Experimental Auctions with Securities*

Zachary Breig† Allan Hernández-Chanto‡

University of Queensland University of Queensland

Declan Hunt§

Reserve Bank of Australia

This Version: October 11, 2024

Abstract

We experimentally implement security-bid auctions, which are used around the world to sell projects that generate large future cash flows that are stochastic. Buyers make bids with debt and equity, linking payments to the project's ex-post revenue. Contrary to the theoretical predictions, we find that debt auctions generate more revenue than equity auctions. This is explained by overbidding in debt auctions. Furthermore, we find that second-price equity auctions generate slightly more surplus than other treatments. We also implement informal auctions and find that buyers use equity more often than theory predicts, and that sellers successfully choose dominant bids.

JEL classification: C70, C90, D44, D47

Keywords: auctions; experiment; securities; debt; equity; risk preferences

*We thank Danelle Kenny for her excellent research assistance. We are grateful for comments from Marina Agranov, Ned Augenblick, Evan Calford, Tim Cason, Marco Faravelli, Paul Feldman, Guillaume Fréchette, Lana Friesen, Tanjim Hossain, Nagore Iriberri, Gregory Kubitz, Tracy Xiao Liu, Andrey Malenko, Nadya Malenko, Claudio Mezzetti, John Morgan, Ryan Oprea, Siqi Pan, Paul Pezanis-Christou, Andrew Schotter, Jason Shachat, Charles Sprenger, Tom Wilkening, and Leeat Yariv, as well as audiences at Agora, ANU, ANZWEE, Chapman University, ESA North America, OEW, QUEX, QUT, Texas A&M, the University of Auckland, the University of Melbourne, and UQ. The informal auctions treatment from this paper was presented as Hunt's honours thesis at the University of Queensland prior to Hunt commencing employment at the Reserve Bank of Australia. The experiments discussed in this paper received ethical approval from UQ's BEL LNR review panel (project numbers 2021/HE000019 and 2021/HE001827). The formal auction treatments in this experiment were preregistered in the American Economic Association's RCT Registry (AEARCTR-0009157). The views expressed in this work are those of the authors and do not necessarily reflect the opinion of the Reserve Bank of Australia.

†z.breig@uq.edu.au

‡a.hernandezchanto@uq.edu.au

§declan.hunt@uq.net.au

1 Introduction

Security-bid auctions are commonly employed to allocate rights to projects that generate future cash flows. Governments use them to sell resources such as oil and spectrum leases, as well as to award public infrastructure contracts. Corporations employ these auctions for takeovers and capital financing, while individuals use them for selling book publishing rights and to set legal fees in class-action suits. A notable feature of these auctions is that future revenue can be verified ex-post, allowing the seller's payment to be securitized.

These auctions can be either formal or informal. In formal auctions, the seller uses a predetermined auction format and security design, while in informal auctions, buyers choose their own securities to signal their types, and the seller allocates the project based on the most attractive bid made ex-post. Standard securities, such as equity and debt, are common in both auction types.[1] In equity auctions, bids represent a share of the future project's revenue, whereas in debt auctions, bids set a default level; such that if the project's revenue falls below this level, the seller retains all revenue; otherwise, only the default level is retained.

The literature on security-bid auctions has focused on how the choice of auction format and security design influences the seller's revenue. DeMarzo et al. (2005) shows that steeper securities increase seller revenue under any formal format, implying that equity-bid auctions should generate higher revenue than debt. Similarly, it demonstrates that informal formats yield worse outcomes than formal formats under any security. Yet, a wide variety of auction formats and security designs—including debt-bids and informal formats—are used in practice, which has led to a variety of explanations for the gap between theoretical predictions and observed practices (Skrzypacz, 2013). Our paper investigates potential explanations for

[1] In project-right allocation auctions, equity refers to a claim over the project's cash flows once implemented by the winning bidder.

the use of securities and auction formats that are theoretically suboptimal by employing an experimental approach.

An experimental approach is ideal for analyzing these mechanisms. The complexity of these auctions requires buyers to perform extensive due diligence to place bids, and the sensitivity of bid and valuation details—potentially exposing critical information to competitors—leads to highly restricted data. Additionally, clear comparisons can be hindered by the unique characteristics of specific applications. As a result, conducting systematic empirical analysis of different selling mechanisms remains challenging, and empirical studies are scarce.

In this paper, we propose an experimental approach to evaluate buyer behavior under five different selling mechanisms. For formal auctions, we compare two formats (first-price and second-price) and two types of securities (debt and equity). This variation allows us to analyze how auction formats and securities affect bidding behavior, revenue, and efficiency, extending beyond the analysis of cash auctions. We also explore an informal mechanism where buyers choose between debt and equity bids, and the seller selects the highest bid ex-post. This setup introduces a signaling game, as the seller must assess each bid's revenue potential according to his beliefs, providing a novel context for studying both buyer behavior and seller decision-making.

Our empirical results challenge the main predictions of the theoretical literature on security-bid auctions. Contrary to predictions, debt auctions generate more revenue than equity auctions, primarily due to overbidding in debt auctions. Meanwhile, efficiency differences between treatments are minimal compared to revenue differences. In informal auctions, subjects frequently use equity but otherwise adhere closely to equilibrium predictions. Revenue from informal auctions is the lowest, aligning with theoretical predictions for risk-neutral buyers.

A motivating example Consider a second-price auction where Alice and Bob compete for a project requiring an initial non-contractible investment of \$1M. Alice expects an NPV of \$4M from the project, and Bob expects \$3M. If the auction is run in cash, Alice bids \$3M and Bob bids \$2M, so Alice wins and pays Bob's bid of \$2M. In contrast, if the auction is run in equity, both bidders offer equity based on their reservation values. Alice bids $\frac{\$4\text{M}-\$1\text{M}}{\$4\text{M}} = \frac{3}{4}$ and Bob bids $\frac{\$3\text{M}-\$1\text{M}}{\$3\text{M}} = \frac{2}{3}$. Alice wins and pays according to Bob's bid, generating a revenue of $\frac{2}{3} \times \$4\text{M} = \$2.67\text{M}$, which is higher than the \$2M generated from the cash auction. The higher revenue with equity arises because the payment is linked to the winning buyer's type, providing greater revenue linkage (Hansen, 1985; DeMarzo et al., 2005).[2]

Background Equity and debt are key securities to study due to their widespread use. For instance, developers frequently auction equity stakes for real estate projects, while debt is common in BOT contracts and takeovers. Theoretically, equity auctions exhibit revenue equivalence between first- and second-price formats, whereas second-price debt auctions generate higher expected revenue than first-price debt auctions. Furthermore, second-price debt auctions produce lower revenue compared to equity auctions.

Equity yields higher revenue than debt because it creates a stronger linkage between the winning buyer's value and the seller's payment. As noted by DeMarzo et al. (2005), equity is *steeper* than debt, implying it extracts more surplus from buyers with higher signals.[3] Additionally, Fioriti and Hernandez-Chanto (2021) shows that equity provides better insurance to risk-averse buyers by demanding lower payments when revenue is low and higher payments when revenue is high, making these buyers more aggressive and further increasing

[2]The same reasoning applies to debt, but demonstrating its superiority over cash requires considering the full revenue distribution, as debt is non-linear.

[3]Equity is *steeper* than debt, because the slope of the payment, as a function of revenue, at the point where the two securities yield the same expected payment is higher for equity than debt.

surplus extraction.

Informal auctions are used in many settings, including mergers and acquisitions, which amounted to $4.1 trillion globally in 2022. These auctions are more complex than formal ones because buyers can initiate bids and freely choose their securities, requiring sellers to form beliefs about buyer types and leading to adverse selection issues (Hansen, 1987; Fishman, 1989; Eckbo et al., 1990). DeMarzo et al. (2005) shows that, in its signaling equilibria with risk-neutral buyers, all bidders opt for the flatter security (i.e., debt). In contrast, Fioriti and Hernandez-Chanto (2021) argues that risk-averse buyers may separate based on their risk preferences.

The auctions we study offer a rich framework to examine the trade-offs of each security design in formats with varying cognitive demands. Second-price auctions (for both securities) have dominant-strategy equilibria, while first-price auctions have Bayesian equilibria. Informal auctions, however, involve multiple steps and may lead to equilibria where buyers either pool within a security or separate based on risk preferences.

Experimental design We construct the simplest environment in which the surplus extraction and insurance provided by each security design can be compared. Subjects act as buyers bidding for the rights to implement a risky project. All subjects are given an endowment, but the winner of the auction must invest that endowment in the project. Essentially, the winner of the auction surrenders her endowment and is given back a lottery whose payoffs depend on the "price" at which she got the project. In the case of the first-price auction, the price is equal to the winner's security-bid, whereas in the second-price auction, it is equal to the second-highest security-bid. The project then generates either high or low revenue. Buyers receive signals indicating the likelihood that the project generates high revenue. Thus, these signals determine their (private) valuations. The endowment, the project's revenue, and all payments are made with experimental points.

In our setting, two buyers bid to acquire the rights to a project with uncertain revenue, which can result in either a low or high payoff. Each buyer knows their own probability of achieving the high payoff, which is private information. We analyze five auction types: (1) first-price debt, (2) first-price equity, (3) second-price debt, (4) second-price equity, and (5) informal auctions. The first four types are formal mechanisms with predetermined formats and security designs that specify the bidding instrument, determine the winner, and set the payment. In informal auctions, a third subject takes on the role of the seller to choose the winner of each auction after observing buyers' submitted bids. This is the minimal competition environment that we need to evaluate the performance of securities across formats. We use a between-subjects design, with one treatment per experimental session.

In all treatments, subjects participate in 20 auction rounds. Buyers receive private signals (uniformly drawn from the unit interval) and place bids. The winner is then determined by auction rules (in formal auctions) or by a third subject (in informal auctions). After each round, all participants are informed of the winner and the bids placed.

After completing the auctions, all subjects participate in 10 rounds of the Andreoni and Harbaugh (2009) risk elicitation task. This allows us to connect bidding behavior to risk attitudes, which the theoretical literature identifies as an important factor in buyers' valuations for these risky projects. Subjects complete the experiment with a short survey.

Findings We obtain mixed results relative to the extant theoretical predictions about revenue and surplus generated by these auctions. Contrary to most theoretical predictions, debt auctions (in both formats) generate the highest revenue. They are followed by first-price equity auctions. Second-price equity auctions and informal auctions generate the lowest revenue. All auctions exhibit some inefficient allocations, but the differences in efficiency between treatments are small relative to the overall surplus.

We find significant overbidding in debt auctions compared to the risk-neutral Nash equilibrium (RNNE), contributing to their higher revenue relative to equity auctions. However, the rate of *dominated* bids is not higher in debt treatments, and the overbidding aligns with risk-loving preferences (though we do not attribute treatment differences to risk preferences). Overbidding declines with experience and correlates with quiz scores and confidence, but not with choices in the Andreoni-Harbaugh task.

In the informal auctions, we find mixed alignment with theoretical predictions. Subjects tend to bid using equity more than debt, contrary to the risk-neutral prediction that all bids should use debt. Average bids align closely with the equilibrium bids in first-price formal auctions. Sellers typically select the better bid when one clearly dominates. These results are notable given the higher cognitive demands of informal auctions compared to formal ones.

External validity and relevance of the experimental approach Despite the fact that security-bid auctions are both common and economically important, empirical evidence about these auctions (discussed further in Section 2) is limited. One of this paper's primary contributions is to compare auction formats and security designs without the need for structural assumptions or identification arguments. Thus, we believe that this is an important building block that complements the extensive theoretical work and the nascent empirical literature.

Previous work has shown that, more often than not, experienced professionals perform similarly to standard laboratory subjects (Fréchette, 2011). For instance, Dyer et al. (1989) shows that in common value auctions, undergraduate experience with no laboratory experience bid similarly to construction executives with years of bidding experience. Furthermore, the results of laboratory experiments have guided the design of complex and valuable auctions such as the FCC's spectrum auctions (Goeree and Holt, 2010; Roth, 2016). While the subjects in our experiment are potentially less sophisticated than firms making bids, the environment is much simpler than similar auctions from the real world.

2 Related Literature

There is growing theoretical literature on auctions with contingent payments. Early work by Hansen (1985) demonstrated that second-price equity auctions generate higher expected revenue than cash auctions, with Riley (1988) and Rhodes-Kropf and Viswanathan (2000) extending this to auctions combining cash and equity. DeMarzo et al. (2005)—henceforth DKS—generalized these findings by introducing the concept of steepness, showing that steeper securities yield higher revenue by linking payments more closely to the winner's true valuation. Fioriti and Hernandez-Chanto (2021) found that steeper securities also offer more insurance to risk-averse buyers, prompting more aggressive bids. However, other works highlight the opposite effect of steeper securities on revenue in more complex settings, like adverse selection (Che and Kim, 2010), moral hazard (Kogan and Morgan, 2010), competition (Gorbenko and Malenko, 2011), and externalities (Hernandez-Chanto and Fioriti, 2019). We abstract from these features to focus on the effects of security design on bidding, revenue, and efficiency.

While the properties of securities auctions are well-studied, empirical evidence is scarce due to the challenges of field-testing, with oil auctions being a notable exception (Kong, 2021; Bhattacharya et al., 2022; Kong et al., 2022). Experimental methods complement this literature by providing controlled environments to observe choices and assess counterfactual selling mechanisms, free from concerns about complementarities, common values, repeated game incentives, or other omitted variables.

The only other experimental analyses of auctions with securities that we are aware of are Kogan and Morgan (2010) and Bajoori et al. (2024), which is contemporaneous to our work. Kogan and Morgan (2010) examines how entrepreneurs bid for funding using equity or debt, focusing on the moral hazard arising from the effort required to make the project successful. Equity, being more extractive, discourages effort, while debt encourages it. They use an ascending English auction where participants choose to pay a cost to exert effort. In contrast, our study abstracts from moral hazard and includes both first- and second-price auctions, as well as informal auctions. Sealed bid auctions in our study allow us to observe all bids and compare different auction formats. Bajoori et al. (2024) examines first- and second-price auctions using cash and equity with online subjects from Prolific. Their results show that first-price equity auctions generate the highest revenue, while both cash formats exceed second-price equity auctions. Our study differs by including informal auctions, comparing two types of securities instead of cash versus securities, and using a richer signal space with two revenue values. We also conduct the experiment in a laboratory setting, allowing subjects to gain experience. Our findings contrast with theirs: we find that debt auctions outperform cash auctions, and overbidding is more prevalent in our data, whereas Bajoori et al. (2024) observes underbidding.

In addition to advancing the experimental security-bid auction literature, our work contributes to the study of auctions with contingent valuations, as explored by Ngangoué and Schotter (2023). They compare common value (CV) and common probability (CP) auctions, finding overbidding in CV auctions, but bids close to the risk-neutral Nash equilibrium in CP auctions. While our security-bid auctions are similar to CP auctions in that bidders receive signals about high revenue, these signals are independent across subjects (i.e., an IPV setting). Our study extends this research by incorporating payments contingent on the asset's payoff.

We revisit the literature on overbidding in cash auctions in Section 6.1 to assess whether existing theories can explain the behavior observed in our experiments. We explore various factors influencing buyer preferences, including risk aversion, spiteful bidding, joy of winning, regret, and probability weighting. Despite the noisy bidding behavior, we find that quantal response equilibrium does not align with our data. We also consider alternative equilibrium concepts such as cursed equilibrium, impulse balance equilibrium, and level-k reasoning, and discuss potential misperceptions by subjects.

3 Theoretical predictions and hypotheses

In this section, we discuss the theoretical results that are relevant to our experimental design. We present the simplest possible environment that captures the main features of security-bid auctions transparently.

There is a risk-neutral seller interested in allocating an indivisible project between two buyers. The seller uses either a formal first- or second-price auction or an informal auction. The seller announces the chosen mechanism and commits to it.

Any buyer must make a non-contractible investment of $\kappa = 2000$ to implement the project, which is common knowledge. This investment represents the opportunity cost of diverted funds. If buyer i acquires the project and invests, it yields a stochastic and contractible revenue $Z_i \in \mathcal{Z} = \{z_L, z_H\}$, where $z_L = 2000$ is the low-state revenue and $z_H = 6000$ is the high-state revenue.[4] The project is useless to the seller, but since the lowest revenue equals the investment cost, it is valuable for any buyer with a positive likelihood of receiving the high revenue.[5]

Each buyer i receives an independent private signal $p_i \in [0, 1]$ that corresponds to the probability of being in the high state. Hence, the distribution of Z_i conditional on the buyer's signal is Bernoulli with parameter p_i. Signals are drawn independently from a uniform distribution, which is common knowledge.

Securities Bids are expressed by derivative securities in which the underlying asset is the project's revenue Z. A security is a function that maps $\mathcal{Z}$ to payments to the seller. We focus on two types of securities: equity and debt, depicted in Figure 1. The choice of debt and equity as securities stems from our desire to analyze situations where payments are contingent on realizations, rather than being deterministic as in cash auctions. Comparing behavior under debt and equity allows us to measure the effect of using steeper securities without using a security that subjects are likely already familiar with (i.e. cash).

Debt and equity auctions share similarities with many real-world auctions. For example, local governments in Arizona, Louisiana, New Mexico, and Texas use fixed-equity auctions to allocate field rights, where the seller sets an equity rate, and buyers bid in cash.[6] Additionally,

[4]In our design, the endowment, investment, and low revenue are all set at 2000 points (\$20). The endowment needed to be weakly higher than the investment to prevent losses, and the low revenue matches the investment to ensure that buyers with low signals cannot profit from bidding above zero.

[5]The project being useless to the seller is a simplifying assumption but may be realistic. For instance, publishing houses (bidders in auctions for book rights) often have far greater opportunities to generate revenue compared to an author (the seller).

[6]Following DeMarzo et al. (2005) and Gorbenko and Malenko (2011), oil auctions can be analyzed within

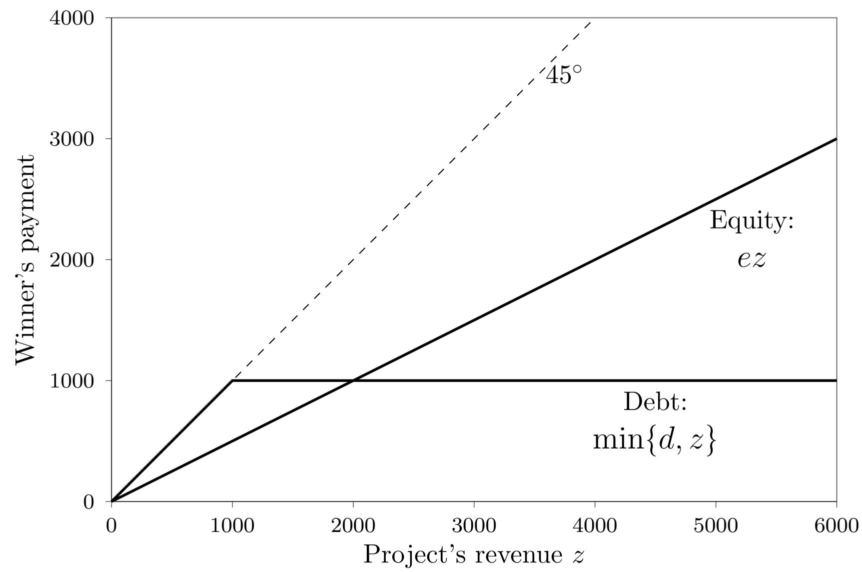


Figure 1: Example payments from the winner to the seller for debt and equity. When the buyer wins the auction at a "price" of d, she retains all revenue above d. Meanwhile, when the buyer wins the auction at a "price" of e, she retains a proportion $1 - e$ of the revenue.

some sellers use "stapled finance" in takeovers, which refers to a loan, in terms of debt or other securities, "stapled" onto an offering by the investment bank advising the seller in a takeover operation.[7]

Selling mechanisms We analyze selling mechanisms based both on formal and informal auctions. In formal auctions, the auction format (first- or second-price) and security design (debt or equity) are predetermined. Hence, buyers are unable to make bids in any security other than the one that the rules specify. In informal auctions, buyers can choose to bid with either debt or equity, but not both, giving them control over the security design, as

the IPV framework, as project revenue depends on the firm's managerial skills and characteristics, which aligns with the empirical literature on oil auctions (Li et al., 2002, 2003; Kim, 2015).

[7]Stapled finance is available to the auction winner but not obligatory to accept. Its growing use in the US and Europe has been shown to increase competition and the final price paid to the seller (Povel and Singh, 2010).

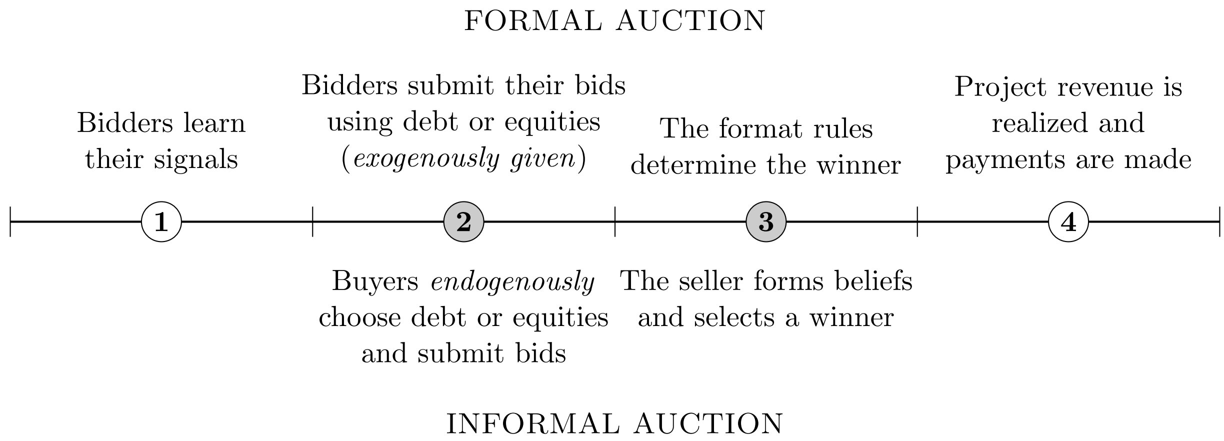


Figure 2: Timing for formal and informal auctions.

noted by DKS. After bids are submitted, the seller updates his beliefs about buyers' signals and selects the most attractive bid. Here, the choice of securities also acts as a signaling device for buyer types. Thus, informal auctions resemble first-price scoring auctions, where the seller's beliefs determine the score of each bid, and buyers pay their security bid.

Timing Figure 2 shows the timeline for formal and informal auctions. In formal auctions, buyers learn their signals, submit bids from the ordered set of securities, and the seller selects the winner based on the auction format (e.g., first- or second-price). Payments are made and payoffs realized based on the chosen security-bid. In informal auctions, buyers freely choose a security (debt or equity) and the seller selects the best bid based on his beliefs about the buyers' signals.

3.1 Behavior in Second-Price Auctions

In a second-price auction, the winner is the buyer who submits the highest bid, and the final price paid corresponds to the second-highest bid.

As in second-price auctions using cash, buyers have a weakly dominant strategy to submit a bid such that they are indifferent between losing the auction and winning at a price equal to their bid. In fact, DKS shows that the unique symmetric equilibrium is for buyers to bid in this way. In the case of equity, this implies that the equilibrium bidding function $e_2^*(p)$ satisfies

$$0 = (1 - e_2^*(p))[pz_H + (1-p)z_L] - \kappa. \tag{1}$$

The left-hand side of equation (1) reflects that the buyer receives a payoff of zero conditional on losing the auction, and the right-hand side gives the expected payoffs of the buyer if she won at a price of $e_2^*(p)$. A similar computation can be carried out for second-price debt auctions. This leads us to our first prediction for the experimental data.

Hypothesis 1. *In second-price auctions using debt, buyers will bid according to*

$$d_2^*(p) = \begin{cases} 4000p \text{ if } p \leqslant \frac{1}{2} \\ 6000 - \frac{2000}{p} \text{ otherwise} \end{cases},$$

while in second-price auctions using equity, buyers will bid according to

$$e_2^*(p) = \frac{2p}{2p+1}.$$

3.2 Behavior in First-Price Auctions

In the first-price auction, the buyer that submits the highest security-bid is selected as the winner and pays her bid. We focus on symmetric and monotone equilibria of these games. For instance, given an equilibrium bidding function of $e_1^*(p)$ in the first-price equity auction, the buyer's maximization problem can be stated as

$$\max_{e\in[0,1]} F(e_1^{*-1}(e))[(1-e)(pz_H + (1-p)z_L) - \kappa]. \tag{2}$$

The first term in (2) is the probability of winning the auction with a bid of e, while the second term corresponds to the buyer's expected payoff conditional on winning. Equilibrium requires that the solution of the problem in (2) is $e_1^*(p)$, implying that the equilibrium bids will be the solution to a differential equation. A similar exercise can be carried out for first-price debt auctions. This gives us predictions for bidding in first-price auctions for both securities.[8]

Hypothesis 2. *In first-price auctions using debt, buyers will bid according to*

$$d_1^*(p) = 2000p,$$

while in first-price auctions using equity, buyers will bid according to

$$e_1^*(p) = \frac{p - 0.5\ln(2p+1)}{p}.$$

3.3 Behavior in Informal Auctions

In informal auctions, buyers can choose any security, not just from a fixed family. This flexibility requires sellers to form beliefs about the revenue potential of each bid to select the winner. Buyers understand that their choice of security affects not only the seller's beliefs about their signal, but also the distribution of payoffs they will receive if they are chosen as the winner. This prompts them to engage in a signaling game.

[8] We confirm that these bidding strategies form an equilibrium in Online Appendix A.1.

To analyze informal auctions, we examine symmetric pure strategy equilibria where buyers select a security-bid from either debt or equity. Each buyer's strategy involves mapping their signal to a security and a bid within that choice. The seller then forms posterior beliefs about each buyer's signal using Bayes' rule. In equilibrium, sellers choose the bid with the highest expected payoffs, while buyers choose securities and bids to maximize their own payoffs.

DKS argues that the seller's beliefs depend on the buyer's choice of security. Buyers with higher signals prefer debt over equity, as equity yields higher payments in the high state.[9] If the seller sees a buyer choose debt, he infers a high signal. However, low-signal buyers may mimic this choice, leading to unraveling under risk neutrality, where all buyers select debt. Thus, the equilibrium outcome resembles a first-price debt auction.

Hypothesis 3. *In informal auctions under risk neutrality, buyers will choose debt and the equilibrium will be equivalent to that of a first-price debt auction.*

Fioriti and Hernandez-Chanto (2021) argues that heterogeneous risk aversion prevents complete unraveling in these auctions. Specifically, if a high-signal buyer is highly risk-averse, she may not deviate to a flatter security. The reason is that although flatter securities extract less surplus ex-post, they offer lower insurance against risk. Therefore, a risk-averse buyer would prefer a steeper security if she sufficiently values the higher insurance it provides.

Hypothesis 4. *In informal auctions, more risk-averse buyers will make bids using equity while less risk-averse buyers will make bids using debt.*

[9] This is related to the fact that equity is "steeper" than debt.

3.4 Revenue and Efficiency

A core focus of the literature on auctions with securities has been the revenue comparisons between different securities and selling mechanisms. Early work by Hansen (1985), Riley (1988), and Rhodes-Kropf and Viswanathan (2000) showed that auctions using equity could be superior to standard cash-bid auctions. This result was later generalized by DKS to standard securities that satisfy two-sided limited liability. Because we can compute explicit equilibria for our parametric model, we can generate clear predictions for the revenue rankings of the security designs and auction formats.[10] The hypotheses that we present are about *interim* revenue and surplus, meaning that they are about expected revenue and surplus conditional on the allocation of the project (but not conditional on the realization of the project's revenue).

Hypothesis 5. *First- and second-price equity auctions generate the highest revenue. First-price debt auctions and informal auctions generate the lowest revenue. Second-price debt auctions generate intermediate revenue.*

It is important to note that while the parametric nature of our model allows us to give point predictions for revenue, the *ranking* implied by these predictions is much more general. This ranking follows the results of DKS, which characterizes securities in terms of what they call steepness. A security is steeper than another if the seller's expected payment has a "greater slope" under the steeper security, starting at the signal level at which both securities yield the same expected payment. From Figure 1, it can be seen that equity is steeper than debt. DKS shows that under fairly general conditions, steeper securities generate higher

[10] With the parametric assumptions we have made, the predicted revenues are approximately: 1722.9 (for first- and second-price equity), 1363.7 (for second-price debt), and 1333.3 (for first-price debt and informal auctions). The computation of these values can be found in Online Appendix A.2.

revenue.[11]

The theoretical results from the securities auction literature also provide strong predictions about the relative efficiency of the auction formats. In the equilibria described above, bidding strategies are increasing in the buyers' private signals. Thus, the project is always assigned to the buyer with the highest chance of generating high revenue.

