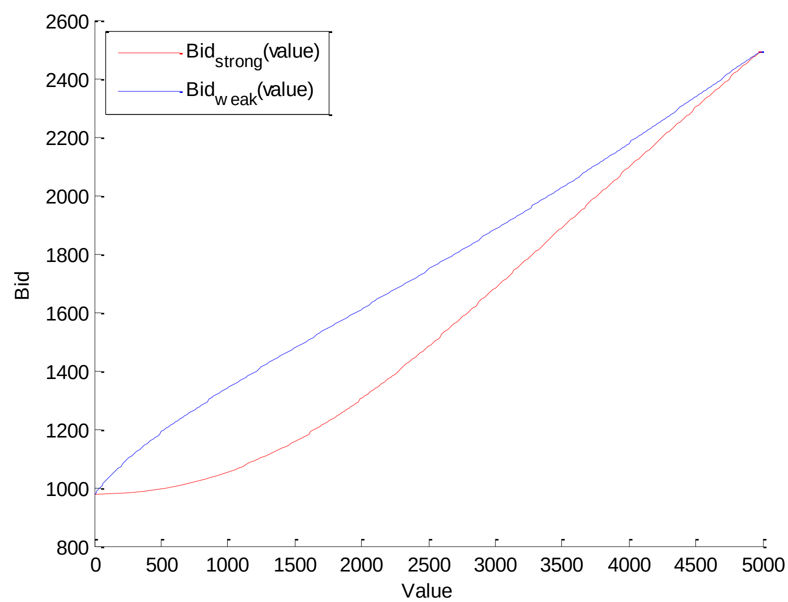
With two strong bidders, the symmetric equilibrium bid function is

$$b_{2strong}(v) = \bar{v}\,\frac{4 + 2\frac{v}{\bar{v}}(4 + 3\frac{v}{\bar{v}}(2 + \frac{v}{\bar{v}}))}{15(1 + \frac{v}{\bar{v}})^2}.$$

With two weak bidders, the symmetric equilibrium bid function is

$$b_{2weak}(v) = \frac{\bar{v}}{10}(1+4\frac{v}{\bar{v}}).$$

When the bidders' values are drawn from different distributions then numerical methods must be used to compute the equilibrium. As an example, we present the case with one strong bidder and one weak bidder in the figure below. Notice that the weak bidder bids more aggressively than the strong bidder to compensate for the weakness; similarly the strong bidder bids less aggressively than the weak bidder in recognition of her relative strength.




## Bidding tool

In addition to the auction system, you will have a bidding tool:

bidding-tool-simultaneous-asymmetric-24oct5pm-xy-role.xlsm.

*Please make a copy of this file and change the name of this tool before you paste your values. In particular, (1) replace "xy" with either an "X" or a "Y" depending on whether you have an X or Y in the URL with your login instructions, and (2) replace "role" with your company name, e.g. Google. Then go to the auction system and copy and paste your values. You may do this in advance of the experiment but be sure to bring you customized file to the lab.*

All bidders have the same tool. The tool allows you to explore alternative bidding strategies. It includes all the information that is common knowledge: the domains, the bidders and which domains each can bid for, the equilibrium bid functions wherever the equilibrium is known (as described above). Note that there is a separate sheet for each auction. Be sure you are using the correct sheet for the particular auction.

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You can then use the tool to explore various bidding strategies. *You may do this in advance of the experimental session.* Once you are happy with your bids, you can enter them directly in the auction system, or if you have many bids, you can upload your bids. To upload bids, you must first create a bid upload file in .csv format. Then go to the auction system and click the Upload button on the Bidding screen to upload the bids. Be sure to check your uploaded bids carefully. Any errors can be corrected directly or through another upload.

Please note that you initially may not have sufficient money on deposit to bid as high as you would like on all of your domains. You may need to limit some bids early on in order to satisfy the limitation on bids coming from your limited deposit. You commitments from active bids and domains won can be at most five times your current deposit.

## Payment conversion

Your profits in each auction in ED currency is converted to the US Dollars by the formula

$$\text{Payment in US dollars} = \text{Profit in ED} \times \text{rate for role}$$

The payout rate for each role is given below:

| | **Rate** |
|---|---|
| **Bidder** | **Asymmetric** |
| Donuts | 0.10% |
| Minds+Machine | 0.36% |
| Google | 0.26% |
| Famous Four | 0.38% |
| Uniregistry | 0.36% |
| Afilias | 1.28% |
| Amazon | 0.36% |
| Radix | 1.20% |

At the end of the session you will receive your total US dollar payoff in cash. The conversion rates have been set so that each subject receives a payment of approximately US$400, regardless of role. The actual payment will be more or less than US$400 depending on the bids of the bidders in the auctions.