Hypothesis 6. *All auctions are efficient.*

The equilibria we describe above rely on the buyers' risk neutrality. However, because the project is inherently risky, risk preferences are expected to play an important role in bidding behavior. The role of risk preferences in first-price auctions is complex, but the dominant-strategy nature of second-price auctions allows us to generate some predictions in this setting. When buyers are risk-averse in second-price auctions, they shave their bids relative to what they would have bid had they been risk neutral. This behavior is more pronounced when buyers are more risk-averse. Hence, with heterogeneous risk aversion, a more risk-averse buyer with a high signal could bid lower than a less risk-averse buyer with a lower signal. In this case, the formal auction mechanisms studied here are not necessarily interim efficient. Fioriti and Hernandez-Chanto (2021) show that, when buyers in second-price auctions are risk-averse, equity provides buyers with more insurance than debt. This is because they smooth payoffs across realizations, asking for lower payments in the low state and for higher payments under the high state. The insurance effect is more valuable for more risk-averse buyers, making them relatively more aggressive. The increase in aggressiveness makes the handicap of risk-averse levels on bids be less severe, increasing the allocative

[11] The Revenue Equivalence Theorem applies to equity auctions but not to debt auctions. This is because equity securities form a convex set, making second-price auctions with equity isomorphic to choosing deterministic bids from equity. In contrast, debt securities form a sub-convex set, meaning second-price auctions involve choosing bids from a steeper security than debt.

efficiency of the auction.

Hypothesis 7. *A second-price auction under equity is weakly more allocatively efficient than a second-price auction under debt.*

4 Experimental Design

The experiment consisted of 16 sessions conducted at the University of Queensland Behavioural Economics Science Cluster (BESC) between August 2021 and April 2022. Subjects were recruited using Sona Systems, and a total of 215 subjects participated. Demographic summary statistics can be found in Online Appendix Table 6. No subject appeared in more than one session. The experiments were completed in-person through computer terminals, and all experiments were coded using oTree (Chen et al., 2016). Screenshots for all parts of the experiment and for all treatments can be found in Online Appendix E.

The experiment consisted of five different treatments, with each subject seeing exactly one treatment (i.e. this was a between-subject design). As discussed above, the treatments were (1) first-price debt auctions, (2) first-price equity auctions, (3) second-price debt auctions, (4) second-price equity auctions, and (5) informal auctions.[12,13] Two subjects acted as buyers in each formal auction. In the informal auctions, two subjects acted as buyers, one subject acted as the seller, and roles were fixed across rounds.

[12]While subjects have been shown to perform better in ascending auctions, we chose to use the second-price format for two reasons. First, using a second-price auction allows for more direct comparison to first-price auctions, which also use sealed bids. Second, an ascending auction makes it impossible to observe the highest bid in the auction. This limits the number of bids observed per auction and complicates inference about bidding functions.

[13]The number of subjects participating in each of these treatments was 38, 40, 40, 40, and 57 respectively. Each formal auction had three sessions, while there were four sessions of the informal auction. Sessions in the formal treatments varied in size from 10 to 16 subjects. Sessions in the informal treatment varied in size from 9 to 21 subjects.

All sessions had the same structure. Subjects were first brought into a lab and directed to their terminal. They were given the opportunity to read a participant information sheet and to sign a consent form. Subjects were presented with instructions, including auction instructions and examples that were specific to their treatment, then took a quiz. They then participated in 20 rounds of auctions. After the auctions, subjects were read the instructions for a risk elicitation task and then completed 10 rounds of that task. After all subjects had completed all tasks, subjects completed a short survey, payments were made, and subjects left the laboratory.

Each subject participated in 20 rounds of auctions. They were randomly assigned a new partner in each round. On each bidding page, subjects were informed of the likelihood that their project would have high revenue. Furthermore, on all bidding pages, subjects were given the same interactive feature that they were given on the examples page, allowing them to easily identify the consequences of their bid.

In the formal auctions, subjects then needed to type in their bid (an integer from 0 to 6000 points in the debt auctions or an integer from 0 to 100 percent in equity auctions). An example bidding page can be found in Figure 3. After both players in a group made their bid, subjects were shown the results of the auction. Winners were told the other player's bid and their likelihood of receiving each potential outcome, but the realization of the outcome was not revealed to them.[14] Losers were told the other player's bid, the payoffs they would receive, and the potential payoffs of the winner. However, the loser was not told the likelihood that the winner would receive the high revenue (i.e. the winner's private valuation) or the

[14]Theoretically speaking, whether or not the realization of the project's outcome is revealed should not have any effect on subjects' subsequent behavior, since it cannot reveal anything about the other player's signal because the probability of the project having high revenue was different for each individual. Thus, this additional information should not affect the buyer's risk preferences for subsequent lotteries because only one round is paid at random. However, as is common in most experiments involving decision-making under risk, the lottery outcome is not realized until the end of the experiment.

realization of the revenue.

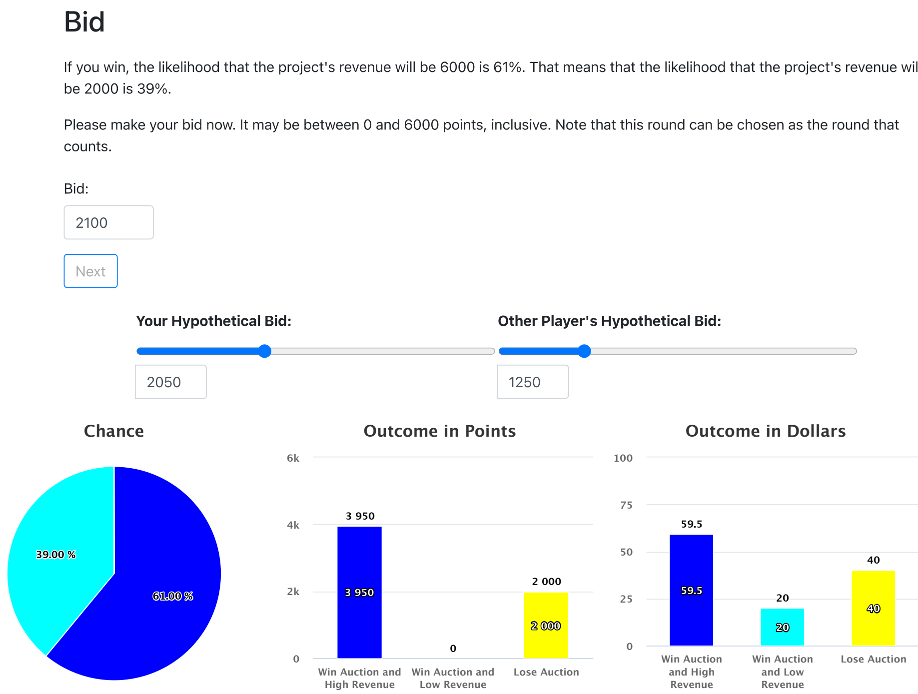


Figure 3: Bidding page for a first-price debt auction

In the informal auctions, buyers both chose their security and made their bid on the same page. Once both buyers made their bid, the seller was informed of the two bids that were made and was given a graphical display representing the potential payoffs that would arise from each bid. The seller then selected which buyer is the winner. As in the formal auctions, both buyers are informed of the bids that were made and who won. The seller is reminded of who they selected to win the auction, the payoffs they could receive as a result of the auction, and the fact that the probability of receiving the high payoff is unknown to them.

After completing the auctions, all subjects participated in 10 rounds of an individual choice task. The task, first developed in Andreoni and Harbaugh (2009), is a risk elicitation task that allows for the evaluation of subjects' attitudes towards both monetary prizes and probabilities of receiving those prizes (Breig and Feldman, 2024). In each task, subjects are asked to trade off between the size of a price and the likelihood of receiving that price using a linear budget. Subjects faced five unique budgets in a random order, and then faced the same five budgets in a newly randomized order. The five budgets that subjects faced had maximum prizes of 8000, 10,000, 12,000, 16,000, and 20,000 points, with corresponding maximum probabilities of 0.8, 1, 0.6, 0.4, and 0.5. A graphed version of these budgets can be found in Online Appendix Figure 16.[15]

Upon the completion of all tasks, the computer randomly selected a single round for each subject from either the auctions or the Andreoni-Harbaugh tasks to be the one that counts. The subject was told which round was selected, as well as the potential outcomes and associated probabilities. After being presented with this information, subjects were informed of the results of any randomization and their total payments. They then completed a survey involving demographic questions, experiment feedback, and a cognitive reflection test (Frederick, 2005).

In addition to any earnings from the round selected for payment, all subjects were paid a \$20 completion fee. Sessions lasted one and a half to two hours. Payments ranged from \$22 to \$110, and the average total payment was \$48.47.

We preregistered the experiment in the American Economic Association's RCT Registry (AEARCTR-0009157). This registration occurred after the informal auction treatment was completed, but before any sessions of the formal auction treatments. We completed power

[15] In addition to measuring risk preferences directly, these 10 tasks allow for a rich set of revealed preference measures. While they are not the focus of our analysis, we discuss these measurements and how they are related to behavior in the experiment in Online Appendix B.

calculations based on the empirical outcomes from the informal auctions (details can be found in the pre-analysis plan published on the AEA RCT Registry).

5 Results

5.1 Revenue and Efficiency

In this section, we compare the results on revenue and efficiency obtained in the experimental auctions vis-à-vis the corresponding theoretical predictions. From a given auction, the revenue and efficiency measures are conditional on the winning buyer's signal; thus, they are computed from an interim perspective. Additionally, to compute the measure of efficiency we look at the *potential surplus*, i.e., the surplus produced in case the project were implemented by the highest-signal buyer. For each measure, we then take the average across auctions within each treatment.

Before stating our results about the allocation of surplus formally, we summarize them graphically with Figure 4, which shows the predicted and realized average distribution of surplus across treatments. One can immediately see that there are large differences between treatments and that the differences do not necessarily reflect the theoretical predictions. Except for the second-price auction under equity, all mechanisms exhibit a higher expected revenue than their theoretical counterparts. Moreover, the differences in revenue are more pronounced in debt than in equity auctions. In fact, the greatest revenue excess is produced under the first-price debt treatment, whereas the lowest is obtained under informal auctions. All treatments display allocative inefficiency, computed as the difference between the actual and potential surplus in each auction. This feature, along with the results on revenue discussed above, implies that the buyer's surplus is lower than in theory for all mechanisms—

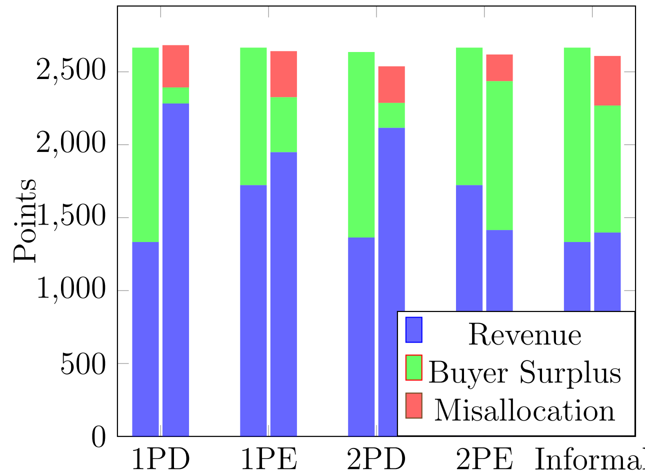


Figure 4: Comparison of average levels revenue and allocative efficiency in all selling mechanisms. For each treatment, theoretical predictions of risk-neutral Nash equilibria are on the left and empirical realizations are on the right.

with the exception of the second-price equity auction. Notably, this treatment is the one that generates the lowest efficiency loss.

Our first result is about the revenue raised within each treatment and relates to Hypothesis 5.

Result 1. *First- and second-price debt auctions raise the highest revenue. First-price equity auctions raise the second highest revenue. Second-price equity auctions and informal auctions raise the lowest revenue.*

The evidence for Result 1 is presented in columns (1)-(3) of Table 1, which present the regression results using interim revenue as the dependent variable. The null hypothesis that all treatment coefficients are equal to zero is rejected at the 1% level for all specifications. In column (1), the independent variables are dummies representing the treatments, with the first-price debt treatment being the omitted treatment. This column shows that, in terms of raw averages, first-price debt auctions raised the highest revenue, followed by second-price debt, first-price equity, second-price equity, and informal auctions.

Table 1: Interim revenue and surplus

	(1) Revenue	(2) Revenue	(3) Revenue	(4) Surplus	(5) Surplus	(6) Surplus
1PE	-333.9***	-307.7***	-307.7***	-67.1	-27.4	-27.5
	(79.6)	(62.7)	(62.9)	(78.7)	(44.8)	(44.6)
2PD	-167.5**	-74.2	-74.0	-106.7	34.7	34.5
	(75.2)	(64.4)	(64.7)	(78.6)	(40.9)	(40.7)
2PE	-867.9***	-827.5***	-827.4***	43.7	105.0***	104.9***
	(77.5)	(65.6)	(65.8)	(76.8)	(39.8)	(39.8)
Informal	-884.5***	-837.4***	-837.3***	-123.5	-52.1	-52.2
	(70.1)	(60.8)	(60.9)	(79.6)	(46.5)	(46.4)
Potential Surplus		0.64***	0.64***		0.97***	0.97***
		(0.022)	(0.022)		(0.012)	(0.012)
Round		-15.8***			3.79	
		(3.61)			(2.37)	
Constant	2283.2***	727.6***	856.2***	2393.0***	-258.2***	-243.2***
	(49.6)	(82.8)	(118.7)	(55.6)	(48.3)	(72.8)
Round FE	No	No	Yes	No	No	Yes
Observations	1960	1960	1960	1960	1960	1960

Notes: Linear regression with robust standard errors. Significance indicated by: *** p<0.01, ** p<0.05, * p<0.1.

Column (2) of Table 1 controls for potential surplus and round.[16] With these controls, the difference between the revenue raised by first- and second-price debt gets smaller and becomes insignificant. The coefficient on round demonstrates that revenue decreases as subjects gain more experience, a point that will be explored further in Section 5.2.

Column (3) is our preferred specification and is our main evidence for Result 1.[17] The

[16] Potential surplus equals the maximum of the two buyers' signals multiplied by 4000. Since this variable is drawn independently of the treatment, it should be uncorrelated with the treatment dummies. However, the changes in coefficients and significance between columns (1) and (2) indicate that, in our sample, potential surplus is correlated with the treatments, as shown in Online Appendix Table 18.

[17] The specification used in columns (3) and (6) were registered as the primary focus of our analysis in our pre-analysis plan. For completeness, we reproduce these regressions with only data from the second half

differences described in the result are statistically and economically significant. The implied gap between the revenue raised by first-price debt auctions and informal auctions is over 30% of the potential surplus generated by these auctions. Thus, we can conclusively reject Hypothesis 5.

Our next result is about the surplus generated by each treatment and relates to Hypotheses 6 and 7.

Result 2. *Second-price equity auctions generate the highest surplus. All other types of auctions generate surplus similar to each other.*

The evidence for Result 2 is presented in columns (4)-(6) of Table 1. The null hypothesis that all treatment coefficients are equal to zero is rejected at the 1% level for the specifications in columns (5) and (6), but not for the specification in column (4) (p-value 0.15). While the difference between second-price equity and the other treatments is not significant in raw averages, this difference does become significant at the 5% level when controlling for potential surplus and Round. Surplus does increase on average with subjects gaining more experience, but the increase is economically small and statistically insignificant.

Our preferred specification is presented in column (6). Here, we find that when controlling for potential surplus and round fixed effects, second-price equity auctions generate higher surplus than the other treatments, whose surpluses are not in general distinguishable from each other. The fact that the auctions are not allocatively efficient contradicts Hypothesis 6. The efficiency ranking of second-price equity over second-price debt is consistent with Hypothesis 7, but the difference is only significant at the 10% level ($p = 0.056$).

of the experiment in Online Appendix Table 8. The qualitative results are unchanged.

5.2 Bidding in Formal Auctions

In this section, we investigate the distinctive features in buyers' behavior that lead to the results in revenue and efficiency found in all formal selling mechanisms. Hypotheses 1 and 2 state the Nash equilibrium bidding strategies for these settings.

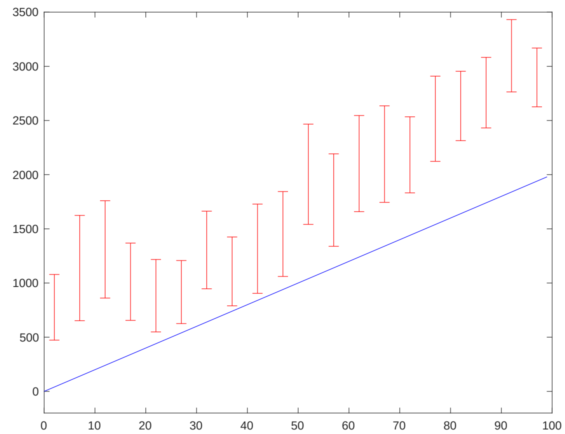
Result 3. *In formal auctions, subjects overbid on average for all signals in both first- and second-price debt auctions. Subjects overbid on average for extreme signals (both high and low) for both first- and second-price equity auctions.*

Figure 5 compares the theoretical Nash equilibrium bidding function under risk neutrality to bids from the experiment. Bids are averaged within windows of 5 signals (0-4, 5-9, etc.) and presented with 95% confidence intervals for the average. It is immediately apparent that in debt auctions there is substantial overbidding under both formats—the risk-neutral Nash equilibrium is outside of the confidence interval for the average bid for each of the ranges of signals. In equity auctions, there is similar overbidding for low and high signals, but average bids are either close to or below the Nash equilibrium for intermediate signals.[18,19] In follow-up work, Breig et al. (2023) shows that the patterns of overbidding observed in this paper's second-price treatments are replicated using a within-subject comparison of second-price equity- and debt-bid auctions. Thus, the differences between security designs are unlikely to be the result of random variation or session-level effects. Hence, the security design is more

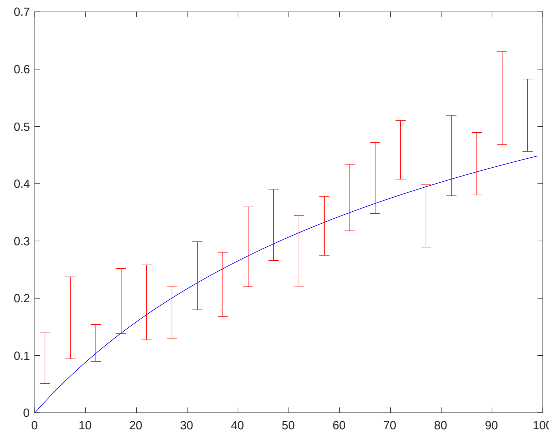
[18] Because the RNNE in both types of second-price auction involve weakly dominant strategies, the equilibrium strategy is also the empirical best response. We compare behavior in the first-price auctions to their respective empirical best responses in Appendix Figure 15. For the majority of signals in both settings, the empirical best response is below the RNNE bid.

[19] We analyze how the buyer's signal affects overbidding nonlinearly in Online Appendix Table 9, which presents regression results of overbidding (bid minus equilibrium bid) on signal and its square with subject fixed effects. Overbidding is generally positive for low signals, decreases for intermediate signals, and rises again for high signals. This parabolic pattern in second-price debt and equity auctions aligns with Fioriti and Hernandez-Chanto (2021), where buyers shave their bids near 0.5, when the project's revenue variance is highest.

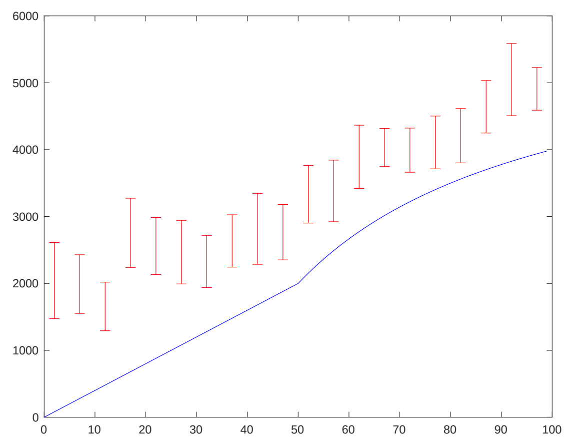
important than the auction format for overbidding.



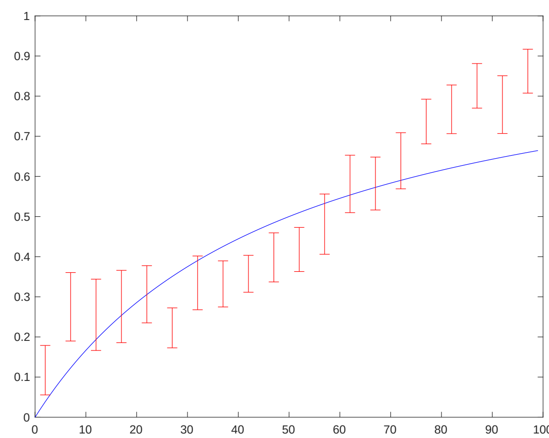
(a) First-price debt



(b) First-price equity



(c) Second-price debt



(d) Second-price equity

Figure 5: Average bids conditional on signal in formal auctions. Bids are averaged in windows of 5 units and presented with 95% confidence intervals. Equilibrium bidding functions are shown in blue.

Since overbidding drives the empirical revenue ranking from the previous section, it warrants closer inspection. Figure 6 categorizes each bid into four types. A bid is "Dominated" if it leads to a lottery first-order stochastically dominated by the buyer's outside option (i.e., higher than 4000 in debt auctions or 66% in equity auctions). A bid is "RA Unrationalizable" if it is not Dominated but undominated for neither risk-neutral nor risk-averse buyers.[20] "Overbids" are bids higher than the Nash equilibrium but not Dominated or RA Unrationalizable. Otherwise, a bid is classified as an "Underbid."

Figure 6 demonstrates that the larger size of average overbidding that we see within debt auctions is *not* due to bids that are Dominated: the rate of Dominated bids is higher in second-price auctions than in first-price auctions, but within formats, the rates are similar across securities. Thus, the difference between securities is coming from bids in debt auctions that are high, but not so high that a risk-loving buyer would not make them.

In Online Appendix D, we examine the time subjects took to make bidding decisions. Response times are nearly identical across treatments. Although differences in response times can have various interpretations (see Spiliopoulos and Ortmann (2018)), the similarity here suggests that subjects did not perceive the treatments as differing in complexity.

Result 4. *In formal auctions, overbidding decreases with experience in all treatments except the second-price debt.*

The link between experience and overbidding is presented in Figure 7. While all treatments start with overbidding rates that are higher than 50%, for all treatments other than second-price debt, this rate decreases with experience. We complete this analysis formally in Online Appendix Table 10 to confirm the result and find that the coefficient on experience is negative and significant for first-price debt, first-price equity, and second-price equity, but positive and insignificant for second-price debt. In the three treatments with decreasing overbidding, the coefficients imply overbidding rates of near 50% by the end of the experiment, which is consistent with approximate equilibrium behavior.

[20]This occurs when a bid exceeds the second-price Nash equilibrium bid. For first-price auctions, bids between the first- and second-price Nash equilibria are rationalizable by certain beliefs, but bids above the second-price Nash equilibrium are not rationalizable for any beliefs when buyers are risk-averse.

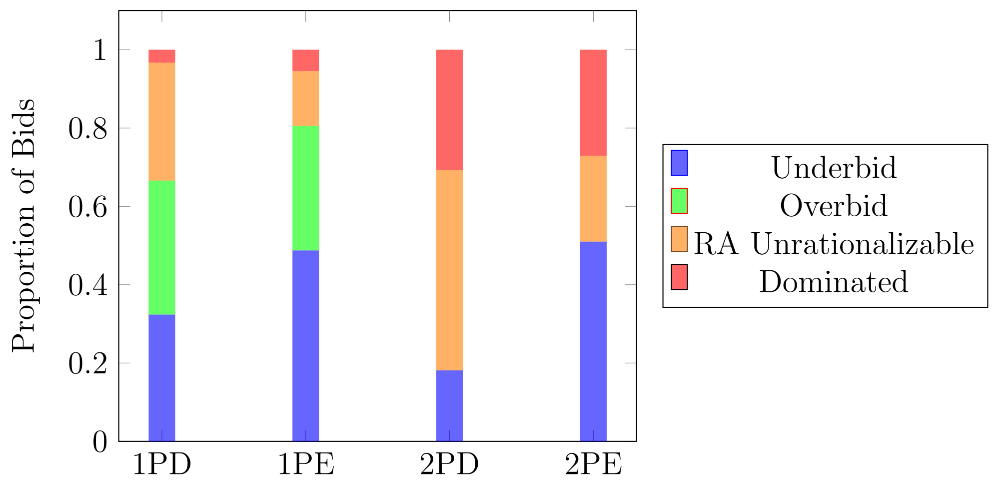


Figure 6: Classification of bids within each treatment. "Dominated" refers to bids that lead to lotteries that are first-order stochastically dominated. "RA Unrationalizable" refers to bids that are not Dominated but cannot be rationalized by a risk-neutral or risk-averse utility function for any beliefs. "Overbid" refers to bids that are not Dominated or RA Unrationalizble, but are higher than the RNNE bid. "Underbid" refers to bids that are equal to or below the RNNE bid.

We now consider the extent to which overbidding is explained by subjects' individual characteristics. As a first step, it is useful to note that overbidding rates (i.e. the proportion of bids that are strictly higher than an appropriate cutoff) vary across subject and are not always equal to zero or one. This can be seen in Online Appendix Figures 18, 19, and 20, which show rates of bids greater than the Nash equilibrium, rates of bids greater than the second-price Nash equilibrium, and rates of bids that are first-order stochastically dominated for each of the treatments, respectively. Because these rates are not equal to zero or one, individual characteristics and the treatments can only partially explain overbidding.

Result 5. *Overbidding is uncorrelated with measured risk aversion, negatively correlated with quiz and CRT scores, and positively correlated with confidence about the experiment.*

The relationship between overbidding and subject characteristics is shown in Table 2,

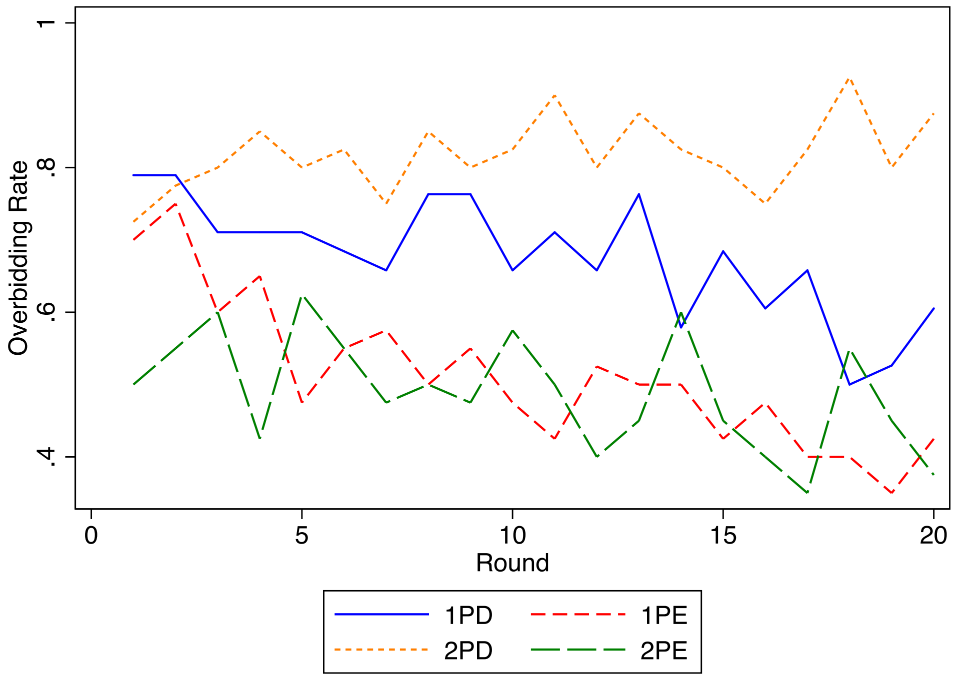


Figure 7: Overbidding rates (relative to RNNE) by round and treatment.

in which we regress binary indicators for overbidding on observable characteristics.[21] The dependent variables in the regressions represented in columns (1), (2), and (3) are binary indicators for bidding higher than the Nash equilibrium, bidding higher than second-price Nash equilibrium, and making stochastically dominated bids, respectively. Here, we confirm the previously observed relationships between these overbidding rates, treatment, and experience.

The first surprising feature of Table 2 is that our measure of risk aversion does not have a statistically significant relationship with overbidding.[22] This is contrary to our *a*

[21]The results are replicated using logistic regressions in Online Appendix Table 11 with patterns of significance generally unchanged.

[22]The variable "Average RA" in the regression is defined as the average choice for the Andreoni-Harbaugh risk aversion tasks that the subject completed. This number can range from 0 to 100, with a choice of 50 representing risk neutrality and choices greater than 50 representing risk aversion. We report additional

Table 2: Overbidding by subject characteristics

	(1) Binary Overbid	(2) RN Unrationalizable	(3) Dominated
1PE	-0.15**	-0.14***	0.016
	(0.059)	(0.052)	(0.025)
2PD	0.17***	0.51***	0.28***
	(0.049)	(0.048)	(0.033)
2PE	-0.17***	0.17***	0.24***
	(0.054)	(0.053)	(0.031)
Round	-0.0071***	-0.0063***	-0.0037***
	(0.0018)	(0.0017)	(0.0012)
Average RA	0.00015	-0.00025	0.0010
	(0.0014)	(0.0013)	(0.00088)
CRT Score	-0.057***	-0.059***	-0.013
	(0.017)	(0.015)	(0.010)
Quiz Score	-0.31***	-0.35***	-0.14***
	(0.079)	(0.083)	(0.048)
Confidence	0.027**	0.027**	0.0025
	(0.011)	(0.010)	(0.0069)
Female	0.0096	0.0045	0.0078
	(0.041)	(0.039)	(0.027)
English	-0.043	-0.0015	0.016
	(0.038)	(0.034)	(0.024)
Economics	-0.0063	-0.027	-0.020
	(0.045)	(0.039)	(0.027)
Age	0.0014	0.0063	0.0014
	(0.0042)	(0.0040)	(0.0029)
Constant	0.81***	0.41***	0.078
	(0.17)	(0.15)	(0.10)
Observations	3160	3160	3160

Notes: Linear regression with standard errors clustered at the subject level. Significance indicated by: *** p<0.01, ** p<0.05, * p<0.1.

priori intuition: the project that the buyers are bidding for is inherently stochastic, and it

results using a nonlinear transformation of this average (computing a CRRA ρ parameter) in Online Appendix Table 13.

should be less valuable for more risk-averse subjects. However, this may not be surprising given the lack of correlation across risk aversion tasks that has previously been found in the experimental literature.[23] We explore this further in Online Appendix Tables 12 and 13, in which we apply the "obviously related instrumental variable" approach proposed in Gillen et al. (2019) to both the average choice and a nonlinear transformation thereof from the Andreoni-Harbaugh task. This approach uses instrumental variables to account for the potential attenuation bias that arises as a result of measurement error in the risk elicitation task. Even with this alternative approach we still do not find a significant relationship between overbidding and measured risk aversion.

While measured risk aversion does not predict overbidding, other observed characteristics do. Cognitive measures, such as the quiz score and the cognitive reflection test from Frederick (2005), are negatively correlated with overbidding, suggesting that subjects with a better grasp of the mechanism are less likely to overbid. Conversely, subjects with higher reported confidence were more likely to overbid and make unrationalizable bids, though not dominated bids. We also control for demographics like gender, first language, economics major, and age, none of which are correlated with overbidding. In Online Appendix B, we extend these results to account for revealed preference indices from the Andreoni-Harbaugh task, finding that while these measures are jointly significant, individual indices are rarely significant and hard to interpret.

[23]Some previous research suggests that deviations from risk neutrality in lab experiments may relate to cognitive ability (Dohmen et al., 2010; Benjamin et al., 2013). We partially control for this in our regressions by including quiz and CRT scores. Additionally, we reanalyzed the data from Table 2, replacing Average RA with dummies for subjects' quartiles of Average RA, allowing for more flexible control and potential non-monotonicities. We find weak evidence that mildly risk-averse subjects (those in the second quartile) are less likely to overbid. Results are available upon request.

5.3 Buyer Behavior in Informal Auctions

We now turn to the analysis of buyer behavior in informal auctions. In these auctions, buyers choose both the type of security they will make a bid with and the value of that bid.

Our first results are about the choice of security in informal auctions and relate to Hypotheses 3 and 4.

Result 6. *In informal auctions, buyers choose to make bids with equity more often than with debt.*

The evidence for Result 6 can be found in Figure 8. The figure shows that buyers choose debt roughly $30 - 40\%$ of the time across signals, and thus clearly rejects the claim of Hypothesis 3 that buyers always choose debt, instead favoring Hypothesis 4. We report a histogram of the rate of choosing equity at the subject level in Online Appendix Figure 21. The distribution appears unimodal, suggesting that subjects mix between securities rather than separating into their preferred security.

Result 7. *In informal auctions, buyers' signal and measured risk aversion are only weakly correlated with their choice of security.*

Appendix Table 14 presents regression analysis showing the relationship between subject characteristics and security choice.[24] Given that only 38 subjects acted as buyers in the informal auctions, we interpret these results with caution.

We find a negative but insignificant relationship between the subject's signal and their likelihood of choosing debt. The estimated relationship suggests that increasing the likelihood that the project generates high revenue from 0 to 100 percent decreases the likelihood

[24]These results are replicated using logistic regressions in Online Appendix Table 15 with patterns of significance generally unchanged.

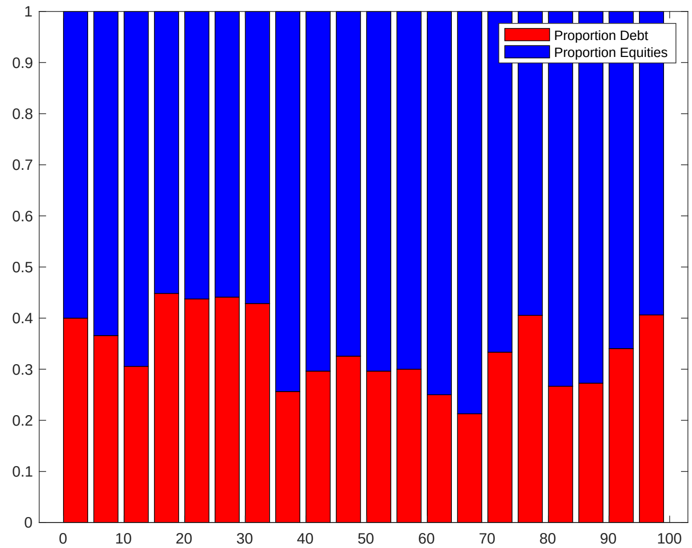


Figure 8: Buyer security choice by signal. Security choices are pooled in windows of 5 signals.

of choosing to bid with debt by 10 percentage points. While the relationship is not significant, we note that this is contrary to the logic presented in DKS and discussed in Section 3.3, which argued that buyers will make bids with debt to signal that they have a high valuation.

Similar to the above analysis of overbidding, we find little relationship between our measure of risk aversion and the type of security that the subject chooses. This is surprising because, as noted in Fioriti and Hernandez-Chanto (2021), equity inherently provides more insurance than debt. We again provide additional evidence for the link between choices and risk aversion in Online Appendix Tables 16 and 17. The relationship between security choice and average choice in the Andreoni-Harbaugh task is not significant in any specification, but we do find some evidence that a higher CRRA risk aversion parameter, which we compute as a nonlinear transformation of the average choice in the Andreoni-Harbaugh task, is negatively correlated with choosing debt. However, given the lack of a significant relationship with the average choice in the Andreoni-Harbaugh task, we interpret this relationship with caution.

Thus, there is (limited) evidence supporting Hypothesis 4.

Result 8. *Average bids in the informal auction are close to the equilibrium bids of the associated formal auction.*

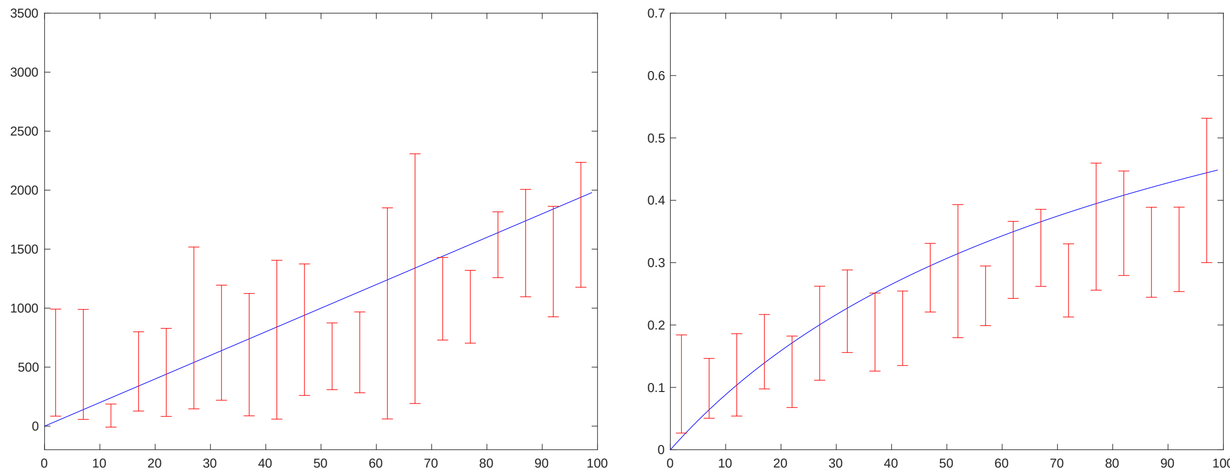
Figure 9 reports average bids from informal auctions and compares them with the equilibrium predictions *from a first-price formal auction*. We again average bids in windows of five signals and present 95% confidence intervals. The main observation is that the empirical average of the bids in this treatment are lower and closer to the equilibrium values than the ones obtained in the formal treatments for both security designs. The improvement in fitting equilibrium bids is especially remarkable for debt.

One potential explanation for this arguably more reasonable bidding pattern is a selection effect. In the formal auctions, subjects are required to make bids with a particular security whether or not they like or understand it. It may be the case that those subjects that *would* be overbidding in debt auctions simply choose to bid using equity. However, we see from Table 14 that there is limited selection by observable characteristics into bidding with debt. Furthermore, if selection were a significant driver of the decrease in overbidding in debt we might expect that the correlates of overbidding found in 2 would predict security selection, but that does not seem to be the case.

5.4 Seller Behavior in Informal Auctions

One of the distinctive characteristics of the informal auctions treatment is that the winner's selection is not based on a predetermined rule. Thus, we can evaluate the quality of the seller's decision-making when facing security bids.

Result 9. *In the informal auction when the seller is faced with two bids using the same*



(a) Debt

(b) Equity

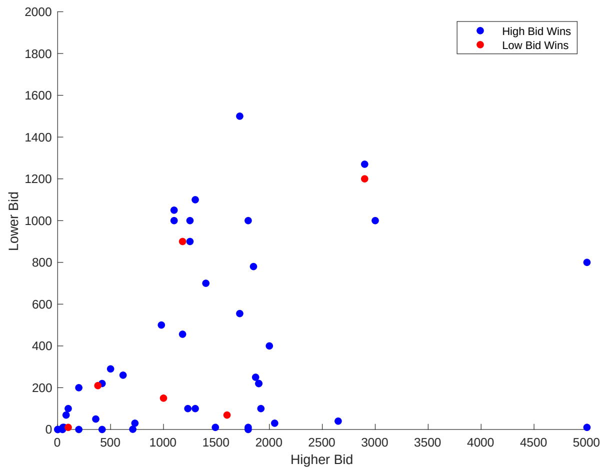
Figure 9: Average bids conditional on signal in informal auctions. Bids are averaged in windows of 5 units and presented with 95% confidence intervals. Equilibrium bidding functions from the first-price formal auctions are shown in blue.

security, they choose the highest bid.

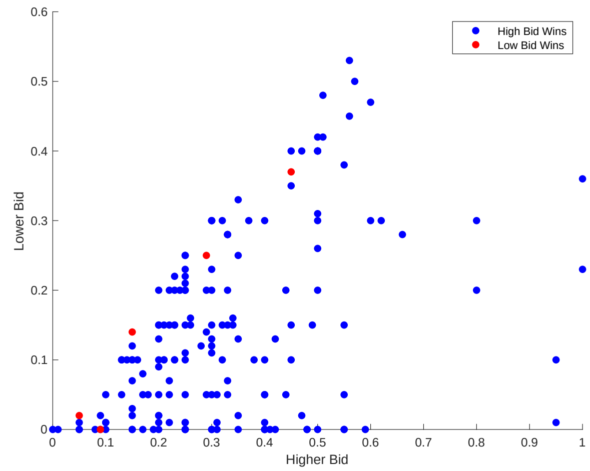
Figure 10 displays seller choices for the sample of auctions in which buyers choose the same security to express their bids: Panel 10a shows the sample for debt and Panel 10b shows the sample for equity. In both figures, the x axis corresponds to the higher bid; thus, all points lie below the 45-degree line by construction. Blue points correspond to those cases in which the seller chooses the highest index in the corresponding ordered set, whereas the red points correspond to the cases where the lowest ones were chosen. Under both securities, sellers overwhelmingly choose the bid with the highest index. This seems intuitive and suggests that sellers do not believe that bids are non-monotonic in the signal.

Result 10. *In the informal auction, when the seller is faced with two bids using different securities, one of which dominates the other, they choose the dominant bid.*

Figure 11 shows the seller's selection when he faces bids from different sets of securities.



(a) Two Debt Bids



(b) Two Equity Bids

Figure 10: Seller behavior when facing two bids from the same security.

While it can be difficult to rank bids made with different securities, in some case the ranking *should* be obvious. For instance, if one buyer makes an equity bid of 40% (giving a minimum payment of 800 points) and the other buyer makes a debt bid of 600 points, the seller should always choose the equity bid. Figure 11 demonstrates that this is generally the case. For bidding pairs that are between the purple line and the y axis, the highest possible equity payment is lower than the lowest possible debt payment. For bidding pairs that are below the yellow line, the highest possible debt payment is lower than the lowest equity payment. In the figure, a red dot corresponds to the case where the seller chooses the bid in debt, whereas a blue dot corresponds to a case where the seller chooses the equity bid. It is immediate to see that in the domination regions, the seller almost always chooses correctly. Moreover, in the ambiguous region, sellers do not seem to have a strong preference for either type of security. The only identifiable pattern is a smooth gradient, shifting from the choice of one security to the other.

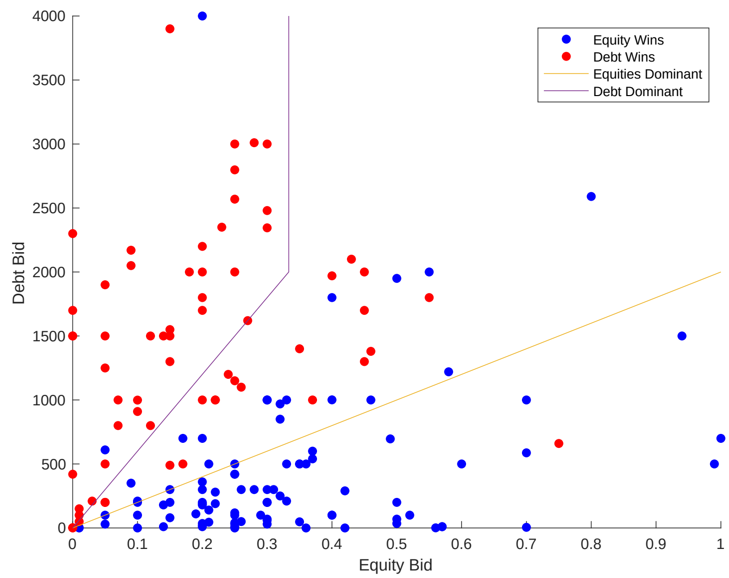


Figure 11: Seller behavior when facing two bids from different securities.

6 Discussion

6.1 Behavioral Models of Overbidding

To understand the drivers of overbidding in our experiment, we examine behavioral models from the literature and assess if they can explain our data while keeping models and parameters fixed across treatments. Specifically, we investigate whether these models account for (1) overbidding in debt auctions for all signals, (2) overbidding for low and high signals in equity auctions, and (3) bidding near or below equilibrium for intermediate signals in equity auctions.

First, we note that if non-standard utility functions were the main driver of overbidding, we should not expect to see overbidding change with experience. However, the decrease in overbidding with experience is documented in Result 4. Thus, *preference*-based explanations can at best partially explain overbidding.

Risk aversion has been studied as a cause of overbidding in first-price auctions, with early work suggesting it leads to overbidding relative to risk-neutral Nash equilibrium (Cox et al., 1988). However, later studies found overbidding even where risk aversion would predict underbidding (Kagel and Levin, 1993; Cason, 1995). Recent work by Goeree et al. (2002) links risk aversion with quantal response equilibrium to explain data from first-price auctions. In our experiment, where bidders face lotteries, risk aversion should *reduce* bids in second-price auctions. The numerous bids unexplainable by any risk-neutral or risk-averse model (see Figure 6) and the lack of correlation between risk aversion (measured by the Andreoni-Harbaugh task) and overbidding (Table 2) suggest risk aversion is not a major driver of overbidding here.

The noisy bidding that is apparent from Figure 5 suggests that models allowing for mistakes, like McKelvey and Palfrey's (1995) quantal response equilibrium (QRE), may help organize the data. QRE has explained overbidding in experimental auctions before (Goeree et al., 2002; Bajari and Hortacsu, 2005; Camerer et al., 2016). In Online Appendix C, however, we find that QRE *cannot* fully explain our results. Although QRE predicts overbidding, it does not match the level observed for high signals in both second-price treatments, and the predicted bidding functions are flatter than those in our data. We also estimate the QRE noise parameter λ using Camerer et al. (2016)'s methods and reject the hypothesis that a single logit QRE parameter fits all treatments, particularly due to differences between second-price equity and the other treatments.

Many papers propose "non-standard" preferences as sources of overbidding in auctions. Morgan et al. (2003) suggests spite as a driver of overbidding in second-price auctions, while Andreoni et al. (2007), Cooper and Fang (2008), and Kirchkamp and Mill (2021) provide experimental evidence supporting this view. However, spite cannot fully explain our experimental data for several reasons. First, it typically addresses overbidding in second-price auctions, not in first-price debt auctions. Second, spite leads to overbidding for low signals, as buyers aim to lower opponents' payoffs; yet Figure 5 shows significant overbidding even at high signals when buyers should expect to win. Lastly, it is unclear why spite would cause overbidding for intermediate signals in second-price debt auctions but not in second-price equity auctions. Regret theory is another non-standard model for overbidding, but it does not account for overbidding in second-price auctions or significant overbidding at low signals (Filiz-Ozbay and Ozbay, 2007).

Probability weighting is another important behavioral model that is relevant when studying auctions (Quiggin, 1982; Tversky and Kahneman, 1992). Probability weighting admits a wide variety of implications for bidding behavior. Armantier and Treich (2009a) shows that "star-shaped" probability weighting functions lead to overbidding, but Keskin (2016) shows that the most commonly used "inverse S-shaped" probability weighting functions lead to underbidding for low valuations and overbidding for high valuations. The introduction of probability weighting into our setting involves additional difficulties because the object subjects are bidding for is itself a lottery. Thus, the auction forms a compound lottery and probability weighting can affect bids even in the second-price format. However, there is reason to be skeptical that probability weighting is the main driver behind bidding patterns in our auction. First, there is no probability weighting function that can rationalize overbidding in the second-price auctions for high signals. Because weighting functions are bounded above by one, buyers should not exceed a bid of 4000 in debt auctions or 66% in equity auctions. Second, it would require extreme overweighting of low probabilities to generate the overbidding seen for low signals in the second-price debt treatment.

Some authors have proposed other variations in the concept of equilibrium to explain patterns of overbidding. Eyster and Rabin (2005) formalizes the concept of "cursed equilibrium" to explain overbidding in common-value auctions, but this explanation applies only to settings where players' private information should affect each others' valuations (thus, it cannot explain overbidding in the private value auctions we study in this paper). Ockenfels and Selten (2005) introduce the concept of "impulse balance equilibrium" in which a buyer bids to balance upwards and downwards impulses. This is extended in Pezanis-Christou and Wu (2019) to the concept of "naive impulse balance equilibrium." But both of these concepts predict no overbidding in second price auctions and thus cannot explain the overbidding in our second-price debt treatment. Following Stahl and Wilson (1994), Nagel (1995), and Stahl and Wilson (1995), Crawford and Iriberri (2007) uses "level-k" thinking to explain behavior in auctions. The naivete of L_0 agents can be expressed by assuming either a uniform-random or a truthful behavior. In either case, this would lead to average bids that are equal to or below equilibrium bids for the highest signals in second-price auctions. Figure 5 shows that this is not borne out by the data.

It may be the case that subjects' misperceptions about the game or their competition lead to overbidding. Armantier and Treich (2009b) states that overbidding in first-price auctions is a consequence of the fact that people underestimate their probability of winning. However, this does not explain our overbidding in second-price auctions, which have a dominant strategy. Georganas et al. (2017) presents a model in which buyers both misperceive the distribution of bids and believe that they will pay a fraction of the realized price. Such a model allows for overbidding in both first- and second-price auctions, but does not explain the difference between overbidding in equity and debt.

Finally, we discuss whether some combination of non-classical explanations can explain the data. The idea that subjects have a "joy of winning" is a fairly parsimonious justification that explains most overbidding, including for both low signals in first-price auctions and high signals in second-price auctions. However, the joy of winning would also lead to overbidding for intermediate signals in equity auctions. Some models such as risk aversion or (pessimistic) probability weighting would predict lower valuations for those intermediate signals, but the negative effect on bids should be *stronger* for debt auctions than for equity auctions because debt auctions tend to have lower payments in the bad state. Thus, even the combination of these features with the joy of winning does not explain the data, and we remain puzzled about exactly what existing models can explain our results.

6.2 Implications for Security-Bid Auction Design

The literature on security-bid auctions predicts that when buyers are risk-neutral, implementation costs are fixed, and there are no moral hazards or externalities, sellers maximize revenue by using securities closely tied to buyers' valuations, such as steeper securities (DeMarzo et al., 2005). Moreover, the security design has a stronger effect on revenue than the auction format. However, for this result to hold, buyers must recognize that steeper securities extract more surplus while providing higher insurance. When buyers fail to fully account for this and deviate from Nash equilibrium, overbidding and noise arise, distorting revenue outcomes.

Second, Results 3 and 4 show that overbidding persists across securities and formats, especially under debt. The differences in overbidding cannot be easily attributed to buyer naivete, as the fraction of dominated bids is similar across securities. This suggests that security complexity and bounded rationality are key factors. While real auctions involve sophisticated buyers, their strategic behavior is likely influenced by security design, which may explain why simpler securities like equity and cash are preferred over complex ones such as convertible debt or levered equity (Skrzypacz, 2013).

In informal auctions, the security-bid literature is ambiguous. DKS claims that, under risk neutrality, the only viable equilibrium is a pooling one with all buyers using the flattest security. However, this conflicts with empirical evidence and earlier studies on informal auctions (Hansen, 1987; Fishman, 1989; Eckbo et al., 1990).[25] Conversely, Fioriti and Hernandez-Chanto (2021) argues that risk-averse high-valuation buyers may prefer steeper securities for better insurance. Our results do not fully support DKS and offer only partial support for Fioriti, suggesting that additional factors related to strategic uncertainty should be explored further.

Our results suggest that new *behavioral* models are needed for securities auctions. While our sample of university undergraduates may influence some findings, there is growing evidence that even professionals face behavioral biases (Malmendier, 2018). Identifying these biases is crucial for designing optimal auctions.

Additionally, our experimental design enables comparison across formal and informal mechanisms, auction formats, and security designs, providing a unified framework to test various theoretical predictions. The mixed results underscore the need for further experimental and empirical analysis of these allocation mechanisms.

7 Conclusion

Our paper offers a unified experimental framework for studying formal and informal security-bid auctions with debt and equity. In these auctions, the seller's payment depends

[25] Fishman (1989) shows that high-valuation buyers use flatter securities or cash as a preemptive strategy, since steeper securities are cheaper for low-valuation buyers.

on the project's realization, allowing for the use of securities. Unlike standard cash auctions where buyers bid based on their deterministic valuation, here buyers receive a signal about the project's potential, effectively bidding on a lottery where the prizes depend on the security design and auction format.

We find that in formal auctions (first- or second-price), buyers overbid on debt across all signals and on equity for low and high signals, but underbid for intermediate signals, where the project is riskier. Despite debt being "flatter," its significant overbidding leads to higher expected revenue for the seller, contradicting theoretical predictions. Overbidding decreases with experience, except in second-price debt auctions, and is less common among buyers with a better understanding of security structure, as indicated by higher quiz and cognitive reflection test scores. Interestingly, the overbidding rate is similar across securities when accounting for the auction format, with main differences arising from bids exceeding RNNE predictions, often reflecting risk-loving behavior.

In informal auctions, where buyers choose their own security and sellers do not commit to a format, buyers often act according to the RNNE equilibrium of their chosen security, and sellers effectively select dominant bids. Despite this rational behavior, informal auctions generate the lowest expected revenue in our experiments.

Our paper analyzed experimental security-bid auctions, testing behavior across mechanisms, formats, and securities. While some theoretical predictions were confirmed, others were challenged, and some remain unexplained. This highlights the need for further empirical and experimental research to better understand these complex, high-value auctions.

References

Afriat, S. N. (1973). On a system of inequalities in demand analysis: an extension of the classical method. *International economic review*, 460–472.

Andreoni, J., Y.-K. Che, and J. Kim (2007). Asymmetric information about rivals' types in standard auctions: An experiment. *Games and Economic Behavior 59*(2), 240–259.

Andreoni, J. and W. Harbaugh (2009). Unexpected utility: Five experimental tests of preferences for risk. *Unpublished Manuscript*.

Armantier, O. and N. Treich (2009a). Star-shaped probability weighting functions and overbidding in first-price auctions. *Economics Letters 104*(2), 83–85.

Armantier, O. and N. Treich (2009b). Subjective probabilities in games: An application to the overbidding puzzle. *International Economic Review 50*(4), 1079–1102.

Bajari, P. and A. Hortacsu (2005). Are structural estimates of auction models reasonable? evidence from experimental data. *Journal of Political Economy 113*(4), 703–741.

Bajoori, E., R. Peeters, and L. Wolk (2024). Security auctions with cash-and equity-bids: An experimental study. *European Economic Review 163*, 104702.

Benjamin, D. J., S. A. Brown, and J. M. Shapiro (2013). Who is 'behavioral'? cognitive ability and anomalous preferences. *Journal of the European Economic Association 11*(6), 1231–1255.

Bhattacharya, V., A. Ordin, and J. W. Roberts (2022). Bidding and drilling under uncertainty: An empirical analysis of contingent payment auctions. *Journal of Political Economy 130*(5), 1319–1363.

Breig, Z. and P. Feldman (2022). Revealed preference tests for linear probability-prize tradeoffs. *Available at SSRN 4324930*.

Breig, Z. and P. Feldman (2024). Revealing risky mistakes through revisions. *Journal of Risk and Uncertainty*, 1–28.

Breig, Z., A. Hernandez-Chanto, and E. Hiller (2023). Competition between sellers in security-bid auctions: An experimental study. *Available at SSRN 4560584*.

Camerer, C., S. Nunnari, and T. R. Palfrey (2016). Quantal response and nonequilibrium beliefs explain overbidding in maximum-value auctions. *Games and Economic Behavior 98*, 243–263.

Cason, T. N. (1995). An experimental investigation of the seller incentives in the EPA's emission trading auction. *The American Economic Review*, 905–922.

Che, Y.-K. and J. Kim (2010). Bidding with securities: Comment. *American Economic Review 100*(4), 1929–35.

Chen, D. L., M. Schonger, and C. Wickens (2016). oTree - an open-source platform for laboratory, online, and field experiments. *Journal of Behavioral and Experimental Finance 9*, 88–97.

Cooper, D. J. and H. Fang (2008). Understanding overbidding in second price auctions: An experimental study. *The Economic Journal 118*(532), 1572–1595.

Cox, J. C., V. L. Smith, and J. M. Walker (1988). Theory and individual behavior of first-price auctions. *Journal of Risk and uncertainty 1*(1), 61–99.

Crawford, V. P. and N. Iriberri (2007). Level-k auctions: Can a nonequilibrium model of strategic thinking explain the winner's curse and overbidding in private-value auctions? *Econometrica 75*(6), 1721–1770.

DeMarzo, P. M., I. Kremer, and A. Skrzypacz (2005). Bidding with securities: Auctions and security design. *American Economic Review 95*(4), 936–959.

Dohmen, T., A. Falk, D. Huffman, and U. Sunde (2010). Are risk aversion and impatience related to cognitive ability? *American Economic Review 100*(3), 1238–1260.

Dyer, D., J. H. Kagel, and D. Levin (1989). A comparison of naive and experienced bidders in common value offer auctions: A laboratory analysis. *The Economic Journal 99*(394), 108–115.

Eckbo, B. E., R. M. Giammarino, and R. L. Heinkel (1990). Asymmetric information and the medium of exchange in takeovers: Theory and tests. *The Review of Financial Studies 3*(4), 651–675.

Eyster, E. and M. Rabin (2005). Cursed equilibrium. *Econometrica 73*(5), 1623–1672.

Filiz-Ozbay, E. and E. Y. Ozbay (2007). Auctions with anticipated regret: Theory and experiment. *American Economic Review 97*(4), 1407–1418.

Fioriti, A. and A. Hernandez-Chanto (2021). Leveling the playing field for risk-averse agents in security-bid auctions. *Management Science*.

Fishman, M. J. (1989). Preemptive bidding and the role of the medium of exchange in acquisitions. *The Journal of Finance 44*(1), 41–57.

Fréchette, G. R. (2011). Laboratory experiments: Professionals versus students. *Available at SSRN 1939219*.

Frederick, S. (2005). Cognitive reflection and decision making. *Journal of Economic Perspectives 19*(4), 25–42.

Georganas, S., D. Levin, and P. McGee (2017). Optimistic irrationality and overbidding in private value auctions. *Experimental Economics 20*(4), 772–792.

Gillen, B., E. Snowberg, and L. Yariv (2019). Experimenting with measurement error: Techniques with applications to the caltech cohort study. *Journal of Political Economy 127*(4), 1826–1863.

Goeree, J. K. and C. A. Holt (2010). Hierarchical package bidding: A paper & pencil combinatorial auction. *Games and Economic Behavior 70*(1), 146–169.

Goeree, J. K., C. A. Holt, and T. R. Palfrey (2002). Quantal response equilibrium and overbidding in private-value auctions. *Journal of Economic Theory 104*(1), 247–272.

Gorbenko, A. S. and A. Malenko (2011). Competition among sellers in securities auctions. *American Economic Review 101*(5), 1806–41.

Hansen, R. G. (1985). Auctions with contingent payments. *The American Economic Review 75*(4), 862–865.

Hansen, R. G. (1987). A theory for the choice of exchange medium in mergers and acquisitions. *Journal of Business*, 75–95.

Hernandez-Chanto, A. and A. Fioriti (2019). Bidding securities in projects with negative externalities. *European Economic Review 118*, 14–36.

Houtman, M. and J. Maks (1985). Determining all maximal data subsets consistent with revealed preference. *Kwantitatieve methoden 19*(1), 89–104.

Kagel, J. H. and D. Levin (1993). Independent private value auctions: Bidder behaviour in first-, second-and third-price auctions with varying numbers of bidders. *The Economic Journal 103*(419), 868–879.

Keskin, K. (2016). Inverse s-shaped probability weighting functions in first-price sealed-bid auctions. *Review of Economic Design 20*(1), 57–67.

Kim, D.-H. (2015). Flexible Bayesian Analysis of First Price Auctions Using Simulated Likelihood. *Quantitative Economics 6*(2), 429–461.

Kirchkamp, O. and W. Mill (2021). Spite vs. risk: Explaining overbidding in the second-price all-pay auction: A theoretical and experimental investigation. *Games and Economic Behavior 130*, 616–635.

Kogan, S. and J. Morgan (2010). Securities auctions under moral hazard: An experimental study. *Review of Finance 14*(3), 477–520.

Kong, Y. (2021). Sequential auctions with synergy and affiliation across auctions. *Journal of Political Economy 129*(1), 148–181.

Kong, Y., I. Perrigne, and Q. Vuong (2022). Multidimensional auctions of contracts: An empirical analysis. *American Economic Review 112*(5), 1703–1736.

Li, T., I. Perrigne, and Q. Vuong (2002). Structural estimation of the affiliated private value auction model. *RAND Journal of Ecoomics 33*, 171–193.

Li, T., I. Perrigne, and Q. Vuong (2003). Semiparametric estimation of the optimal reserve price in first-price auctions. *Journal of Business & Economic Statistics 21*(1), 53–64.

Malmendier, U. (2018). Behavioral corporate finance. In *Handbook of Behavioral Economics: Applications and Foundations 1*, Volume 1, pp. 277–379. Elsevier.

McKelvey, R. D. and T. R. Palfrey (1995). Quantal response equilibria for normal form games. *Games and Economic Behavior 10*(1), 6–38.

Morgan, J., K. Steiglitz, and G. Reis (2003). The spite motive and equilibrium behavior in auctions. *Contributions in Economic Analysis & Policy 2*(1), 1–25.

Nagel, R. (1995). Unraveling in guessing games: An experimental study. *The American Economic Review 85*(5), 1313–1326.

Ngangoué, M. K. and A. Schotter (2023). The common-probability auction puzzle. *American Economic Review 113*(6), 1572–1599.

Ockenfels, A. and R. Selten (2005). Impulse balance equilibrium and feedback in first price auctions. *Games and Economic Behavior 51*(1), 155–170.

Pezanis-Christou, P. and H. Wu (2019). An individual decision-making approach to bidding in first-price and all-pay auctions. *Available at SSRN 3233164*.

Polisson, M., J. K.-H. Quah, and L. Renou (2020). Revealed preferences over risk and uncertainty. *American Economic Review 110*(6), 1782–1820.

Povel, P. and R. Singh (2010). Stapled finance. *The Journal of Finance 65*(3), 927–953.

Quiggin, J. (1982). A theory of anticipated utility. *Journal of economic behavior & organization 3*(4), 323–343.

Rhodes-Kropf, M. and S. Viswanathan (2000). Corporate reorganizations and non-cash auctions. *The Journal of Finance 55*(4), 1807–1849.

Riley, J. G. (1988). Ex post information in auctions. *The Review of Economic Studies 55*(3), 409–429.

Roth, A. E. (2016). Experiments in market design. *The Handbook of Experimental Economics, Volume 2 2*, 290.

Skrzypacz, A. (2013). Auctions with contingent payments-an overview. *International Journal of Industrial Organization 31*(5), 666–675.

Spiliopoulos, L. and A. Ortmann (2018). The bcd of response time analysis in experimental economics. *Experimental economics 21*, 383–433.

Stahl, D. O. and P. W. Wilson (1994). Experimental evidence on players' models of other players. *Journal of Economic Behavior & Organization 25*(3), 309–327.

Stahl, D. O. and P. W. Wilson (1995). On players' models of other players: Theory and experimental evidence. *Games and Economic Behavior 10*(1), 218–254.

Tversky, A. and D. Kahneman (1992). Advances in prospect theory: Cumulative representation of uncertainty. *Journal of Risk and uncertainty 5*(4), 297–323.

Internet Appendix

A Theoretical equilibrium outcomes

A.1 First-price equilibria

Here, we confirm that the bidding strategies that we state in Hypothesis 2 form an equilibrium.

First, consider the first-price debt auction and suppose that the other buyer is bidding according to

$$d_{1,-i}(p_{-i}) = 2000p_{-i}.$$

Then, given a signal of p_i, the expected payoffs of making a bid $d \leqslant 2000$ are

$$\left(1 - \frac{d}{2000}\right)(6000p_i + 2000(1 - p_i) - 2000 - d).$$

First-order conditions give

$$\left(\frac{d_1^*}{2000}\right)(-1) + \left(\frac{1}{2000}\right)(6000p_i + 2000(1 - p_i) - 2000 - d_1^*) = 0,$$

which simplifies to $d_1^* = 2000p_i$ and confirms that the proposed strategy profile is an equilibrium.

Next, consider the first-price equity auction and suppose that the other buyer is bidding according to

$$e_{1,-i}(p_{-i}) = \frac{p_{-i} - 0.5\ln(2p_{-i}+1)}{p_{-i}}.$$

We can define $p_{-i}(e)$ as the inverse of this bidding function so that given a signal of p_i, the expected payoffs of making a bid of e are

$$p_{-i}(e)[(1-e)(6000p_i + 2000(1-p_i)) - 2000].$$

Given that

$$p'_{-i}(e) = \frac{2(p_{-i}(e))^2(1+2p_{-i}(e))}{(1+2p_{-i}(e))\ln(2p_{-i}(e)+1) - 2p_{-i}(e)},$$

the first-order conditions of the buyer's problem can be written as

$$\frac{2(p_{-i}(e^*))^2(1+2p_{-i}(e^*))}{(1+2p_{-i}(e^*))\ln(2p_{-i}(e^*)+1) - 2p_{-i}(e^*)}[(1-e^*)(6000p_i + 2000(1-p_i)) - 2000]$$
$$= p_{-i}(e^*)(6000p_i + 2000(1-p_i)).$$

Thus, for the proposed strategy profile to be an equilibrium, it must be the case that

$$\left[\frac{2p_i^2(1+2p_i)}{(1+2p_i)\ln(2p_i+1) - 2p_i}\right]\left[\left(1 - \frac{p_i - 0.5\ln(2p_i+1)}{p_i}\right)(6000p_i + 2000(1-p_i)) - 2000\right]$$
$$= p_i(6000p_i + 2000(1-p_i))$$

which one can check always holds. Thus, the proposed strategy profile is an equilibrium.

A.2 Equilibrium Surplus Distribution

The equilibria described in Hypotheses 1 and 2 are all increasing and symmetric. Thus, these equilibria are efficient and expected total surplus is

$$E[\text{Total Surplus}] = \int_0^1 [6000p + 2000(1-p) - 2000](2p)dp = \frac{8000}{3}.$$

Using the bidding functions found in the hypotheses, we can compute expected revenue for the risk-neutral Nash equilibrium for each of the treatments (note that the predicted revenue for informal auctions is the same as that of first-price debt auctions).

$$\begin{aligned} E[\text{Revenue}|\text{First-price Debt}] &= \int_0^1 (2000p)(2p)dp \\ &= \frac{4000}{3} \end{aligned}$$

$$\begin{aligned} E[\text{Revenue}|\text{First-price Equity}] &= \int_0^1 \left(\frac{p - 0.5\ln(2p+1)}{p}\right)(6000p + 2000(1-p))(2p)dp \\ &= \frac{20000}{3} - 4500\ln(3) \\ &\approx 1722.9 \end{aligned}$$

$$
\begin{aligned}
E[\text{Revenue}|\text{Second-price Debt}] = & \int_0^{\frac{1}{2}} \left[\int_0^{p_2} (4000p_1) \left(\frac{1}{p_2}\right) dp_1 \right] (2p_2) dp_2 \\
& + \int_{\frac{1}{2}}^{1} \left[\int_0^{\frac{1}{2}} (4000p_1) \left(\frac{1}{p_2}\right) dp_1 \right] (2p_2) dp_2 \\
& + \int_{\frac{1}{2}}^{1} \left[\int_{\frac{1}{2}}^{p_2} \left[\left(6000 - \frac{2000}{p_1}\right) p_2 + 2000(1-p_2) \right] \left(\frac{1}{p_2}\right) dp_1 \right] (2p_2) dp_2 \\
= & \frac{500}{3} + 500 + \frac{6250}{3} - 2000\ln(2) \\
= & 2750 - 2000\ln(2) \\
\approx & 1363.7
\end{aligned}
$$

$$
\begin{aligned}
E[\text{Revenue}|\text{Second-price Equity}] &= \int_0^1 \left[\int_0^{p_2} \frac{2p_1}{2p_1+1} [6000p_2 + 2000(1-p_2)] \left(\frac{1}{p_2}\right) dp_1 \right] (2p_2) dp_2 \\
&= \frac{20000}{3} - 4500\ln(3) \\
&\approx 1722.9
\end{aligned}
$$

Expected buyer surplus is given by total surplus minus revenue, so we have

$$
\begin{aligned}
E[\text{Buyer Surplus}|\text{First-price Debt}] &= \frac{8000}{3} - \frac{4000}{3} \\
&= \frac{4000}{3}
\end{aligned}
$$

$$E[\text{Buyer Surplus}|\text{First-price Equity}] = \frac{8000}{3} - \left(\frac{20000}{3} - 4500\ln(3)\right)$$
$$= 4500\ln(3) - 4000$$

$$E[\text{Buyer Surplus}|\text{Second-price Debt}] = \frac{8000}{3} - (2750 - 2000\ln(2))$$
$$= 2000\ln(2) - \frac{250}{3}$$

$$E[\text{Buyer Surplus}|\text{Second-price Equity}] = \frac{8000}{3} - \left(\frac{20000}{3} - 4500\ln(3)\right)$$
$$= 4500\ln(3) - 4000$$

B Revealed Preference Results

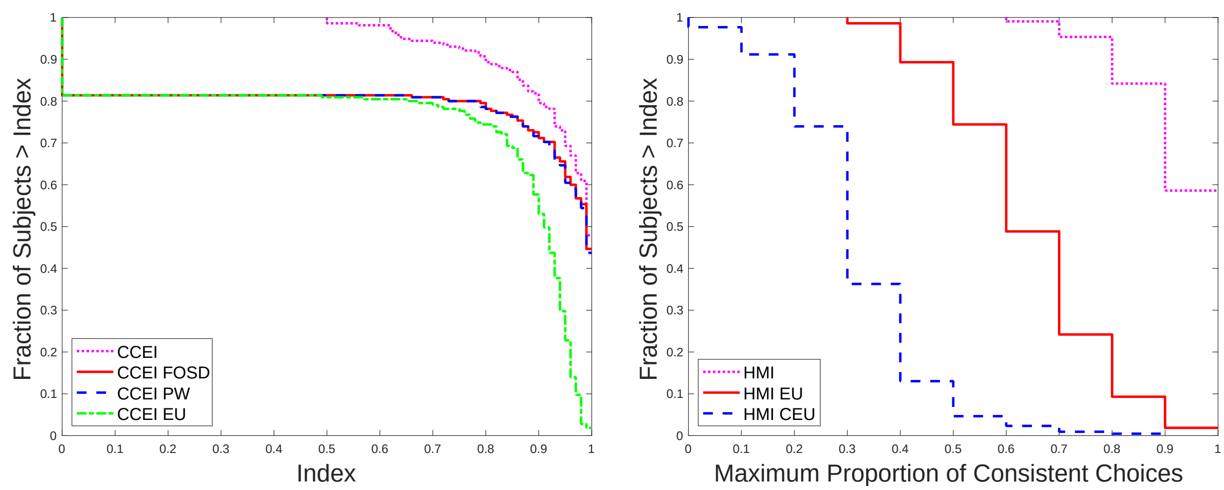
In this section, we report results related to revealed preference measures that we derive from subjects' choices in the Andreoni-Harbaugh task. We first discuss the measurements that we make and then show how those measurements correlate with behavior in auctions.

The first class of indices that we discuss are Critical Cost Efficiency Indices (CCEIs). A CCEI is an index between 0 and 1 that is meant to capture how close a set of choices is to being rationalized by some model. The original CCEI proposed in Afriat (1973) is a measure of how close a set of decisions is to being rationalized by a strictly monotonic utility function. Formally, a set of choices has a CCEI of e if e is the highest number such that there exists a utility function that assigns higher utility to each choice than it does to all options in the budget scaled by a factor of e. One can further define CCEIs for specific *families* of utility functions, measuring how close a set of choices is to being rationalized by some member of that family. Breig and Feldman (2024) uses intuitions from Polisson et al. (2020) to show how to calculate CCEI indices for utility functions respecting first-order stochastic dominance, probability-weighting utility functions, and expected utility functions using the Andreoni-Harbaugh task.

The second class of indices that we discuss is Houtman-Maks Indices (HMIs) (Houtman and Maks, 1985). The classic HMI measures the proportion of choices from a data set that can be rationalized by a strictly monotonic utility function. Breig and Feldman (2022) extend this index within the context of the Androeni-Harbaugh task to show how to compute the proportion of choices that are consistent with expected utility and concave expected utility.

Figure 12 reports the distributions of the indices for all 215 subjects in our experiment. While the specific quantitative results differ from previous work (as is to be expected, given different budgets and different numbers of choices), the qualitative patterns are very similar.

Considering CCEI indices, the CCEI index for models respecting first-order stochastic dominance is much lower than the classic index, and the index for expected utility is much lower than that for probability weighting. The results using HMI indices match those of Breig and Feldman (2022), with significant gaps between each of the indices. As discussed in Breig and Feldman (2022), the HMI CEU index is particularly low because being consistent with concave expected utility requires that the *exact* same choice be made for all budgets with the same maximal prize. Because subjects choose from each budget twice in this experiment, even minimal decision noise leads to indices below 0.5



(a) CCEI Indices (b) HMI Indices

Figure 12: Distributions of revealed preference indices

In Table 3, we present the empirical relationship between the measured revealed preference indices and overbidding in formal auctions, still controlling for the treatment variables and subject characteristics from Table 2. We caution that the individual coefficients can be difficult to interpret due to the high correlation and similar interpretations of the variables. However, we conduct F-tests for whether the measures as a whole are significantly correlated with bidding behavior, and we find that the relationship is significant for overbidding at the

5% level and for making dominated bids at the 1% level.

Table 3: Overbidding by Revealed Preference Indices

	(1) Binary Overbid	(2) RN Unrationalizable	(3) Dominated
HMI	-0.42	-0.40	-0.31
	(0.32)	(0.29)	(0.24)
HMI EU	0.072	0.024	-0.19
	(0.21)	(0.18)	(0.12)
HMI CEU	0.013	-0.011	-0.013
	(0.17)	(0.17)	(0.13)
CCEI	0.20	0.32	0.44*
	(0.31)	(0.32)	(0.25)
CCEI FOSD	3.35*	-0.81	-1.62
	(1.81)	(3.23)	(1.99)
CCEI PW	-4.30**	0.48	1.07
	(1.92)	(3.25)	(2.00)
CCEI EU	0.92*	0.15	0.44
	(0.52)	(0.46)	(0.28)
Other Controls	Yes	Yes	Yes
F-test p-value	.046	.142	.009
Observations	3160	3160	3160

Notes: Linear regression with standard errors clustered at the subject level. "Other Controls" refers to all independent variables used in Table 2, including treatment variables. The "F-test p-value" refers to the p-value arising from the F-test that coefficients on all seven revealed preference indices are zero. Significance indicated by: *** p<0.01, ** p<0.05, * p<0.1.

C Quantal Response Equilibrium

In this section, we discuss how our results relate to the logit formulation of Quantal Response Equilibrium (QRE) (McKelvey and Palfrey, 1995). We take two complementary approaches to establish this relationship. First, we estimate the quantal response noise parameters that best fit the data from our experiments. With this, we can statistically test whether the data across all four treatments is likely to have been generated by a single QRE noise parameter. Second, using the structure of the formal auctions, we compute quantal response equilibria for various parameters and for each game. We generate average bidding functions based on these equilibria and compare them to our empirical average bidding functions.

In a quantal response equilibrium, decision-makers know the distribution of actions that they will face in a game, but do not always make choices that maximize their payoffs. Instead, they randomize in a way that makes choices leading to higher payoffs more likely than choices leading to lower payoffs. In particular, decision-makers choose *as if* the utility they receive from each option is equal to the numerical payoff from that option plus a random draw from an extreme value distribution.

To formalize the application of QRE to the formal auctions presented in this paper, we need some additional notation. For each treatment $k \in \{1\mathrm{PE}, 1\mathrm{PE}, 2\mathrm{PD}, 2\mathrm{PE}\}$, we define the set of possible bids as B_k. Thus, $B_{1\mathrm{PD}} = B_{2\mathrm{PD}} = \{0, 0.5, 1, \ldots, 59.5, 60\}$ and $B_{1\mathrm{PE}} = B_{2\mathrm{PE}} = \{0, 0.01, 0.02, \ldots, 0.99, 1\}$.[26,27] We refer to a bid from buyer i as b_i and their private signal as

[26]The QRE noise parameter is not invariant to the scale of payoffs, so in order to allow for comparison to other results, in this section we state both payoffs and debt bids in terms of Australian dollars rather than experimental points.

[27]While $B_{1\mathrm{PE}}$ and B_{2PE} correctly represent the choices available to subjects in our experiment, subjects in the two debt treatments could make bids with any integer between 0 and 6000. We focus on bids made with multiples of 50 in order to simplify the analysis. The vast majority (≈85%) of bids were already made in these multiples of 50, but for our empirical analysis, we round all bids to the nearest multiple of 50.

p_i. With these definitions, the probability that buyer i bids b is

$$P(b_i = b|p_i) = \frac{\exp\left(\lambda \mathbb{E}[u_k(b, p_i)|p_i]\right)}{\sum\limits_{b' \in B^k} \exp\left(\lambda \mathbb{E}[u_k(b', p_i)|p_i]\right)} \tag{3}$$

where $\mathbb{E}[u_k(b, p_i)|p_i]$ is the expected payoff for buyer i when they make bid b in treatment k. For instance, in the case of first-price debt auctions, we have

$$\begin{aligned}\mathbb{E}[u_{1\text{PD}}(b, p_i)|p_i] = &\left[\mathbb{P}(b_j < b) + 0.5\mathbb{P}(b_j = b)\right]\left((1 - p_i)\max\{20 - b, 0\} + p_i(60 - b)\right) \\ &+ \left[\mathbb{P}(b < b_j) + 0.5\mathbb{P}(b_j = b)\right](20).\end{aligned}$$

For this to be an equilibrium, we require that beliefs match the equilibrium distribution of bids, so

$$\mathbb{P}(b_j < b) = \int \left[\sum_{b' : b' < b} P(b_i = b'|p_i)\right] f(p_i) dp_i.$$

The parameter λ in equation (3) captures the amount of noise in buyers' bids. We estimate the best fit for λ within each treatment and then jointly for all treatments in Section C.1. We then show average bidding functions under QRE (computed using a fixed-point algorithm) across treatments and for various values of λ in Section C.2.

C.1 Estimation of Quantal Response Equilibrium Parameters

In this section, we estimate the QRE λ parameter that best fits the distribution of bids in our formal auction treatments. We follow Camerer et al. (2016) in using the intuition from Bajari and Hortacsu (2005) to estimate these parameters. In particular, under the assumption that subjects are playing a QRE for some λ, then the empirical distribution of bids is a consistent estimator for the equilibrium distribution of bids. We can then use this empirical distribution to compute subjects' expected payoffs from each potential bid, allowing us to estimate the maximum likelihood estimator for λ.

In what follows, we describe the procedure to estimate the QRE parameters in detail. Throughout, we use k to refer to treatment (1PD, 1PE, 2PD, or 2PE), i to refer to subject, and t to refer to round.

1. Given N_k, the number of subjects in treatment k, compute the empirical probability mass function $\hat{f}^k(b)$ for all $b \in B_k$:

$$\hat{f}^k(b) = \frac{\sum_{i,t} \mathbb{1}(b_{k,i,t} = b)}{20N_k}$$

2. Define expected payoffs for bid b under signal p as

$$\begin{aligned}
\hat{u}_{1\mathrm{PD}}(b, p_i) &= \left[\sum_{\{b' \in B_{1\mathrm{PD}} : b' < b\}} \hat{f}^{1\mathrm{PD}}(b') + 0.5 \hat{f}^{1\mathrm{PD}}(b) \right] \left((1 - p_i) \max(20 - b, 0) + p_i(60 - b)\right) \\
&+ \left[\sum_{\{b' \in B_{1\mathrm{PD}} : b < b'\}} \hat{f}^{1\mathrm{PD}}(b') + 0.5 \hat{f}^{1\mathrm{PD}}(b) \right] (20) \\
\hat{u}_{1\mathrm{PE}}(b, p_i) &= \left[\sum_{\{b' \in B_{1\mathrm{PE}} : b' < b\}} \hat{f}^{1\mathrm{PE}}(b') + 0.5 \hat{f}^{1\mathrm{PE}}(b) \right] (1 - b) \left((1 - p_i)(20) + p_i(60)\right) \\
&+ \left[\sum_{\{b' \in B_{1\mathrm{PE}} : b < b'\}} \hat{f}^{1\mathrm{PE}}(b') + 0.5 \hat{f}^{1\mathrm{PE}}(b) \right] (20) \\
\hat{u}_{2\mathrm{PD}}(b, p_i) &= \sum_{\{b' \in B_{2\mathrm{PD}} : b' < b\}} \hat{f}^{2\mathrm{PD}}(b') \left((1 - p_i) \max(20 - b', 0) + p_i(60 - b')\right) \\
&+ \hat{f}^{2\mathrm{PD}}(b) \left[0.5 \left((1 - p_i) \max(20 - b, 0) + p_i(60 - b)\right) + 0.5(20)\right] \\
&+ \left[\sum_{\{b' \in B_{2\mathrm{PD}} : b' > b\}} \hat{f}^{2\mathrm{PD}}(b') \right] (20) \\
\hat{u}_{2\mathrm{PE}}(b, p_i) &= \sum_{\{b' \in B_{2\mathrm{PE}} : b' < b\}} \hat{f}^{2\mathrm{PE}}(b')(1 - b') \left((1 - p_i)(20) + p_i(60)\right) \\
&+ \hat{f}^{2\mathrm{PE}}(b) \left[0.5(1 - b) \left((1 - p_i)(20) + p_i(60)\right) + 0.5(20)\right] \\
&+ \left[\sum_{\{b' \in B_{2\mathrm{PE}} : b' > b\}} \hat{f}^{2\mathrm{PE}}(b') \right] (20)
\end{aligned}$$

3. Conditional on the QRE parameter λ and signal p, define choice probabilities for each treatment k and each bid $b \in B_k$ as

$$\mathbb{P}_k(b; p, \lambda) = \frac{\exp(\lambda \hat{u}_k(b, p))}{\sum_{b' \in B_k} \exp(\lambda \hat{u}_k(b', p))}$$

4. Solve for the maximum likelihood estimator for each treatment, as well as the pooled estimator:

$$\hat{\lambda}_k = \underset{\lambda}{\text{argmax}} \sum_{i,t} \ln\left(\mathbb{P}_k\left(\hat{b}_{k,i,t}; p_{k,i,t}, \lambda\right)\right)$$
$$\hat{\lambda}_{\text{Pooled}} = \underset{\lambda}{\text{argmax}} \sum_{k,i,t} \ln\left(\mathbb{P}_k\left(\hat{b}_{k,i,t}; p_{k,i,t}, \lambda\right)\right)$$

Carrying out this process gives us the estimates that we report in Table 4. We compute confidence intervals by inverting the likelihood ratio test. We find that the estimated values of λ for the first-price debt, first-price equity, second-price treatments, and the pooled estimate are quite close to each other. However, λ_{2PE} is roughly three times the size of the other estimates. A likelihood ratio test rejects equality of the parameter λ across all four treatments with a p-value less than 0.01.

Table 4: Quantal Response Equilibrium Estimates

	1PD	1PE	2PD	2PE	Pooled
$\hat{\lambda}$	0.129	0.136	0.144	0.427	0.145
Confidence Interval	[0.115,0.142]	[0.12,0.151]	[0.118,0.171]	[0.368,0.489]	[0.135,0.154]
Bidders	38	40	40	40	158
Observations	760	800	800	800	3160
Log Likelihood	-3397	-3464	-3770	-3541	-14230

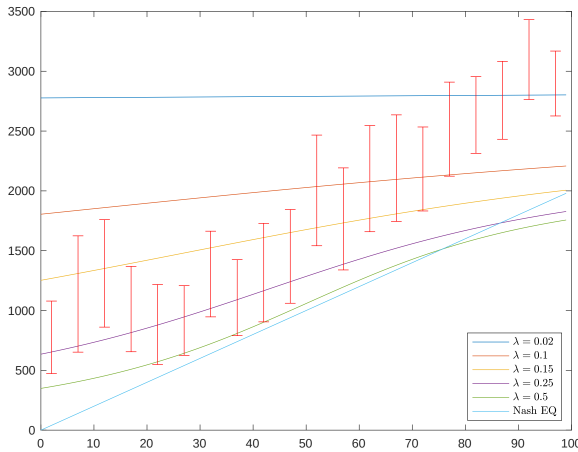
C.2 Computation of Quantal Response Equilibria

In this section, we report the results of computing bidding probabilities for various QRE parameters in each game. We compute these probabilities iteratively. For each value of λ, we initialize bidding probabilities to be uniform over all bids.[28] With this distribution and for each signal, we compute the expected payoff for each potential bid. We then update the bidding probabilities by plugging the expected payoffs and λ into Equation 3. This process is iterated until the bidding functions reach a fixed point.

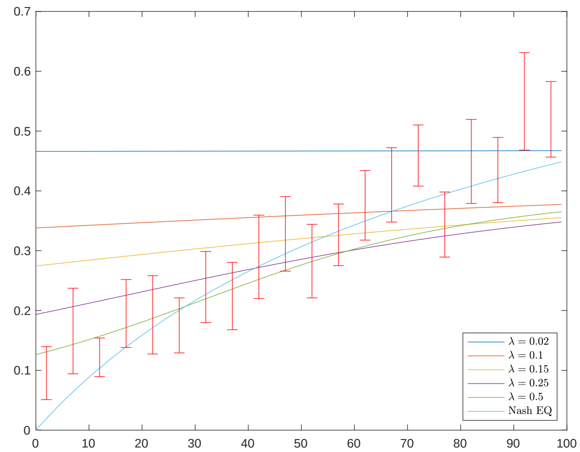
Figure 13 shows the average bidding functions generated by QRE equilibria for various values of λ. For λ near zero, bidding probabilities are close to uniform across all possible bids, leading to average bids that are near 3000 in debt auctions and 0.5 in equity auctions. As λ increases, the average bidding functions generally get closer to the Nash Equilibrium bidding functions (although this is not uniformly the case).

While there are some interesting similarities between the average bidding functions implied by QRE and our empirical average bids, the overall patterns do not seem to match. QRE's noisy bidding combined with the fact that all bids are bounded below by zero leads to overbidding for low signals, as we find in our data. However, we find that no value of λ can match the overbidding that we observe for high signals across treatments. In fact, for many values of λ, QRE leads to *underbidding* for high signals relative to the RNNE.

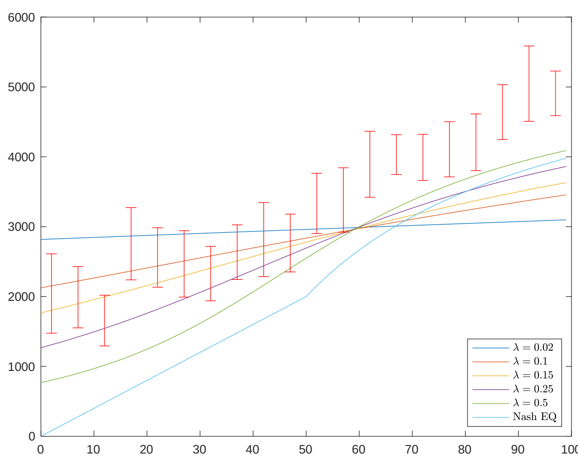
[28] In this section we again restrict all debt bids to be made in multiples of 50.



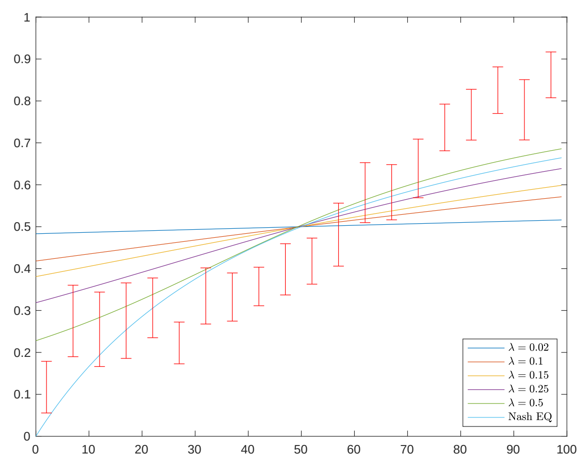
(a) First-price debt



(b) First-price equity



(c) Second-price debt



(d) Second-price equity

Figure 13: Average bidding functions based on Quantal Response Equilibria for various parameters and for each type of formal auction. The QRE are presented alongside the Nash Equilibria and the empirical averages for bids conditional on signal, as in Figure 5.

D Decision Times

In this section, we report results related to the time subjects took when making their bids. Due to technical difficulties, decision times were not recorded for the final two sessions, which consisted of first- and second-price equity auctions. Thus, the dataset consists of 38 subjects in first-price debt auctions, 26 subjects in first-price equity auctions, 40 subjects in second-price debt auctions, and 28 subjects in second-price equity auctions. We find no evidence of differences in time taken to make bids between treatments.

We show the empirical distribution of bidding times in Figure 14. There is no obvious difference between the treatments in this distribution. We carry out a Kruskall-Wallis test of the equality of distributions of bidding times and bidding times averaged at the subject level. Neither test rejects equality of distributions (p-values of 0.29 and 0.83, respectively).

In Table 5, we regress bidding time on treatment dummies and controls for experience. None of the treatment coefficients are significant at the 10% level, and the F-test for equality of all treatments gives a p-value of 0.76.

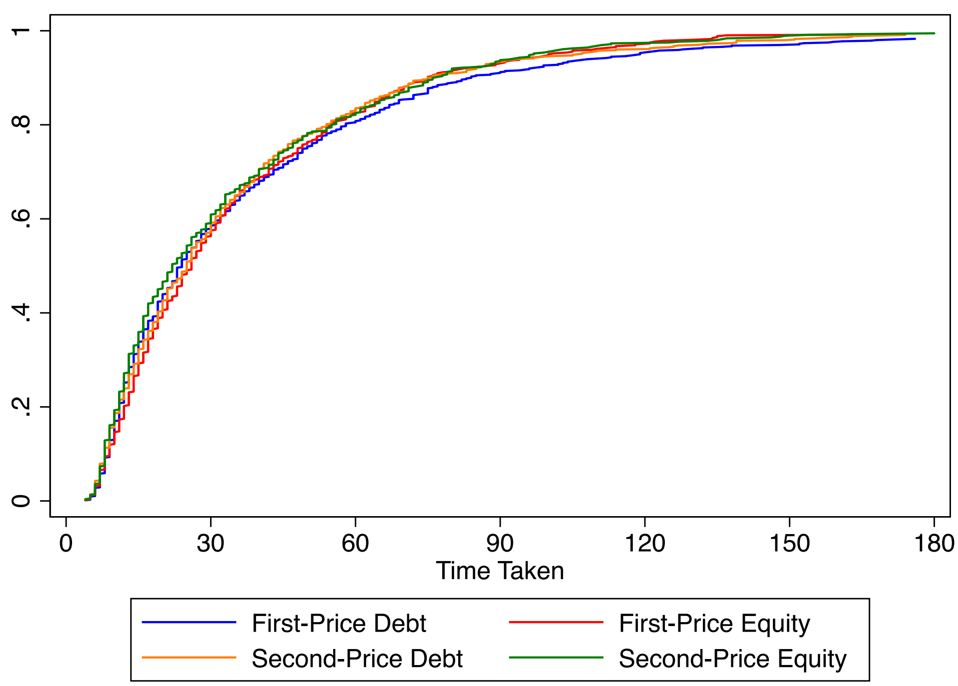


Figure 14: CDFs of bidding times by treatment. CDFs are truncated at 180 seconds.

Table 5: Time taken by treatment and round

	(1) Time Taken	(2) Time Taken
1PE	-3.46	-3.46
	(5.29)	(5.29)
2PD	-3.81	-3.81
	(4.62)	(4.62)
2PE	-5.37	-5.37
	(5.12)	(5.12)
Round		-7.70***
		(0.76)
Round Squared		0.26***
		(0.030)
Constant	39.8***	83.5***
	(3.78)	(6.07)
Observations	2640	2640

Notes: Linear regression with standard errors clustered at the subject level. Significance indicated by: *** p<0.01, ** p<0.05, * p<0.1.

E Additional Results

Table 6: Summary Statistics

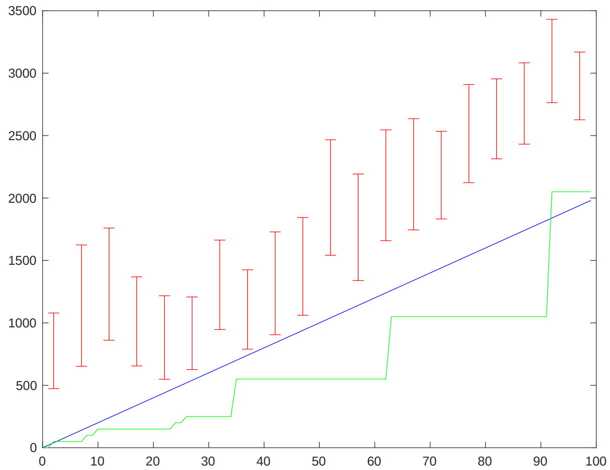
	Mean	Std. Dev.
CRT Score	1.45	1.14
Female	0.60	0.49
Age	22.76	4.27
English	0.41	0.49
Economics	0.33	0.47
Subjects	215.00	

Notes: CRT Score is the number of correct answers on a Cognitive Reflection Test, ranging from 0 to 3. Female, English, and Economics are equal to one if the subjects report being female, speaking English as a first language, and majoring in Economics, respectively.

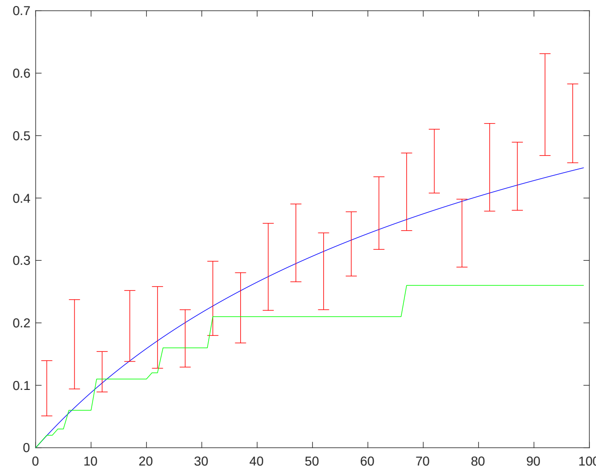
Table 7: Summary Statistics from the Andreoni-Harbaugh Task

	Mean	Std. Dev.
16,000 Max Prize, 0.4 Max Probability (first choice)	57.11	23.61
20,000 Max Prize, 0.5 Max Probability (first choice)	59.98	23.56
12,000 Max Prize, 0.6 Max Probability (first choice)	60.25	21.31
8,000 Max Prize, 0.8 Max Probability (first choice)	56.94	20.87
10,000 Max Prize, 1.0 Max Probability (first choice)	53.50	26.84
16,000 Max Prize, 0.4 Max Probability (second choice)	60.58	23.30
20,000 Max Prize, 0.5 Max Probability (second choice)	62.57	22.88
12,000 Max Prize, 0.6 Max Probability (second choice)	61.93	19.89
8,000 Max Prize, 0.8 Max Probability (second choice)	60.53	19.75
19,000 Max Prize, 1.0 Max Probability (second choice)	56.75	22.10
Subjects	215.00	

Notes: This table reports summary statistics for the average choice made for each Andreoni-Harbaugh task. Each subject saw two copies of five unique budgets. The ordering of the five budgets was randomized at the subject level, but no subject saw the second copy of a budget before seeing all five first copies. The reported choice is the proportion out of 100 of the budget allocated towards increasing the probability of receiving the prize, so a choice of 70 from the first budget is a $\frac{70}{100} \times 0.4 = 0.28$ chance of receiving $\left(1 - \frac{70}{100}\right) \times 16000 = 4800$ points. The expected value is maximized at a choice of 50, so the reported averages are consistent with mild risk aversion.



(a) Debt



(b) Equity

Figure 15: Empirical best responses in formal first-price auctions. Equilibria are given in blue and empirical best responses are given in green. Bids are averaged in windows of 5 units and presented with 95% confidence intervals. Generally, empirical best responses are below Nash Equilibrium bids, which are themselves below the empirical average of bids conditional on signals.

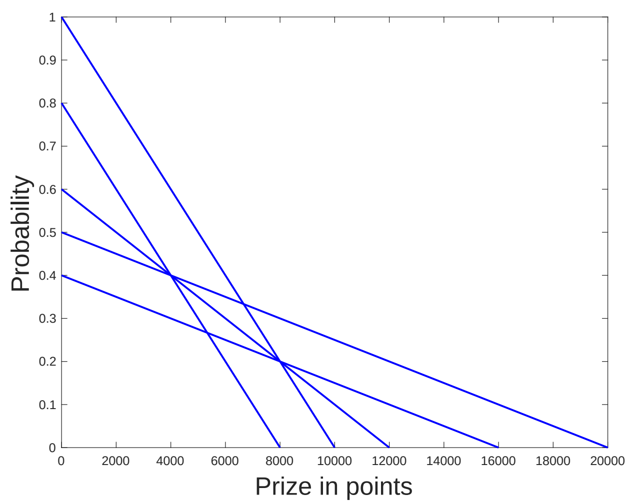


Figure 16: Budgets from the Andreoni-Harbaugh task. Each budget was seen twice, for a total of ten choices. One hundred points corresponds to one dollar. The expected value-maximizing choice is to choose the middle of the budget line.

Table 8: Interim revenue and surplus: Last 10 Rounds

	(1) Revenue	(2) Revenue	(3) Revenue	(4) Surplus	(5) Surplus	(6) Surplus
1PE	-246.5**	-262.1***	-262.1***	22.4	-1.60	-1.56
	(111.8)	(88.5)	(89.0)	(111.2)	(55.2)	(55.1)
2PD	5.60	105.7	105.8	-182.9	-28.5	-28.7
	(105.5)	(90.6)	(91.0)	(113.3)	(57.7)	(57.6)
2PE	-763.4***	-723.6***	-723.5***	42.1	103.5**	103.4*
	(108.9)	(92.5)	(92.6)	(110.3)	(52.7)	(52.9)
Informal	-750.9***	-766.3***	-766.3***	-66.7	-90.5	-90.5
	(97.4)	(86.0)	(86.1)	(114.2)	(63.1)	(63.0)
Potential Surplus		0.64***	0.64***		0.98***	0.98***
		(0.030)	(0.031)		(0.015)	(0.016)
Round		-21.3**			1.34	
		(10.1)			(6.13)	
Constant	2089.5***	757.8***	523.6***	2353.7***	-229.2**	-155.9**
	(69.6)	(185.4)	(136.0)	(80.5)	(112.3)	(71.3)
Round FE	No	No	Yes	No	No	Yes
Observations	980	980	980	980	980	980

Notes: Linear regression with robust standard errors. Significance indicated by: *** p<0.01, ** p<0.05, * p<0.1.
This table replicates the results from Table 1, restricting only to data in the last 10 rounds (when subjects had gained experience). The general patterns remain, with debt-bid auctions generating substantially more revenue than informal and equity-bid auctions.

Table 9: Overbidding

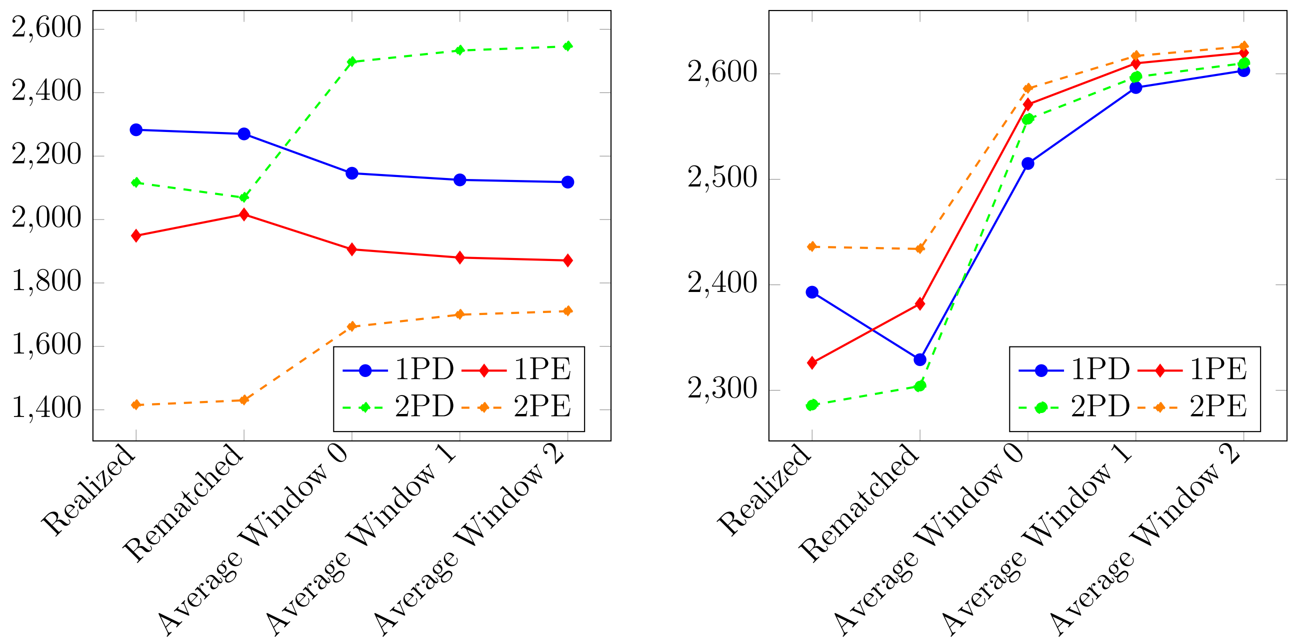
	(1) Overbid	(2) Overbid	(3) Overbid	(4) Overbid
Signal	-11.3	-0.0039***	-26.7***	-0.0095***
	(6.93)	(0.00091)	(7.61)	(0.0012)
Signal Squared	0.17***	0.000038***	0.19**	0.00011***
	(0.061)	(0.0000096)	(0.077)	(0.000012)
Constant	790.3***	0.10***	1885.7***	0.13***
	(192.1)	(0.026)	(206.0)	(0.034)
Treatment	1PD	1PE	2PD	2PE
Subject FE	Yes	Yes	Yes	Yes
Observations	760	800	800	800

Notes: Linear regression with standard errors clustered at the subject level. The dependent variable is the subject's bid minus the RNNE bid. Significance indicated by: *** p<0.01, ** p<0.05, * p<0.1.
This table studies the potential nonlinear effect of different signals on average overbidding. The regression is run separately for each type of formal auction. In all cases, overbidding is a convex function, and the implied minimum level of overbidding is reached at intermediate signal levels (from 33 to 70).

Table 10: Overbidding

	(1) Binary Overbid	(2) Binary Overbid	(3) Binary Overbid	(4) Binary Overbid
Round	-0.010***	-0.015***	0.0036	-0.0067**
	(0.0039)	(0.0031)	(0.0034)	(0.0031)
Constant	0.79***	0.67***	0.78***	0.56***
	(0.057)	(0.051)	(0.052)	(0.044)
Treatment	1PD	1PE	2PD	2PE
Subject FE	Yes	Yes	Yes	Yes
Observations	760	800	800	800

Notes: Linear regression with standard errors clustered at the subject level. The dependent variable is the subject's bid minus the RNNE bid. Significance indicated by: *** p<0.01, ** p<0.05, * p<0.1. This table studies the effects of experience on propensity to overbid separately for each treatment. The relationship is negative and statistically significant for all treatments, except for second-price debt-bid auctions.



(a) Revenue

(b) Surplus

Figure 17: Average surplus and revenue after rematching and averaging. "Realized" refers to the data from the experiment. "Rematched" gives average revenue and surplus after rematching every bid against every other bid from the same treatment. For the averaged numbers, bids are averaged within a particular window and then each average bid is matched against each other average bid from the same treatment. "Average Window 0" shows the results from averaging of all bids that received a particular signal, "Average Window 1" shows the results from averaging all bids within one percentage point of a signal, and "Average Window 2" shows the results from averaging all bids within two percentage points of a signal. Reducing decision noise (but retaining average bidding functions) leads to lower revenue in first-price auctions, higher revenue in second-price auctions, and higher surplus in all auctions.

Table 11: Overbidding by subject characteristics (Logit)

	(1) Binary Overbid	(2) RN Unrationalizable	(3) Dominated
1PE	-0.66**	-0.80***	0.49
	(0.27)	(0.29)	(0.51)
2PD	0.98***	2.52***	2.66***
	(0.29)	(0.29)	(0.35)
2PE	-0.75***	0.78***	2.47***
	(0.24)	(0.25)	(0.35)
Round	-0.035***	-0.035***	-0.030***
	(0.0087)	(0.0100)	(0.0099)
Average RA	0.0011	-0.0014	0.0091
	(0.0067)	(0.0071)	(0.0070)
CRT Score	-0.27***	-0.33***	-0.086
	(0.083)	(0.087)	(0.090)
Quiz Score	-1.57***	-1.83***	-1.24***
	(0.43)	(0.46)	(0.40)
Confidence	0.13**	0.16***	0.040
	(0.053)	(0.058)	(0.052)
Female	0.040	0.019	0.056
	(0.20)	(0.21)	(0.22)
English	-0.18	-0.018	0.11
	(0.18)	(0.19)	(0.20)
Economics	-0.013	-0.15	-0.26
	(0.22)	(0.22)	(0.22)
Age	0.0047	0.030	0.021
	(0.021)	(0.023)	(0.027)
Constant	1.47*	-0.35	-3.43***
	(0.80)	(0.85)	(0.93)
Observations	3160	3160	3160

Notes: Logistic regression with standard errors clustered at the subject level. Significance indicated by: *** p<0.01, ** p<0.05, * p<0.1.
This table reports the Logit version of the linear regression shown in Table 2. Patters of signs and statistical significance are essentially identical across the two tables.

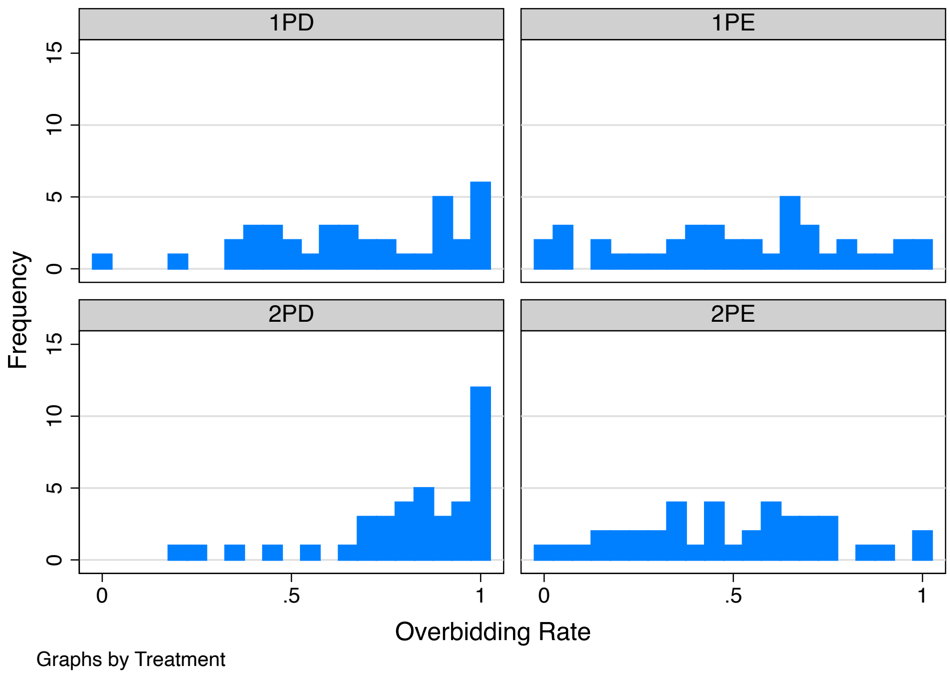


Figure 18: Subject-Level Overbidding Rates by Treatment. This figure shows how many subjects overbid at various rates within each treatment. The overbidding rate for a subject is computed as the number of bids that were strictly over the Nash equilibrium bid divided by the total number of bids (20 in each treatment). Thus, the rightmost three values of the first panel of the figure shows that in the first-price debt treatment, six subjects overbid in every round, two subjects overbid in exactly 19 out of 20 rounds, and five subjects overbid in exactly 18 out of 20 rounds. Similarly, the leftmost three values of the second panel of the figure show that in the first-price equity treatment, two subjects never overbid, three subjects overbid in exactly 1 out of 20 rounds, and zero subjects overbid in exactly 2 out of 20 rounds.

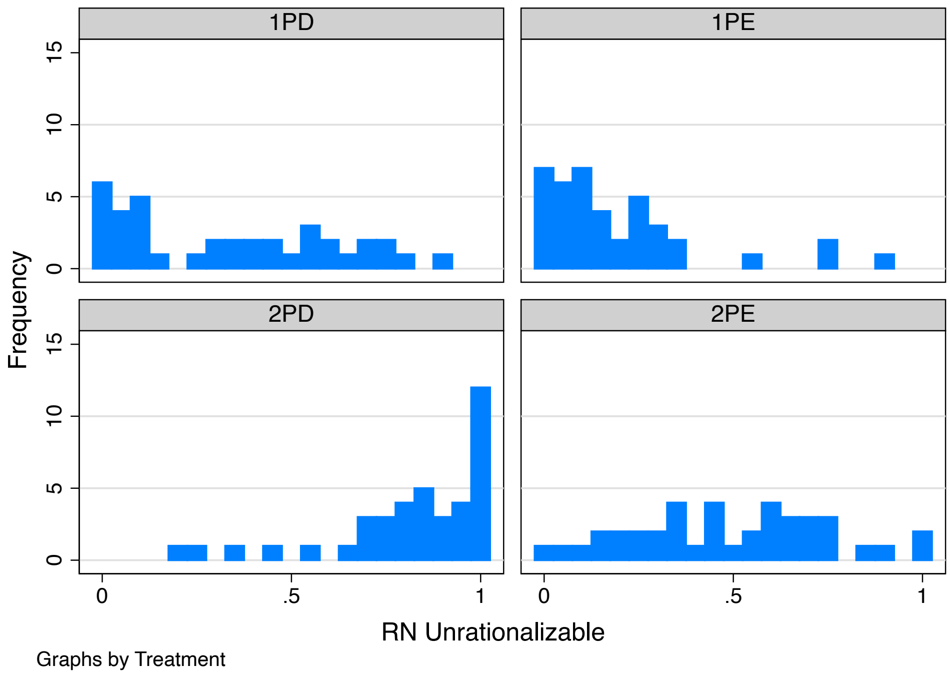


Figure 19: Subject-Level Risk-Neutral Unrationalizable Rates by Treatment. This figure shows how many subjects make risk-neutral unrationalizable bids at various rates within each treatment. A bid is defined as unrationalizable if it there is no combination of beliefs and concave utility function that would rationalize the bid for a given signal. In practice and for a given security, this is equivalent to bidding higher than the risk-neutral Nash Equilibrium of the second-price auction using that security. The rate is then computed as the number of risk-neutral unrationalizable bids divided by the total number of bids (20 in each treatment). Thus, the rightmost three values of the first panel of the figure show that in the first-price debt treatment, no subjects made risk-neutral unrationalizable bids in 19 or more rounds, while one subject made unrationalizable bids in exactly 18 out of 20 rounds. Similarly, the leftmost three values of the second panel of the figure show that in the first-price equity treatment, seven subjects never made a risk-neutral unrationalizable bid, six subjects made risk-neutral unrationalizable bids in exactly 1 out of 20 rounds, and seven subjects made exactly risk-neutral unrationalizable bids in exactly 2 out of 20 rounds.

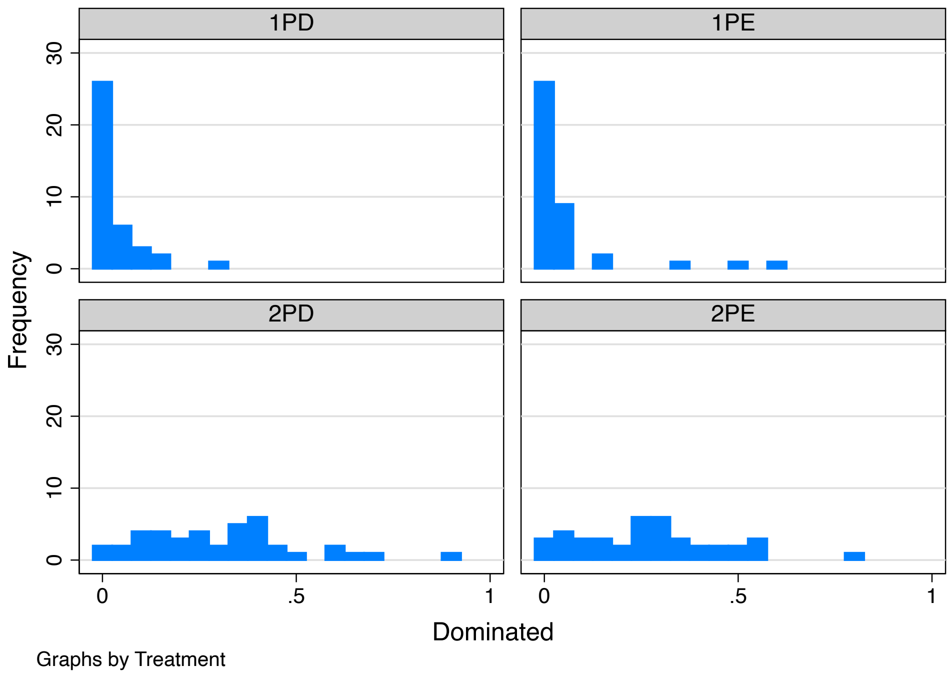


Figure 20: Subject-Level Dominated Rates by Treatment. This figure shows how many subjects made dominated bids at various rates within each treatment. The dominated rate for a subject is computed as the number of bids that were strictly over 4000 (in debt treatments) or 66% (in equity treatments) divided by the total number of bids (20 in each treatment). Thus, the leftmost three values of the first panel of the figure shows that in the first-price debt treatment, twenty-six subjects never made a dominated bid, six subjects made a dominated bid in exactly 1 out of 20 rounds, and three subjects made a dominated bid in exactly 2 out of 20 rounds. Similarly, the leftmost three values of the second panel of the figure show that in the first-price equity treatment, twenty-six subjects never made a dominated bid, nine subjects made a dominated bid in exactly 1 out of 20 rounds, and zero subjects made dominated bids in exactly 2 out of 20 rounds.

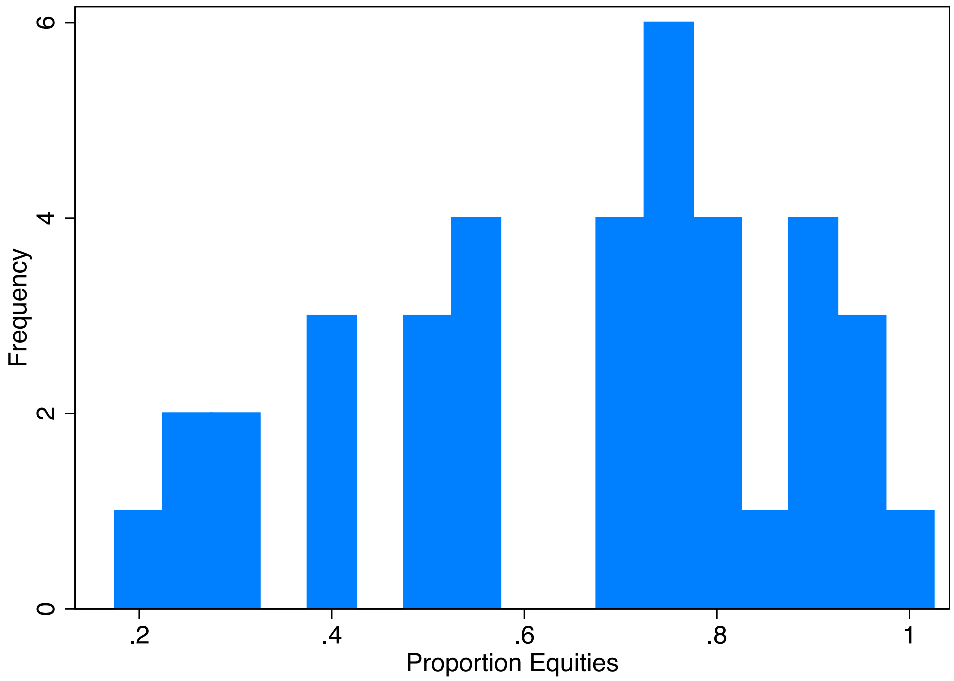


Figure 21: Proportion Equity by Subject. This figure shows how many subjects chose to make bids using equity at various rates in the informal auction treatment. The rate of choosing equity for a subject is computed as the number of rounds in which a bid was made using equity divided by the number of rounds in which the subject acted as a buyer (this varied from subject to subject). Thus, the figure shows that one subject chose to use equities in roughly twenty percent of the opportunities they had to do so, while three subjects chose to use equities in roughly forty percent of the opportunities they had to do so.

Table 12: Overbidding by Subject Characteristics

	(1) Binary Overbid	(2) Binary Overbid	(3) Binary Overbid
Average RA	0.00015		
	(0.0014)		
Average RA (round 1-5)		0.00090	
		(0.0015)	
Average RA (round 6-10)		-0.00086	
		(0.0017)	
Instrumented RA			0.00020
			(0.0018)
Other Controls	Yes	Yes	Yes
ORIV	No	No	Yes
Observations	3160	3160	6320

Notes: Linear regression with standard errors clustered at the subject level. "Other Controls" refers to all variables included in Table 2. Significance indicated by: *** p<0.01, ** p<0.05, * p<0.1.

This table reports the linear relationship between the propensity to overbid and average choices from the Andreoni-Harbaugh task. In the first column, the independent variable is the average proportion of the AH budget assigned to probability across all ten choices from this task. In the second column, the independent variables are the same average computed over the first five tasks (made from the 5 unique budgets) and the second five tasks (each of which is a second copy of one of the 5 unique budgets). The third column uses the Obviously Related Instrumental Variable approach from Gillen et al. (2019) in which each observation is duplicated. In half of those observations, the average choices in the first five rounds is used to instrument for the average choice in rounds 6-10, and in the other half of the observations, the reverse is carried out.

Table 13: Overbidding by Subject Characteristics

	(1) Binary Overbid	(2) Binary Overbid	(3) Binary Overbid
CRRA ρ	0.010		
	(0.026)		
CRRA ρ (round 1-5)		-0.026*	
		(0.015)	
CRRA ρ (round 6-10)		0.037	
		(0.023)	
Instrumented CRRA ρ			0.0084
			(0.033)
Other Controls	Yes	Yes	Yes
ORIV	No	No	Yes
Observations	3160	3160	6320

Notes: Linear regression with standard errors clustered at the subject level. "Other Controls" refers to all variables included in Table 2. Significance indicated by: *** p<0.01, ** p<0.05, * p<0.1.

This table reports the linear relationship between the propensity to overbid and a nonlinear transformation of average choices from the Andreoni-Harbaugh task. In particular, as mentioned in Breig and Feldman (2024), CRRA decision makers with parameter ρ would assign the constant proportion $\frac{1-\rho}{2-\rho}$ of their budget on increasing the prize chosen. Thus, labeling the average Andreoni-Harbaugh choice as $\bar{AH}$, one estimate of ρ is $\frac{1-2\bar{AH}}{1-\bar{AH}}$. This estimate is the independent variable included in the first column. The second column uses the same procedure to estimate two values of ρ, the first from the average of the first five Andreoni-Harbaugh choices and the second from the average of rounds 6-10. Both of these estimates are then included as regressions. Finally, the third column again estimates two values of ρ in the same was as was used for the second column. We then use the Obviously Related Instrumental Variable approach from Gillen et al. (2019) in which each observation is duplicated. In half of these observations, the estimated value of ρ from the first five rounds is used to instrument for the second five rounds, while in the other half of the observations the reverse is carried out.

Table 14: Security choice by subject characteristics

	(1) Debt	(2) Debt
Signal	-0.00100	-0.0010
	(0.00088)	(0.00089)
Round	0.0036	0.0036
	(0.0041)	(0.0042)
Average RA		-0.0035
		(0.0026)
CRT Score		0.016
		(0.050)
Quiz Score		-0.13
		(0.25)
Confidence		0.030
		(0.042)
Female		0.027
		(0.094)
English		0.18**
		(0.069)
Economics		-0.077
		(0.081)
Age		0.0048
		(0.0064)
Constant	0.35***	0.24
	(0.063)	(0.31)
Observations	760	760

Notes: Linear regression with standard errors clustered at the subject level. Significance indicated by: *** p<0.01, ** p<0.05, * p<0.1.
This table reports the linear relationship between security choice in the informal auctions and subject characteristics.

Table 15: Buyer security choice by subject characteristics

	(1) Debt	(2) Debt
Signal	-0.0044	-0.0048
	(0.0039)	(0.0041)
Round	0.016	0.017
	(0.018)	(0.019)
Average RA		-0.016
		(0.013)
CRT Score		0.080
		(0.24)
Quiz Score		-0.65
		(1.17)
Confidence		0.13
		(0.20)
Female		0.13
		(0.43)
English		0.80**
		(0.33)
Economics		-0.36
		(0.38)
Age		0.018
		(0.031)
Constant	-0.61**	-1.01
	(0.28)	(1.47)
Observations	760	760

Notes: Logistic regression with standard errors clustered at the subject level. Significance indicated by: *** p<0.01, ** p<0.05, * p<0.1.
This table reports the Logit version of the linear regression shown in Table 14. Patters of signs and statistical significance are essentially identical across the two tables.

Table 16: Buyers' Security Choice by Subject Characteristics

	(1) Debt	(2) Debt	(3) Debt
Average RA	-0.0035		
	(0.0026)		
Average RA (round 1-5)		-0.0028	
		(0.0038)	
Average RA (round 6-10)		-0.00047	
		(0.0048)	
Instrumented RA			-0.0048
			(0.0032)
Other Controls	Yes	Yes	Yes
ORIV	No	No	Yes
Observations	760	760	1520

Notes: Linear regression with standard errors clustered at the subject level. "Other Controls" refers to all variables included in Table 14. Significance indicated by: *** p<0.01, ** p<0.05, * p<0.1.
This table reports the linear relationship between the choice to bid using debt and average choices from the Andreoni-Harbaugh task. In the first column, the independent variable is the average proportion of the AH budget assigned to probability across all ten choices from this task. In the second column, the independent variables are the same average computed over the first five tasks (made from the 5 unique budgets) and the second five tasks (each of which is a second copy of one of the 5 unique budgets). The third column uses the Obviously Related Instrumental Variable approach from Gillen et al. (2019) in which each observation is duplicated. In half of those observations, the average choices in the first five rounds is used to instrument for the average choice in rounds 6-10, and in the other half of the observations, the reverse is carried out.

Table 17: Buyers' Security Choice by Subject Characteristics

	(1) Debt	(2) Debt	(3) Debt
CRRA ρ	-0.11*		
	(0.062)		
CRRA ρ (round 1-5)		-0.030	
		(0.057)	
CRRA ρ (round 6-10)		-0.091	
		(0.15)	
Instrumented CRRA ρ			-0.17**
			(0.082)
Other Controls	Yes	Yes	Yes
ORIV	No	No	Yes
Observations	760	760	1520

Notes: Linear regression with standard errors clustered at the subject level. "Other Controls" refers to all variables included in Table 14. Significance indicated by: *** p<0.01, ** p<0.05, * p<0.1.

This table reports the linear relationship between the choice to bid using debt and a nonlinear transformation of average choices from the Andreoni-Harbaugh task. In particular, as mentioned in Breig and Feldman (2024), CRRA decision makers with parameter ρ would assign the constant proportion $\frac{1-\rho}{2-\rho}$ of their budget on increasing the prize chosen. Thus, labeling the average Andreoni-Harbaugh choice as $\bar{AH}$, one estimate of ρ is $\frac{1-2\bar{AH}}{1-\bar{AH}}$. This estimate is the independent variable included in the first column. The second column uses the same procedure to estimate two values of ρ, the first from the average of the first five Andreoni-Harbaugh choices and the second from the average of rounds 6-10. Both of these estimates are then included as regressions. Finally, the third column again estimates two values of ρ in the same way as was used for the second column. We then use the Obviously Related Instrumental Variable approach from Gillen et al. (2019) in which each observation is duplicated. In half of these observations, the estimated value of ρ from the first five rounds is used to instrument for the second five rounds, while in the other half of the observations, the reverse is carried out.

Table 18: Potential Surplus

	(1) Potential Surplus	(2) Potential Surplus	(3) Potential Surplus
1PE	-40.8	-40.8	-40.8
	(67.8)	(67.7)	(67.8)
2PD	-145.3**	-145.3**	-145.3**
	(67.1)	(67.0)	(66.9)
2PE	-62.9	-62.9	-62.9
	(65.3)	(65.2)	(65.5)
Informal	-73.4	-73.4	-73.4
	(68.6)	(68.6)	(68.7)
Round		-5.69	
		(3.73)	
Constant	2682.9***	2742.7***	2714.0***
	(46.9)	(60.4)	(103.7)
Round FE	No	No	Yes
Observations	1960	1960	1960

Notes: Linear regression with robust standard errors. Significance indicated by: *** p<0.01, ** p<0.05, * p<0.1.
This table reports a linear regression of the potential surplus of an auction on the treatment variables. Potential surplus is defined as the maximum of the two signals of the bidders in the auction multiplied by 4000. Despite the fact that signals are drawn independently of treatment, the sample of signals drawn for the second-price debt auctions was lower than the other treatments, leading to a negative and statistically significant coefficient.

Experimental Screenshots

Below we copy screenshots of what subjects saw in the experiment.

Instructions

PLEASE READ CAREFULLY AND DO NOT PRESS NEXT UNTIL INSTRUCTED TO DO SO.

Thank you for participating in this study. This study is about decision-making. It should take about 120 minutes, and you will be paid based on your earnings from the experiment. The money you earn will be paid either in cash at the end of the study or electronically within a few days of the end of the study.

Please do not use any electronic devices or talk with other participants during this study.

There will be no deception in this study. Every game or decision you make will be carried out exactly as they are described in the instructions. Anything else would violate the human ethics protocol under which we run the study (UQ Human Research Ethics Approval 2021/HE000019).

The study will have two parts. In each part, you will make decisions which will affect the amount of money you earn. Part 1 of the study consists of games that you will play with other randomly selected players. The players that you are paired with in a round are independent of who you play with in any other round. In Part 2, you will make decisions individually and no other participant can affect your earnings.

If you have questions at any point, please raise your hand and we will answer your questions privately.

Next

Figure 22: Initial instructions for all formal auctions.

Instructions

PLEASE READ CAREFULLY AND DO NOT PRESS NEXT UNTIL INSTRUCTED TO DO SO.

Thank you for participating in this study. This study is about decision-making. It should take about 120 minutes, and you will be paid based on your earnings from the experiment. The money you earn will be paid either in cash at the end of the study or electronically within a few days of the end of the study.

Please do not use any electronic devices or talk with other participants during this study.

There will be no deception in this study. Every game or decision you make will be carried out exactly as they are described in the instructions. Anything else would violate the human ethics protocol under which we run the study (UQ Human Research Ethics Approval 2021/HE001827).

The study will have two parts. In each part, you will make decisions which will affect the amount of money you earn. Part 1 of the study consists of games that you will play with other randomly selected players. The players that you are paired with in a round are independent of who you play with in any other round. In Part 2, you will make decisions individually and no other participant can affect your earnings.

If you have questions at any point, please raise your hand and we will answer your questions privately.

Next

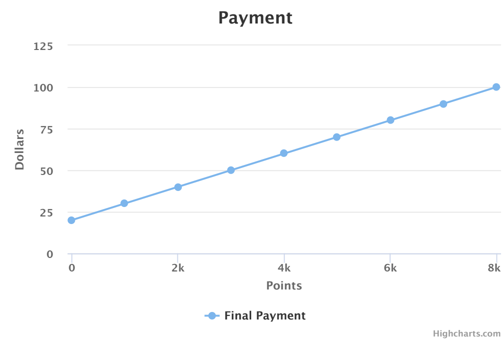
Figure 23: Initial instructions for informal auctions.

Instructions

PLEASE READ CAREFULLY AND DO NOT PRESS NEXT UNTIL INSTRUCTED TO DO SO.

In this study, you will receive points based on the choices you and other participants make. Your dollar earnings at the end of the study will depend on how many points you receive. **You will receive $20 for completing the experiment. You will be paid $2 for each question about the instructions you answer correctly. You will be paid an additional $1 for each 100 points you receive.**

At the end of the study, we will select **one** round at random to be the one that counts. Your points will be determined based on the outcome of that round. Each round is equally likely to be chosen. Because each round may be the one that counts, it is in your best interest to make each choice as if it were going to be implemented.



Important: The amount of points you receive determines how much you are paid at the end of the experiment. It is in your best interest to maximise the number of points you receive in each task.

Next

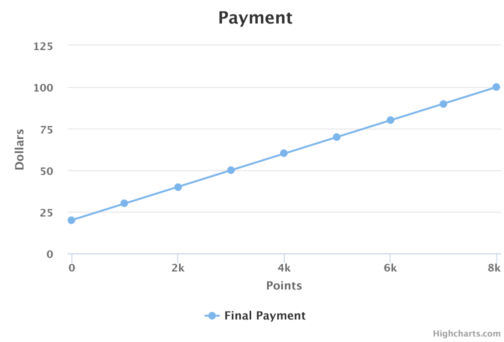
Figure 24: Payment explanation for all formal auctions.

Instructions

PLEASE READ CAREFULLY AND DO NOT PRESS NEXT UNTIL INSTRUCTED TO DO SO.

In this study, you will receive points based on the choices you and other participants make. Your dollar earnings at the end of the study will depend on how many points you receive. **You will receive $20 for completing the experiment. You will be paid $1 for each question about the instructions you answer correctly. You will be paid an additional $1 for each 100 points you receive.**

At the end of the study, we will select **one** round at random to be the one that counts. Your points will be determined based on the outcome of that round. Each round is equally likely to be chosen. Because each round may be the one that counts, it is in your best interest to make each choice as if it were going to be implemented.



Important: The amount of points you receive determines how much you are paid at the end of the experiment. It is in your best interest to maximise the number of points you receive in each task.

Next

Figure 25: Payment explanation for informal auctions.

Instructions

PLEASE READ CAREFULLY AND DO NOT PRESS NEXT UNTIL INSTRUCTED TO DO SO.

In this part of the experiment, you will participate in 20 rounds of auctions. Each auction begins with the computer randomly pairing you with another participant. The player that you are paired with in a round is selected independently of who you play with in any other round. You will not know the player you are paired with.

Before each round, you will be provided with 2000 points.

In each auction you will bid for the opportunity to make a risky investment. The cost of making the investment is the 2000 points that you are provided with at the beginning of the round. However, this investment generates revenue. The revenue of the investment is either 2000 points or 6000 points. Each bidder has a different likelihood of the investment having a revenue of 6000 points, and the likelihoods are uniformly distributed between 0 out of 100 and 100 out of 100. If you do not win the auction, you will keep the 2000 points you were initially provided with.

Important: The bids in this auction will be slightly different to auctions you may have seen before. Both players will make their bids in terms of **points** . The winner will be the player with the highest bid, and the "price" will be equal to the winner's bid. **If the revenue is higher than the price, then the winner will pay the price. If the revenue is lower than the price, then the winner pays all of the revenue.** If both players make the same bid, the winner is chosen randomly and the price is equal to their bid.

For instance, suppose that Player 1 bids 3500 while Player 2 bids 4500. Then Player 1 loses the auction and keeps the 2000 points they were provided with. Player 2 invests their 2000 points and must make a payment depending on the revenue of the investment. Because the winner's bid is higher than 2000, if the revenue is 2000 points, the winner pays 2000 points. If the revenue is instead 6000 points, the winner pays 4500 points.

The next page contains a few more examples to familiarize you with how this works. Take your time and make sure you understand how it works. After the examples, there will be a short quiz about the rules of this game. You will earn $2 for each question you answer correctly.

Next

Figure 26: Auction instructions for the first-price debt treatment

Instructions

PLEASE READ CAREFULLY AND DO NOT PRESS NEXT UNTIL INSTRUCTED TO DO SO.

In this part of the experiment, you will participate in 20 rounds of auctions. Each auction begins with the computer randomly pairing you with another participant. The player that you are paired with in a round is selected independently of who you play with in any other round. You will not know the player you are paired with.

Before each round, you will be provided with 2000 points.

In each auction you will bid for the opportunity to make a risky investment. The cost of making the investment is the 2000 points that you are provided with at the beginning of the round. However, this investment generates revenue. The revenue of the investment is either 2000 points or 6000 points. Each bidder has a different likelihood of the investment having a revenue of 6000 points, and the likelihoods are uniformly distributed between 0 out of 100 and 100 out of 100. If you do not win the auction, you will keep the 2000 points you were initially provided with.

Important: The bids in this auction will be slightly different to auctions you may have seen before. Both players will make their bids in terms of **percentages** . The winner will be the player with the highest bid, and the "price" will be equal to the winner's bid. However, the amount the winner pays may depend on the revenue that the investment generates. **The winner pays a percentage of their revenue equal to the price.** If both players make the same bid, the winner is chosen randomly and the price is equal to their bid.

For instance, suppose that Player 1 bids 20% while Player 2 bids 45%. Then Player 1 loses the auction and keeps the 2000 points they were provided with. Player 2 invests their 2000 points, but receives (1 - 0.45) × 6000 = 3300 points if the revenue is high and (1 - 0.45) × 2000 = 1100 points if the revenue is low.

The next page contains a few more examples to familiarize you with how this works. Take your time and make sure you understand how it works. After the examples, there will be a short quiz about the rules of this game. You will earn $2 for each question you answer correctly.

Next

Figure 27: Auction instructions for the first-price equity treatment.

Instructions

PLEASE READ CAREFULLY AND DO NOT PRESS NEXT UNTIL INSTRUCTED TO DO SO.

In this part of the experiment, you will participate in 20 rounds of auctions. Each auction begins with the computer randomly pairing you with another participant. The player that you are paired with in a round is selected independently of who you play with in any other round. You will not know the player you are paired with.

Before each round, you will be provided with 2000 points.

In each auction you will bid for the opportunity to make a risky investment. The cost of making the investment is the 2000 points that you are provided with at the beginning of the round. However, this investment generates revenue. The revenue of the investment is either 2000 points or 6000 points. Each bidder has a different likelihood of the investment having a revenue of 6000 points, and the likelihoods are uniformly distributed between 0 out of 100 and 100 out of 100. If you do not win the auction, you will keep the 2000 points you were initially provided with.

Important: The bids in this auction will be slightly different to auctions you may have seen before. Both players will make their bids in terms of **points** . The winner will be the player with the highest bid, and the "price" will be equal to the loser's bid. **If the revenue is higher than the price, then the winner will pay the price. If the revenue is lower than the price, then the winner pays all of the revenue.** If both players make the same bid, the winner is chosen randomly and the price is equal to their bid.

For instance, suppose that Player 1 bids 3500 while Player 2 bids 4500. Then Player 1 loses the auction and keeps the 2000 points they were provided with. Player 2 invests their 2000 points and must make a payment depending on the revenue of the investment. Because the loser's bid is higher than 2000, if the revenue is 2000 points, the winner pays 2000 points. If the revenue is instead 6000 points, the winner pays 3500 points.

The next page contains a few more examples to familiarize you with how this works. Take your time and make sure you understand how it works. After the examples, there will be a short quiz about the rules of this game. You will earn $2 for each question you answer correctly.

Next

Figure 28: Auction instructions for the second-price debt treatment.

Instructions

PLEASE READ CAREFULLY AND DO NOT PRESS NEXT UNTIL INSTRUCTED TO DO SO.

In this part of the experiment, you will participate in 20 rounds of auctions. Each auction begins with the computer randomly pairing you with another participant. The player that you are paired with in a round is selected independently of who you play with in any other round. You will not know the player you are paired with.

Before each round, you will be provided with 2000 points.

In each auction you will bid for the opportunity to make a risky investment. The cost of making the investment is the 2000 points that you are provided with at the beginning of the round. However, this investment generates revenue. The revenue of the investment is either 2000 points or 6000 points. Each bidder has a different likelihood of the investment having a revenue of 6000 points, and the likelihoods are uniformly distributed between 0 out of 100 and 100 out of 100. If you do not win the auction, you will keep the 2000 points you were initially provided with.

Important: The bids in this auction will be slightly different to auctions you may have seen before. Both players will make their bids in terms of **percentages** . The winner will be the player with the highest bid, and the "price" will be equal to the loser's bid. However, the amount the winner pays may depend on the revenue that the investment generates. **The winner pays a percentage of their revenue equal to the price.** If both players make the same bid, the winner is chosen randomly and the price is equal to their bid.

For instance, suppose that Player 1 bids 20% while Player 2 bids 45%. Then Player 1 loses the auction and keeps the 2000 points they were provided with. Player 2 invests their 2000 points, but receives (1 - 0.2) × 6000 = 4800 points if the revenue is high and (1 - 0.2) × 2000 = 1600 points if the revenue is low.

The next page contains a few more examples to familiarize you with how this works. Take your time and make sure you understand how it works. After the examples, there will be a short quiz about the rules of this game. You will earn $2 for each question you answer correctly.

Next

Figure 29: Auction instructions for the second-price equity treatment.

Instructions

PLEASE READ CAREFULLY AND DO NOT PRESS NEXT UNTIL INSTRUCTED TO DO SO.

In this part of the experiment, you will participate in 20 rounds of auctions. Each auction begins with the computer randomly pairing you with another two participants. The players that you are paired with in a round are selected independently of who you play with in any other round. You will not know the players you are paired with. Each auction stands alone — your choices in one round do not affect the outcome of subsequent rounds.

You will be randomly assigned the role of either a bidder or a seller at the start of the experiment. You will remain in this role throughout the experiment.

Before each auction, players who are bidders will be provided with 2000 points.

In each auction, bidders will bid for the opportunity to make a risky investment. The cost of making the investment is the 2000 points that bidders are provided with before each auction. This investment generates revenue. The revenue from the investment is either 2000 points or 6000 points. Each bidder has a different likelihood of the investment having a revenue of 6000 points, and **the likelihoods are uniformly distributed between 0% and 100%**. If you do not win the auction, you will keep the 2000 points you were initially provided with, and this will be your payoff for the round.

Important: The bids in this auction will be slightly different to auctions you may have seen before. Bidders will make their bids in terms of **equity percentages** or **debt payments**. The winning bid of each auction will be chosen by the player acting as the seller. The "price" will be equal to the winner's bid.

The amount the winner pays and seller receives may depend on the bid type and revenue that the investment generates.

The bidder chooses whether to submit a debt or equity bid.

Equity Bids: If the winner bids with equity, the winner **pays a percentage of their revenue equal to the price** (their bid). The bidder receives either (1 - Bid %) × 6000 or (1 - Bid %) × 2000 points as their payoff. The seller receives either (Bid %) × 6000 or (Bid %) × 2000 points as their payoff.

Debt Bids: If the winner bids with debt, the winner **pays a fixed amount of revenue equal to the price** (their bid) before receiving any revenue earned over their bid. Thus, the bidder either receives (6000 - Bid) or (2000 - Bid) points as their payoff. The bidder cannot receive less than 0 points. The seller receives the price as their guaranteed payoff.

In each auction, the seller will choose which bid is the winner.

The next page contains examples to familiarize you with how this works. Take your time and make sure you understand how it works. We will not begin until everybody completes these examples.

Very Important: For each auction, the sliders are tools to help you decide the bid you like the best. Therefore, it is in your best interest to move them around to help you determine which bid you like better.

Next

Figure 30: Auction instructions for the informal treatment.

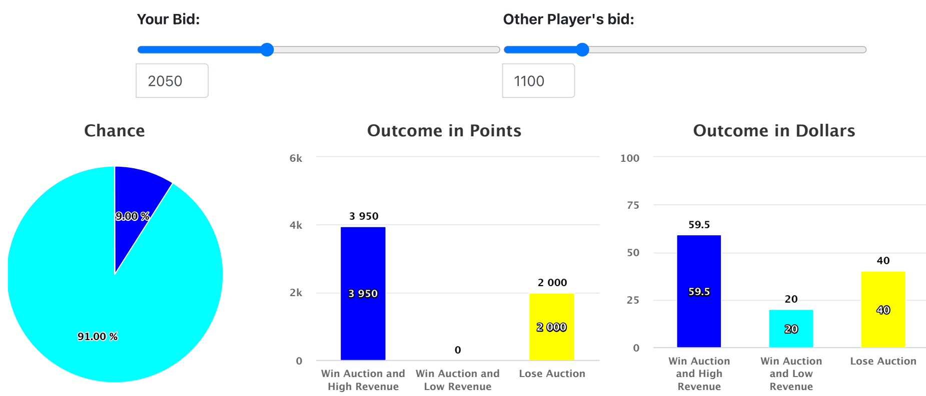
Examples

Example 1: Alice and Bob participate in this type of auction. Alice finds out that her project has a 53% chance of generating a high revenue, while Bob finds out that his project has an 81% chance of generating the high revenue.
Alice bids 1000 points and Bob bids 1800 points. Then Alice loses the auction and is guaranteed a payoff of 2000 points.
Bob wins the auction and has an 81% chance of receiving 6000 - 1800 = 4200 points and a 19% chance of receiving 2000 - 1800 = 200 points.

Example 2: Carmen and Daron participate in this type of auction. Carmen finds out that her project has a 42% chance of generating a high revenue, while Daron finds out that his project has an 55% chance of generating the high revenue.
Carmen bids 2400 points and Daron bids 2200 points. Then Daron loses the auction and is guaranteed a payoff of 2000 points.
Carmen wins the auction and has a 42% chance of receiving 6000 - 2400 = 3600 points, but because Carmen's bid is higher than 2000, Carmen has a 58% chance of receiving 0 points.

Compare bids: The interactive figure below will help show you what your payoffs will be conditional on your and your and the other player's bids. Once you move a slider, the diagram will show you the likelihood of winning the auction with high revenue, the likelihood of winning the auction with low revenue, and the likelihood of losing the auction. It will also show you the number of points and the final dollar outcomes associated with each of these outcomes. Try out different bids to make sure you understand the consequences of your choices.

For instance, suppose that if you win, the likelihood that the project's revenue will be 6000 is 9%. That means that the likelihood that the project's revenue will be 2000 is 91%.



When you are ready to continue, press next and you will begin the quiz.

Next

Figure 31: Examples for the first-price debt treatment.

Examples

Example 1: Alice and Bob participate in this type of auction. Alice finds out that her project has a 53% chance of generating a high revenue, while Bob finds out that his project has an 81% chance of generating the high revenue.
Alice bids 30% and Bob bids 43%. Then Alice loses the auction and is guaranteed a payoff of 2000 points.
Bob wins the auction and has an 81% chance of receiving (1 - 0.43) × 6000 = 3420 points and a 19% chance of receiving (1 - 0.43) × 2000 = 1140 points.

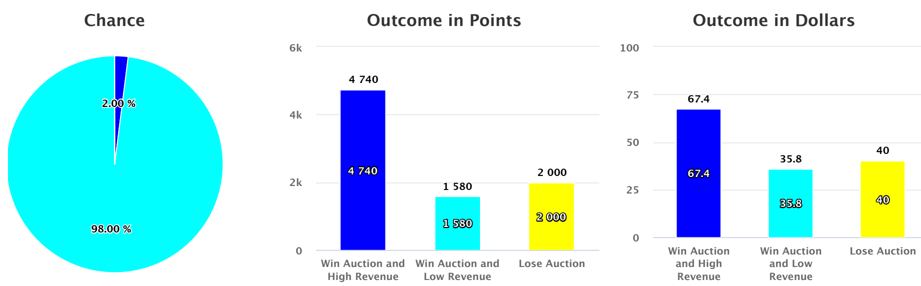
Example 2: Carmen and Daron participate in this type of auction. Carmen finds out that her project has a 42% chance of generating a high revenue, while Daron finds out that his project has an 55% chance of generating the high revenue.
Carmen bids 27% and Daron bids 22%. Then Daron loses the auction and is guaranteed a payoff of 2000 points.
Carmen wins the auction and has a 42% chance of receiving (1 - 0.27) × 6000 = 4380 points and a 58% chance of receiving (1 - 0.27) × 2000 = 1460 points.

Compare bids: The interactive figure below will help show you what your payoffs will be conditional on your and your and the other player's bids. Once you move a slider, the diagram will show you the likelihood of winning the auction with high revenue, the likelihood of winning the auction with low revenue, and the likelihood of losing the auction. It will also show you the number of points and the final dollar outcomes associated with each of these outcomes. Try out different bids to make sure you understand the consequences of your choices.

For instance, suppose that if you win, the likelihood that the project's revenue will be 6000 is 2%. That means that the likelihood that the project's revenue will be 2000 is 98%.

Your Bid: 21

Other Player's bid: 16



When you are ready to continue, press next and you will begin the quiz.

Next

Figure 32: Examples for the first-price equity treatment.

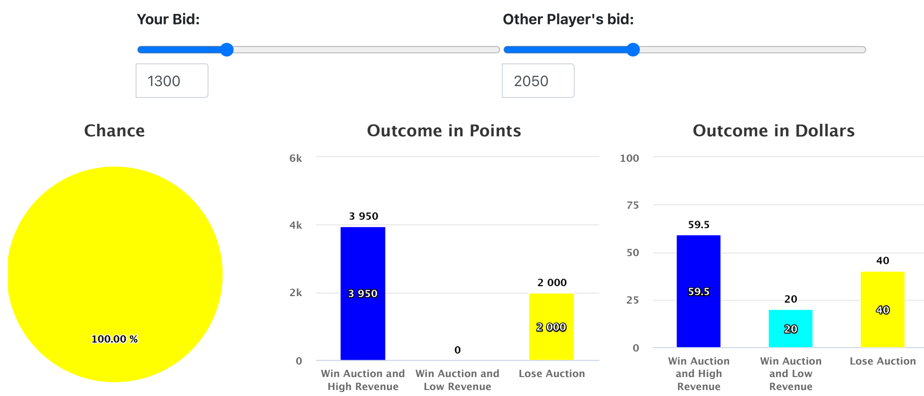
Examples

Example 1: Alice and Bob participate in this type of auction. Alice finds out that her project has a 53% chance of generating a high revenue, while Bob finds out that his project has an 81% chance of generating the high revenue.
Alice bids 1000 points and Bob bids 1800 points. Then Alice loses the auction and is guaranteed a payoff of 2000 points.
Bob wins the auction and has an 81% chance of receiving 6000 - 1000 = 5000 points and a 19% chance of receiving 2000 - 1000 = 1000 points.

Example 2: Carmen and Daron participate in this type of auction. Carmen finds out that her project has a 42% chance of generating a high revenue, while Daron finds out that his project has an 55% chance of generating the high revenue.
Carmen bids 2400 points and Daron bids 2200 points. Then Daron loses the auction and is guaranteed a payoff of 2000 points.
Carmen wins the auction and has a 42% chance of receiving 6000 - 2200 = 3800 points, but because Daron's bid is higher than 2000, Carmen has a 58% chance of receiving 0 points.

Compare bids: The interactive figure below will help show you what your payoffs will be conditional on your and your and the other player's bids. Once you move a slider, the diagram will show you the likelihood of winning the auction with high revenue, the likelihood of winning the auction with low revenue, and the likelihood of losing the auction. It will also show you the number of points and the final dollar outcomes associated with each of these outcomes. Try out different bids to make sure you understand the consequences of your choices.

For instance, suppose that if you win, the likelihood that the project's revenue will be 6000 is 74%. That means that the likelihood that the project's revenue will be 2000 is 26%.



When you are ready to continue, press next and you will begin the quiz.

Next

Figure 33: Examples for the second-price debt treatment.

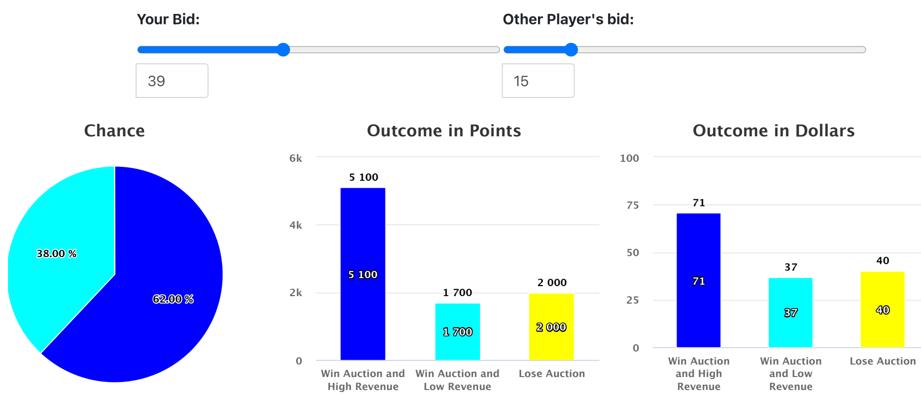
Examples

Example 1: Alice and Bob participate in this type of auction. Alice finds out that her project has a 53% chance of generating a high revenue, while Bob finds out that his project has an 81% chance of generating the high revenue.
Alice bids 30% and Bob bids 43%. Then Alice loses the auction and is guaranteed a payoff of 2000 points.
Bob wins the auction and has an 81% chance of receiving (1 - 0.3) × 4200 = 3420 points and a 19% chance of receiving (1 - 0.3) × 2000 = 1400 points.

Example 2: Carmen and Daron participate in this type of auction. Carmen finds out that her project has a 42% chance of generating a high revenue, while Daron finds out that his project has an 55% chance of generating the high revenue.
Carmen bids 27% and Daron bids 22%. Then Daron loses the auction and is guaranteed a payoff of 2000 points.
Carmen wins the auction and has a 42% chance of receiving (1 - 0.22) × 6000 = 4680 points and a 58% chance of receiving (1 - 0.22) × 2000 = 1560 points.

Compare bids: The interactive figure below will help show you what your payoffs will be conditional on your and your and the other player's bids. Once you move a slider, the diagram will show you the likelihood of winning the auction with high revenue, the likelihood of winning the auction with low revenue, and the likelihood of losing the auction. It will also show you the number of points and the final dollar outcomes associated with each of these outcomes. Try out different bids to make sure you understand the consequences of your choices.

For instance, suppose that if you win, the likelihood that the project's revenue will be 6000 is 62%. That means that the likelihood that the project's revenue will be 2000 is 38%.



When you are ready to continue, press next and you will begin the quiz.

Next

Figure 34: Examples for the second-price equity treatment.

Examples

Example 1: Aditya, Bridget, and Callum participate in this type of auction. Aditya and Bridget are bidders, and Callum is a seller. Aditya finds out that his project has a 53% chance of generating the high revenue, while Bridget finds out that her project has an 81% chance of generating the high revenue. Both bid with equity. Aditya bids 27% and Bridget bids 30%. The seller (Callum) then chooses the winner without knowing the high revenue chances of each of the bidders.

In this example, we will say that Callum chooses Bridget as the winner. Aditya loses the auction and is guaranteed a payoff of 2000 points. Bridget wins the auction and has an 81% chance of receiving (1 - 0.3) × 6000 = 4200 points and a 19% chance of receiving (1 - 0.3) × 2000 = 1400 points. This means that Callum has an 81% chance of receiving 0.3 × 6000 = 1800 points and a 19% chance of receiving 0.3 × 2000 = 600 points.

Example 2: Declan, Edward, and George participate in this type of auction. Declan finds out that his project has a 42% chance of generating the high revenue, while Edward finds out that his project has a 55% chance of generating the high revenue. Both bid with debt. Declan bids 1800 points and Edward bids 1500 points. The seller (George) then chooses the winner without knowing the high revenue chances of each of the bidders.

In this example, we will say that George chooses Declan as the winner. Edward loses the auction and is guaranteed a payoff of 2000 points. Declan wins the auction and has a 42% chance of receiving 6000 - 1800 = 4200 points and a 58% chance of receiving 2000 - 1800 = 200 points. Players cannot receive negative points. As George has selected a debt bid as the winner, he is guaranteed to receive 1800 points as his payoff.

Example 3: Maja, Nicole, and Tom participate in this type of auction. Maja finds out that her project has a 40% chance of generating the high revenue, while Nicole finds out that her project has a 50% chance of generating the high revenue. Maja makes an equity bid of 45%, and Nicole makes a debt bid of 1800. The seller (Tom) then chooses the winner without knowing the high revenue chances of each of the bidders.

Tom's preferences will determine his choice between a debt and equity bid. If Tom chooses Maja as the winner, he has a 40% chance of receiving 0.45 × 6000 = 2700 points and a 60% chance of receiving 0.45 × 2000 = 900 points. If Tom chooses Nicole as the winner, he will receive a guaranteed 1800 points.

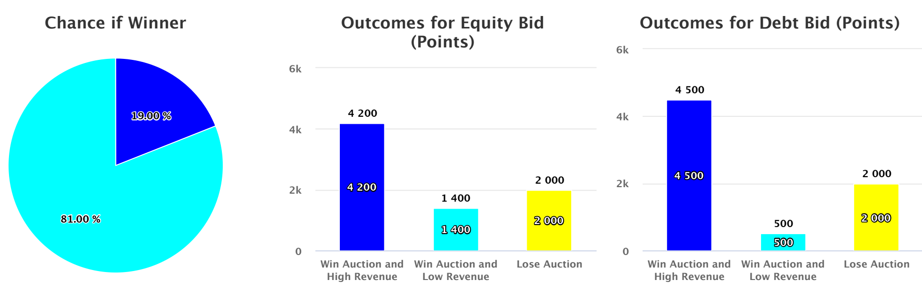
Important: In every auction, the seller does not know the percentage chances of the bidders' revenue being high or low.

Try it out: For each auction, players will be given an interactive figure that will help show what their payoffs will be, conditional on their choices. Below are the diagrams displayed to bidders in each auction. Once you move a slider, the diagram will show you the likelihood of winning the auction with high revenue, and the likelihood of winning the auction with low revenue. It will also show you the number of points you stand to receive under a debt or equity bid of different values. Try out different bids below to make sure you understand the consequences of your choices.

For instance, suppose that if you win, the likelihood that the project's revenue will be 6000 is 19%. That means that the likelihood that the project's revenue will be 2000 is 81%.

Example hypothetical equity bid: 30

Example hypothetical debt bid: 1500



When you are ready to continue, press next to answer some questions to test your understanding.

Next

Figure 35: Examples for the informal treatment.

Quiz

You will now be given a series of questions to check your understanding of the instructions and examples. You will be paid $2 for each answer you get correct.

How is the auction winner decided?

- [ ] Another player chooses the winner.
- [ ] The computer randomly chooses the winner from all bidders.
- [x] The computer randomly chooses the winner from the highest bidders.

What will each player know about the chance of high revenue?

- [x] Each player only knows their own chance.
- [ ] Each player knows their chance and the other player's chance.
- [ ] Each player knows their chance and learns the other player's chance after the auction.
- [ ] Neither player knows either player's chance.

How will the auction's price be set?

- [x] The price is equal to the highest bid.
- [ ] The price is equal to the second highest bid.
- [ ] The price is randomly selected from the two bids.
- [ ] The price is a randomly selected value between the two bids.

How is the price used when computing payoffs?

- [ ] The auction's winner pays either the price or their revenue, whichever is smaller.
- [x] The auction's winner receives either the price or their revenue, whichever is smaller.
- [ ] The auction's loser pays either the price or their revenue, whichever is smaller.
- [ ] The auction's loser receives either the price or their revenue, whichever is smaller.

Suppose that the other player bids 1000 points and you bid 500 points. How many points will each player receive?

- [ ] You will receive 2000 points. The other player will receive 1000 points if the revenue is low and 5000 points if the revenue is high.
- [x] You will receive 2000 points. The other player will receive 1500 points if the revenue is low and 5500 points if the revenue is high.
- [ ] You will receive 1000 points if the revenue is low and 5000 points if the revenue is high. The other player will receive 2000 points.
- [ ] You will receive 1500 points if the revenue is low and 5500 points if the revenue is high. The other player will receive 2000 points.

Suppose that the other player bids 1000 points and you bid 5500 points. How many points will each player receive?

- [x] You will receive 2000 points. The other player will receive 1000 points if the revenue is low and 5000 points if the revenue is high.
- [ ] You will receive 2000 points. The other player will receive 0 points if the revenue is low and 500 points if the revenue is high.
- [ ] You will receive 1000 points if the revenue is low and 5000 points if the revenue is high. The other player will receive 2000 points.
- [ ] You will receive 0 points if the revenue is low and 500 points if the revenue is high. The other player will receive 2000 points.

Suppose that the other player bids 4500 points and you bid 500 points. How many points will each player receive?

- [ ] You will receive 2000 points. The other player will receive 0 points if the revenue is low and 1500 points if the revenue is high.
- [ ] You will receive 2000 points. The other player will receive 1500 points if the revenue is low and 5500 points if the revenue is high.

Figure 36: Quiz for the first-price debt treatment.

- (selected) You will receive 0 points if the revenue is low and 1500 points if the revenue is high. The other player will receive 2000 points.
- You will receive 1500 points if the revenue is low and 5500 points if the revenue is high. The other player will receive 2000 points.

Suppose that the other player bids 4500 and you bid 5500 points. How many points will each player receive?

- (selected) You will receive 2000 points. The other player will receive 0 points if the revenue is low and 1500 points if the revenue is high.
- You will receive 2000 points. The other player will receive 0 points if the revenue is low and 500 points if the revenue is high.
- You will receive 0 points if the revenue is low and 1500 points if the revenue is high. The other player will receive 2000 points.
- You will receive 0 points if the revenue is low and 500 points if the revenue is high. The other player will receive 2000 points.

When you believe you have answered all questions correctly, press next to check your answers.

Next

Figure 37: Quiz for the first-price debt treatment.

Quiz

You will now be given a series of questions to check your understanding of the instructions and examples. You will be paid $2 for each answer you get correct.

How is the auction winner decided?

- ○ Another player chooses the winner.
- ○ The computer randomly chooses the winner from all bidders.
- ◉ The computer randomly chooses the winner from the highest bidders.

What will each player know about the chance of high revenue?

- ◉ Each player only knows their own chance.
- ○ Each player knows their chance and the other player's chance.
- ○ Each player knows their chance and learns the other player's chance after the auction.
- ○ Neither player knows either player's chance.

How will the auction's price be set?

- ○ The price is equal to the highest bid.
- ◉ The price is equal to the second highest bid.
- ○ The price is randomly selected from the two bids.
- ○ The price is a randomly selected value between the two bids.

How is the price used when computing payoffs?

- ○ The auction's winner pays a percentage of their revenue equal to the price.
- ○ The auction's winner receives a percentage of their revenue equal to the price.
- ◉ The auction's loser pays a percentage of their revenue equal to the price
- ○ The auction's loser receives a percentage of their revenue equal to the price.

Suppose that the other player bids 20% and you bid 10%. How many points will each player receive?

- ◉ You will receive 2000 points. The other player will receive 1600 points if the revenue is low and 4800 points if the revenue is high.
- ○ You will receive 2000 points. The other player will receive 1800 points if the revenue is low and 5400 points if the revenue is high.
- ○ You will receive 1600 points if the revenue is low and 4800 points if the revenue is high. The other player will receive 2000 points.
- ○ You will receive 1800 points if the revenue is low and 5400 points if the revenue is high. The other player will receive 2000 points.

Suppose that the other player bids 20% and you bid 80%. How many points will each player receive?

- ○ You will receive 2000 points. The other player will receive 1600 points if the revenue is low and 4800 points if the revenue is high.
- ○ You will receive 2000 points. The other player will receive 400 points if the revenue is low and 1200 points if the revenue is high.
- ○ You will receive 1600 points if the revenue is low and 4800 points if the revenue is high. The other player will receive 2000 points.
- ◉ You will receive 400 points if the revenue is low and 1200 points if the revenue is high. The other player will receive 2000 points.

Suppose that the other player bids 70% and you bid 10%. How many points will each player receive?

- ◉ You will receive 2000 points. The other player will receive 600 points if the revenue is low and 1800 points if the revenue is high.
- ○ You will receive 2000 points. The other player will receive 1800 points if the revenue is low and 5400 points if the revenue is high.

Figure 38: Quiz for the first-price equity treatment.

- You will receive 600 points if the revenue is low and 1800 points if the revenue is high. The other player will receive 2000 points.
- You will receive 1800 points if the revenue is low and 5400 points if the revenue is high. The other player will receive 2000 points.

Suppose that the other player bids 70% and you bid 80%. How many points will each player receive?

- You will receive 2000 points. The other player will receive 600 points if the revenue is low and 1800 points if the revenue is high.
- You will receive 2000 points. The other player will receive 400 points if the revenue is low and 1200 points if the revenue is high.
- You will receive 600 points if the revenue is low and 1800 points if the revenue is high. The other player will receive 2000 points.
- You will receive 400 points if the revenue is low and 1200 points if the revenue is high. The other player will receive 2000 points.

When you believe you have answered all questions correctly, press next to check your answers.

Next

Figure 39: Quiz for the first-price equity treatment.

Quiz

You will now be given a series of questions to check your understanding of the instructions and examples. You will be paid $2 for each answer you get correct.

How is the auction winner decided?

- ○ Another player chooses the winner.
- ○ The computer randomly chooses the winner from all bidders.
- ◉ The computer randomly chooses the winner from the highest bidders.

What will each player know about the chance of high revenue?

- ○ Each player only knows their own chance.
- ○ Each player knows their chance and the other player's chance.
- ◉ Each player knows their chance and learns the other player's chance after the auction.
- ○ Neither player knows either player's chance.

How will the auction's price be set?

- ○ The price is equal to the highest bid.
- ◉ The price is equal to the second highest bid.
- ○ The price is randomly selected from the two bids.
- ○ The price is a randomly selected value between the two bids.

How is the price used when computing payoffs?

- ○ The auction's winner pays either the price or their revenue, whichever is smaller.
- ◉ The auction's winner receives either the price or their revenue, whichever is smaller.
- ○ The auction's loser pays either the price or their revenue, whichever is smaller.
- ○ The auction's loser receives either the price or their revenue, whichever is smaller.

Suppose that the other player bids 1000 points and you bid 500 points. How many points will each player receive?

- ○ You will receive 2000 points. The other player will receive 1000 points if the revenue is low and 5000 points if the revenue is high.
- ◉ You will receive 2000 points. The other player will receive 1500 points if the revenue is low and 5500 points if the revenue is high.
- ○ You will receive 1000 points if the revenue is low and 5000 points if the revenue is high. The other player will receive 2000 points.
- ○ You will receive 1500 points if the revenue is low and 5500 points if the revenue is high. The other player will receive 2000 points.

Suppose that the other player bids 1000 points and you bid 5500 points. How many points will each player receive?

- ○ You will receive 2000 points. The other player will receive 1000 points if the revenue is low and 5000 points if the revenue is high.
- ◉ You will receive 2000 points. The other player will receive 0 points if the revenue is low and 500 points if the revenue is high.
- ○ You will receive 1000 points if the revenue is low and 5000 points if the revenue is high. The other player will receive 2000 points.
- ○ You will receive 0 points if the revenue is low and 500 points if the revenue is high. The other player will receive 2000 points.

Suppose that the other player bids 4500 points and you bid 500 points. How many points will each player receive?

- ○ You will receive 2000 points. The other player will receive 0 points if the revenue is low and 1500 points if the revenue is high.
- ◉ You will receive 2000 points. The other player will receive 1500 points if the revenue is low and 5500 points if the revenue is high.

Figure 40: Quiz for the second-price debt treatment.

- You will receive 0 points if the revenue is low and 1500 points if the revenue is high. The other player will receive 2000 points.
- You will receive 1500 points if the revenue is low and 5500 points if the revenue is high. The other player will receive 2000 points.

Suppose that the other player bids 4500 and you bid 5500 points. How many points will each player receive?

- You will receive 2000 points. The other player will receive 0 points if the revenue is low and 1500 points if the revenue is high.
- You will receive 2000 points. The other player will receive 0 points if the revenue is low and 500 points if the revenue is high.
- You will receive 0 points if the revenue is low and 1500 points if the revenue is high. The other player will receive 2000 points.
- You will receive 0 points if the revenue is low and 500 points if the revenue is high. The other player will receive 2000 points.

When you believe you have answered all questions correctly, press next to check your answers.

Next

Figure 41: Quiz for the second-price debt treatment.

Quiz

You will now be given a series of questions to check your understanding of the instructions and examples. You will be paid $2 for each answer you get correct.

How is the auction winner decided?

- Another player chooses the winner.
- The computer randomly chooses the winner from all bidders.
- The computer randomly chooses the winner from the highest bidders.

What will each player know about the chance of high revenue?

- Each player only knows their own chance.
- Each player knows their chance and the other player's chance.
- Each player knows their chance and learns the other player's chance after the auction.
- Neither player knows either player's chance.

How will the auction's price be set?

- The price is equal to the highest bid.
- The price is equal to the second highest bid.
- The price is randomly selected from the two bids.
- The price is a randomly selected value between the two bids.

How is the price used when computing payoffs?

- The auction's winner pays a percentage of their revenue equal to the price.
- The auction's winner receives a percentage of their revenue equal to the price.
- The auction's loser pays a percentage of their revenue equal to the price
- The auction's loser receives a percentage of their revenue equal to the price.

Suppose that the other player bids 20% and you bid 10%. How many points will each player receive?

- You will receive 2000 points. The other player will receive 1600 points if the revenue is low and 4800 points if the revenue is high.
- You will receive 2000 points. The other player will receive 1800 points if the revenue is low and 5400 points if the revenue is high.
- You will receive 1600 points if the revenue is low and 4800 points if the revenue is high. The other player will receive 2000 points.
- You will receive 1800 points if the revenue is low and 5400 points if the revenue is high. The other player will receive 2000 points.

Suppose that the other player bids 20% and you bid 80%. How many points will each player receive?

- You will receive 2000 points. The other player will receive 1600 points if the revenue is low and 4800 points if the revenue is high.
- You will receive 2000 points. The other player will receive 400 points if the revenue is low and 1200 points if the revenue is high.
- You will receive 1600 points if the revenue is low and 4800 points if the revenue is high. The other player will receive 2000 points.
- You will receive 400 points if the revenue is low and 1200 points if the revenue is high. The other player will receive 2000 points.

Suppose that the other player bids 70% and you bid 10%. How many points will each player receive?

- You will receive 2000 points. The other player will receive 600 points if the revenue is low and 1800 points if the revenue is high.
- You will receive 2000 points. The other player will receive 1800 points if the revenue is low and 5400 points if the revenue is high.

Figure 42: Quiz for the second-price equity treatment.

- ○ You will receive 600 points if the revenue is low and 1800 points if the revenue is high. The other player will receive 2000 points.
- ○ You will receive 1800 points if the revenue is low and 5400 points if the revenue is high. The other player will receive 2000 points.

Suppose that the other player bids 70% and you bid 80%. How many points will each player receive?

- ○ You will receive 2000 points. The other player will receive 600 points if the revenue is low and 1800 points if the revenue is high.
- ○ You will receive 2000 points. The other player will receive 400 points if the revenue is low and 1200 points if the revenue is high.
- ○ You will receive 600 points if the revenue is low and 1800 points if the revenue is high. The other player will receive 2000 points.
- ◉ You will receive 400 points if the revenue is low and 1200 points if the revenue is high. The other player will receive 2000 points.

When you believe you have answered all questions correctly, press next to check your answers.

Next

Figure 43: Quiz for the second-price equity treatment.

Quiz

You will now be given a series of questions to check your understanding of the instructions and examples. You will be paid $1.00 for each answer you get correct.

How is the auction winner decided?

- ○ The seller chooses the winner
- ○ The computer randomly chooses the winner
- ○ The highest equity bid always wins
- ○ The highest debt bid always wins

Which of the following best describes a winning EQUITY bid?

- ○ The first 30% of the revenue earned (either 1800 or 600 points) goes to the seller, the rest is kept by the buyer
- ○ The first 1800 points of the revenue earned goes to the seller, the rest is kept by the buyer

Which of the following best describes a winning DEBT bid?

- ○ The first 30% of the revenue earned (either 1800 or 600 points) goes to the seller, the rest is kept by the buyer
- ○ The first 1800 points of the revenue earned goes to the seller, the rest is kept by the buyer

Are the chances of earning the high revenue the same for both bidders?

- ○ Yes
- ○ No

Does the seller know the chances of bidders earning the high revenue?

- ○ Yes
- ○ No

What happens for the bidder that loses the auction?

- ○ They keep their endowment of 2000 points, this becomes their payoff
- ○ They lose their endowment of 2000 points, and receive no payoff
- ○ They receive the same payoff as the seller
- ○ They receive the same payoff as the winner

Example A: An equity bid of 25% wins the auction. What are the winning bidder's payoffs in the high (6000) and low (2000) revenue states?

- ○ High = 1500 and Low = 500
- ○ High = 4500 and Low = 1500
- ○ High = 6000 and Low = 2000
- ○ High = 3000 and Low = 1000

Example A: An equity bid of 25% wins the auction. What are the seller's payoffs in the high (6000) and low (2000) revenue states?

- ○ High = 1500 and Low = 500
- ○ High = 4500 and Low = 1500
- ○ High = 6000 and Low = 2000
- ○ High = 3000 and Low = 1000

Example B: A debt bid of 500 points wins the auction. What are the winning bidder's payoffs in the high (6000) and low (2000) revenue states?

- ○ High = 500 and Low = 500

Figure 44: Quiz for the informal treatment.

○ High = 5500 and Low = 1500

○ High = 6000 and Low = 2000

○ High = 3000 and Low = 1000

Example B: A debt bid of 500 points wins the auction. What are the seller's payoffs in the high (6000) and low (2000) revenue states?

○ High = 500 and Low = 500

○ High = 5500 and Low = 1500

○ High = 6000 and Low = 2000

○ High = 3000 and Low = 1000

When you believe you have answered all questions correctly, press next to check your answers.

Next

Figure 45: Quiz for the informal treatment.

Quiz Answers

The answers for the quiz are given below. Please review the answers and note any mistakes you have made.

Question 1: How is the auction winner decided?
Correct Answer: The computer randomly chooses the winner from the highest bidders.
Your Answer: The computer randomly chooses the winner from the highest bidders.

Question 2: What will each player know about the chance of high revenue?
Correct Answer: Each player only knows their own chance.
Your Answer: Each player only knows their own chance.

Question 3: How will the auction's price be set?
Correct Answer: The price is equal to the highest bid.
Your Answer: The price is equal to the highest bid.

Question 4: How is the price used when computing payoffs?
Correct Answer: The auction's winner pays either the price or their revenue, whichever is smaller.
Your Answer: The auction's winner receives either the price or their revenue, whichever is smaller.

Question 5: Suppose that the other player bids 1000 points and you bid 500 points. How many points will each player receive?
Correct Answer: You will receive 2000 points. The other player will receive 1000 points if the revenue is low and 5000 points if the revenue is high.
Your Answer: You will receive 2000 points. The other player will receive 1500 points if the revenue is low and 5500 points if the revenue is high.

Question 6: Suppose that the other player bids 1000 points and you bid 5500 points. How many points will each player receive?
Correct Answer: You will receive 0 points if the revenue is low and 500 points if the revenue is high. The other player will receive 2000 points.
Your Answer: You will receive 2000 points. The other player will receive 1000 points if the revenue is low and 5000 points if the revenue is high.

Question 7: Suppose that the other player bids 4500 points and you bid 500 points. How many points will each player receive?
Correct Answer: You will receive 2000 points. The other player will receive 0 points if the revenue is low and 1500 points if the revenue is high.
Your Answer: You will receive 0 points if the revenue is low and 1500 points if the revenue is high. The other player will receive 2000 points.

Question 8: Suppose that the other player bids 4500 and you bid 5500 points. How many points will each player receive?
Correct Answer: You will receive 0 points if the revenue is low and 500 points if the revenue is high. The other player will receive 2000 points.
Your Answer: You will receive 2000 points. The other player will receive 0 points if the revenue is low and 1500 points if the revenue is high.

You earned $6.0 from your correct answers. Please review any questions you answered incorrectly. When you are ready to begin the auction, click the next button.

Next

Figure 46: Quiz answers for the first-price debt treatment.

Quiz Answers

The answers for the quiz are given below. Please review the answers and note any mistakes you have made.

Question 1: How is the auction winner decided?
Correct Answer: The computer randomly chooses the winner from the highest bidders.
Your Answer: The computer randomly chooses the winner from the highest bidders.

Question 2: What will each player know about the chance of high revenue?
Correct Answer: Each player only knows their own chance.
Your Answer: Each player only knows their own chance.

Question 3: How will the auction's price be set?
Correct Answer: The price is equal to the highest bid.
Your Answer: The price is equal to the second highest bid.

Question 4: How is the price used when computing payoffs?
Correct Answer: The auction's winner pays a percentage of their revenue equal to the price.
Your Answer: The auction's loser pays a percentage of their revenue equal to the price

Question 5: Suppose that the other player bids 20% and you bid 10%. How many points will each player receive?
Correct Answer: You will receive 2000 points. The other player will receive 1600 points if the revenue is low and 4800 points if the revenue is high.
Your Answer: You will receive 2000 points. The other player will receive 1600 points if the revenue is low and 4800 points if the revenue is high.

Question 6: Suppose that the other player bids 20% and you bid 80%. How many points will each player receive?
Correct Answer: You will receive 400 points if the revenue is low and 1200 points if the revenue is high. The other player will receive 2000 points.
Your Answer: You will receive 400 points if the revenue is low and 1200 points if the revenue is high. The other player will receive 2000 points.

Question 7: Suppose that the other player bids 70% and you bid 10%. How many points will each player receive?
Correct Answer: You will receive 2000 points. The other player will receive 600 points if the revenue is low and 1800 points if the revenue is high.
Your Answer: You will receive 2000 points. The other player will receive 600 points if the revenue is low and 1800 points if the revenue is high.

Question 8: Suppose that the other player bids 70% and you bid 80%. How many points will each player receive?
Correct Answer: You will receive 400 points if the revenue is low and 1200 points if the revenue is high. The other player will receive 2000 points.
Your Answer: You will receive 2000 points. The other player will receive 600 points if the revenue is low and 1800 points if the revenue is high.

You earned $10.0 from your correct answers. Please review any questions you answered incorrectly. When you are ready to begin the auction, click the next button.

Next

Figure 47: Quiz answers for the first-price equity treatment.

Quiz Answers

The answers for the quiz are given below. Please review the answers and note any mistakes you have made.

Question 1: How is the auction winner decided?
Correct Answer: The computer randomly chooses the winner from the highest bidders.
Your Answer: The computer randomly chooses the winner from the highest bidders.

Question 2: What will each player know about the chance of high revenue?
Correct Answer: Each player only knows their own chance.
Your Answer: Each player knows their chance and learns the other player's chance after the auction.

Question 3: How will the auction's price be set?
Correct Answer: The price is equal to the second highest bid.
Your Answer: The price is equal to the second highest bid.

Question 4: How is the price used when computing payoffs?
Correct Answer: The auction's winner pays either the price or their revenue, whichever is smaller.
Your Answer: The auction's winner receives either the price or their revenue, whichever is smaller.

Question 5: Suppose that the other player bids 1000 points and you bid 500 points. How many points will each player receive?
Correct Answer: You will receive 2000 points. The other player will receive 1500 points if the revenue is low and 5500 points if the revenue is high.
Your Answer: You will receive 2000 points. The other player will receive 1500 points if the revenue is low and 5500 points if the revenue is high.

Question 6: Suppose that the other player bids 1000 points and you bid 5500 points. How many points will each player receive?
Correct Answer: You will receive 1000 points if the revenue is low and 5000 points if the revenue is high. The other player will receive 2000 points.
Your Answer: You will receive 2000 points. The other player will receive 0 points if the revenue is low and 500 points if the revenue is high.

Question 7: Suppose that the other player bids 4500 points and you bid 500 points. How many points will each player receive?
Correct Answer: You will receive 2000 points. The other player will receive 1500 points if the revenue is low and 5500 points if the revenue is high.
Your Answer: You will receive 2000 points. The other player will receive 1500 points if the revenue is low and 5500 points if the revenue is high.

Question 8: Suppose that the other player bids 4500 and you bid 5500 points. How many points will each player receive?
Correct Answer: You will receive 0 points if the revenue is low and 1500 points if the revenue is high. The other player will receive 2000 points.
Your Answer: You will receive 2000 points. The other player will receive 0 points if the revenue is low and 500 points if the revenue is high.

You earned $8.0 from your correct answers. Please review any questions you answered incorrectly. When you are ready to begin the auction, click the next button.

Next

Figure 48: Quiz answers for the second-price debt treatment.

Quiz Answers

The answers for the quiz are given below. Please review the answers and note any mistakes you have made.

Question 1: How is the auction winner decided?
Correct Answer: The computer randomly chooses the winner from the highest bidders.
Your Answer: The computer randomly chooses the winner from the highest bidders.

Question 2: What will each player know about the chance of high revenue?
Correct Answer: Each player only knows their own chance.
Your Answer: Each player only knows their own chance.

Question 3: How will the auction's price be set?
Correct Answer: The price is equal to the second highest bid.
Your Answer: The price is equal to the highest bid.

Question 4: How is the price used when computing payoffs?
Correct Answer: The auction's winner pays a percentage of their revenue equal to the price.
Your Answer: The auction's loser pays a percentage of their revenue equal to the price

Question 5: Suppose that the other player bids 20% and you bid 10%. How many points will each player receive?
Correct Answer: You will receive 2000 points. The other player will receive 1800 points if the revenue is low and 5400 points if the revenue is high.
Your Answer: You will receive 1600 points if the revenue is low and 4800 points if the revenue is high. The other player will receive 2000 points.

Question 6: Suppose that the other player bids 20% and you bid 80%. How many points will each player receive?
Correct Answer: You will receive 1600 points if the revenue is low and 4800 points if the revenue is high. The other player will receive 2000 points.
Your Answer: You will receive 2000 points. The other player will receive 1600 points if the revenue is low and 4800 points if the revenue is high.

Question 7: Suppose that the other player bids 70% and you bid 10%. How many points will each player receive?
Correct Answer: You will receive 2000 points. The other player will receive 1800 points if the revenue is low and 5400 points if the revenue is high.
Your Answer: You will receive 2000 points. The other player will receive 600 points if the revenue is low and 1800 points if the revenue is high.

Question 8: Suppose that the other player bids 70% and you bid 80%. How many points will each player receive?
Correct Answer: You will receive 600 points if the revenue is low and 1800 points if the revenue is high. The other player will receive 2000 points.
Your Answer: You will receive 400 points if the revenue is low and 1200 points if the revenue is high. The other player will receive 2000 points.

You earned $4.0 from your correct answers. Please review any questions you answered incorrectly. When you are ready to begin the auction, click the next button.

Next

Figure 49: Quiz answers for the second-price equity treatment.

Quiz Answers

The answers for the quiz are given below. Please review the answers and note any mistakes you have made.

Question 1: How is the auction winner decided?
Correct Answer: The seller chooses the winner.
Your Answer: The seller chooses the winner.

Question 2: Which of the following best describes a winning EQUITY bid?
Correct Answer: The first 30% of the revenue earned (either 1800 or 600 points) goes to the seller, the rest is kept by the buyer.
Your Answer: The first 30% of the revenue earned (either 1800 or 600 points) goes to the seller, the rest is kept by the buyer.

Question 3: Which of the following best describes a winning DEBT bid?
Correct Answer: The first 1800 points of the revenue earned goes to the seller, the rest is kept by the buyer
Your Answer: The first 30% of the revenue earned (either 1800 or 600 points) goes to the seller, the rest is kept by the buyer.

Question 4: Are the chances of earning the high revenue the same for both bidders?
Correct Answer: No.
Your Answer: Yes.

Question 5: Does the seller know the chances of bidders earning the high revenue?
Correct Answer: No.
Your Answer: Yes.

Question 6: "What happens for the bidder that loses the auction?
Correct Answer: They keep their endowment of 2000 points, this becomes their payoff.
Your Answer: They keep their endowment of 2000 points, this becomes their payoff.

Question 7: Example A: An equity bid of 25% wins the auction. What are the winning bidder's payoffs in the high (6000) and low (2000) revenue states?
Correct Answer: High = 4500 and Low = 1500
Your Answer: High = 1500 and Low = 500.

Question 8: Example A: An equity bid of 25% wins the auction. What are the seller's payoffs in the high (6000) and low (2000) revenue states?
Correct Answer: High = 1500 and Low = 500
Your Answer: High = 1500 and Low = 500.

Question 9: Example B: A debt bid of 500 points wins the auction. What are the winning bidder's payoffs in the high (6000) and low (2000) revenue states?
Correct Answer: High = 5500 and Low = 1500
Your Answer: High = 500 and Low = 500.

Question 10: Example B: A debt bid of 500 points wins the auction. What are the seller's payoffs in the high (6000) and low (2000) revenue states?
Correct Answer: High = 500 and Low = 500
Your Answer: High = 500 and Low = 500.

You answered 5 questions correctly, and received $5.0.
Please review any questions you answered incorrectly. When you are ready to begin the auction, click the next button.

Next

Figure 50: Quiz answers for the informal treatment.

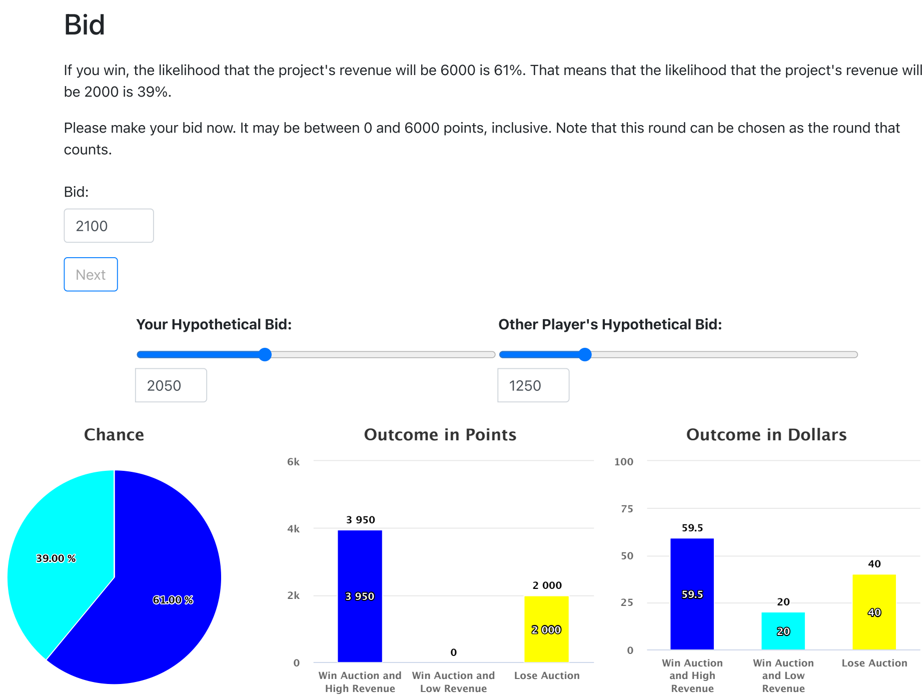


Figure 51: Bidding page for the first-price debt treatment.

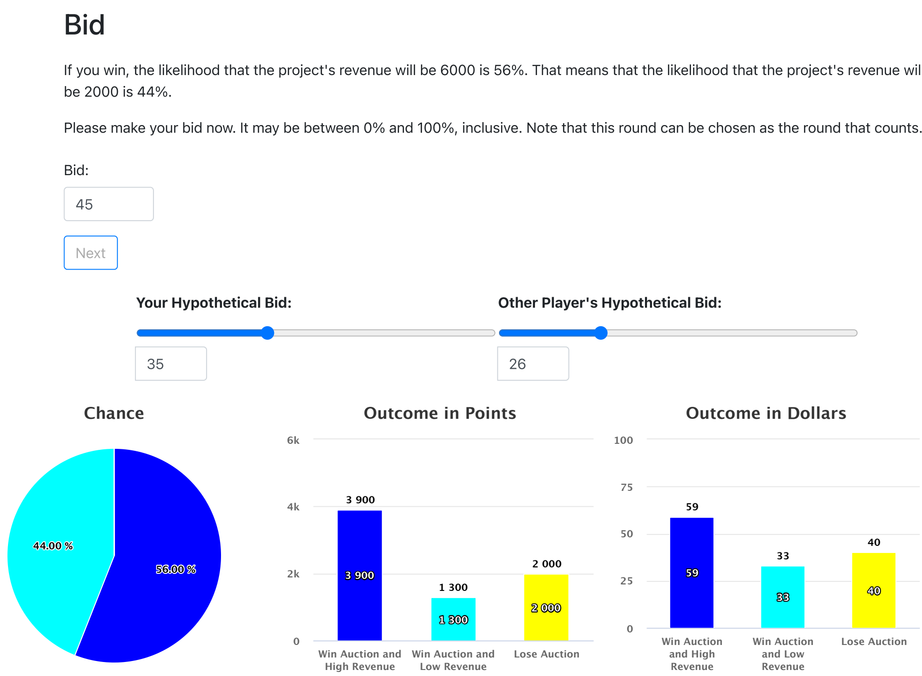


Figure 52: Bidding page for the first-price equity treatment.

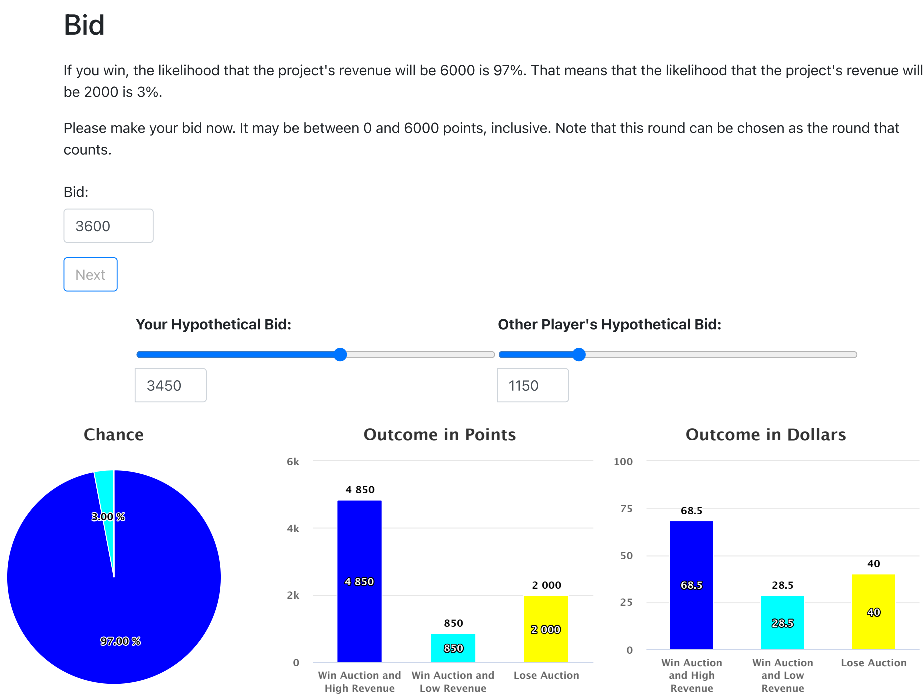


Figure 53: Bidding page for the second-price debt treatment.

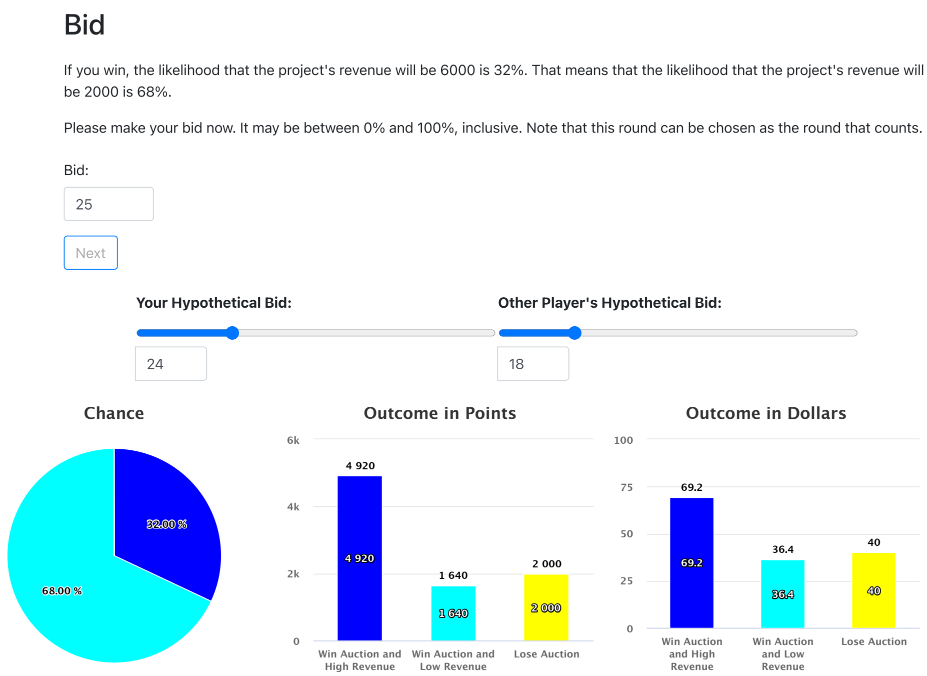


Figure 54: Bidding page for the second-price equity treatment.

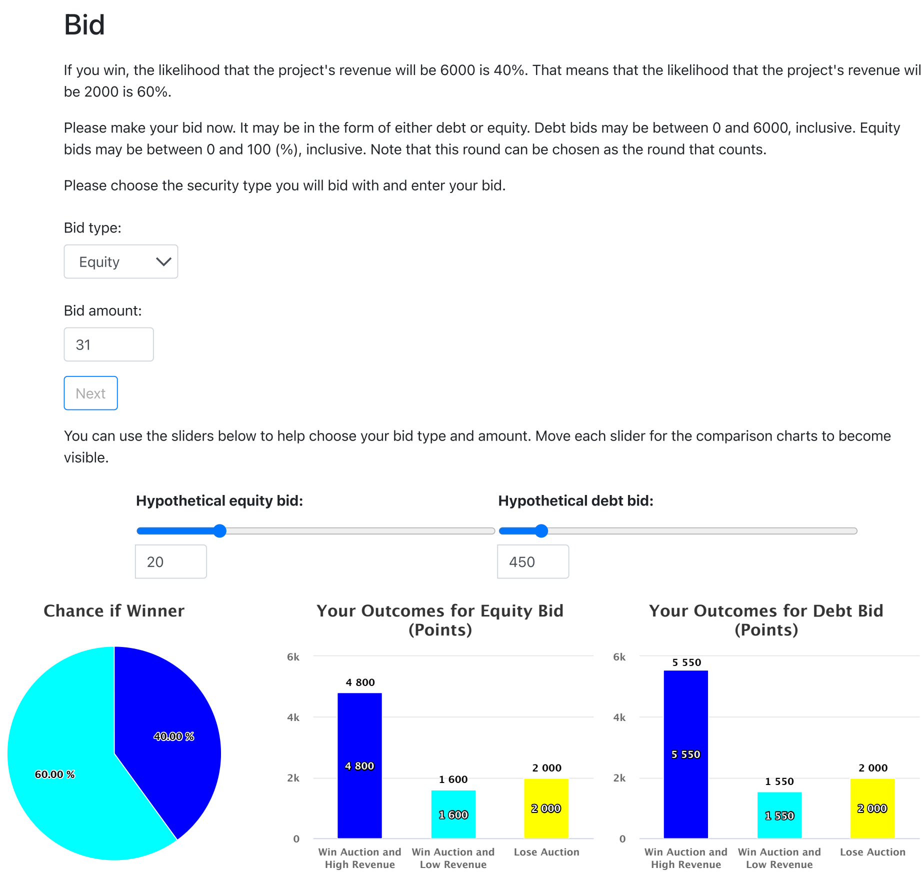


Figure 55: Bidding page for the informal treatment.

Choose

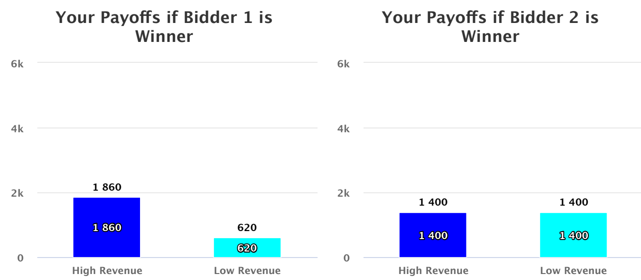
The bidders in this auction have made the following bids. Please review the bids and choose the winner of the auction.

Bidder	Bid Type	Bid
1	Equity	31
2	Debt	1400

The payoffs you will receive if you select Bidder 1 or Bidder 2 as the winner are shown in the diagrams below.

Important: You do not know the chance of receiving the different payoffs.

Important: The chances of receiving the high and low payoff may be different for each bidder.



Please choose which bidder is the winner of the auction. Note that this round may be chosen as the round that counts.

Win choice:

1

Figure 56: Seller choice page for the informal treatment.

Results

You won the auction! Your bid was 2100 points while the second highest bid was 400 points. That means that if this round is chosen for payment, you will have a 61% chance of receiving 3900 points and a 39% chance of receiving 0 points. The other player will receive 2000 points.

Next

Figure 57: Winning result page for the first-price debt treatment.

Results

You won the auction! Your bid was 45% while the second highest bid was 13%. That means that if this round is chosen for payment, you will have a 56% chance of receiving 3300 points and a 44% chance of receiving 1100 points. The other player will receive 2000 points.

Next

Figure 58: Winning result page for the first-price equity treatment.

Results

You won the auction! Your bid was 3600 points while the second highest bid was 2100 points. That means that if this round is chosen for payment, you will have a 97% chance of receiving 3900 points and a 3% chance of receiving 0 points. The other player will receive 2000 points.

Next

Figure 59: Winning result page for the second-price debt treatment.

Results

You won the auction! Your bid was 25% while the second highest bid was 11%. That means that if this round is chosen for payment, you will have a 32% chance of receiving 5340 points and a 68% chance of receiving 1780 points. The other player will receive 2000 points.

Next

Figure 60: Winning result page for the second-price equity treatment.

Results

You won the auction! You made an Equity bid of 31 %. Your opponent made a Debt bid of 1400 points.
That means that if this round is chosen for payment, you will have a 40% chance of receiving 4140.0 points and a 60% chance of receiving 1380.0 points. Your opponent will receive 2000 points for losing the auction.

Next

Figure 61: Winning result page for the informal treatment.

Results

You did not win the auction. Your bid was 400 points while the winning bid was 2100 points. That means that if this round is chosen for payment, you will receive 2000 points. The other player will receive either 3900 or 0 points.

Next

Figure 62: Losing result page for the first-price debt treatment.

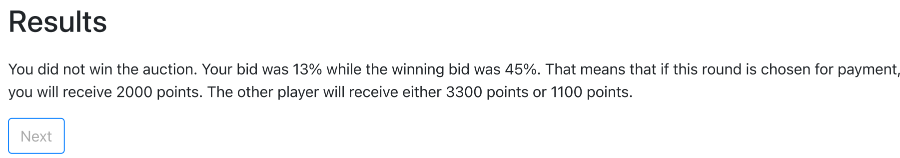


Figure 63: Losing result page for the first-price equity treatment.

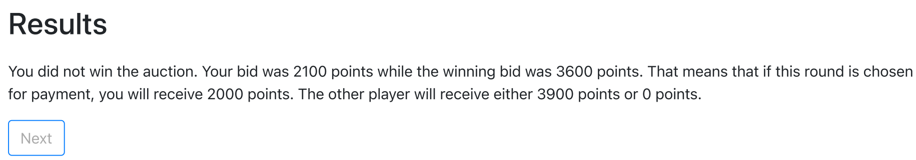


Figure 64: Losing result page for the second-price debt treatment.

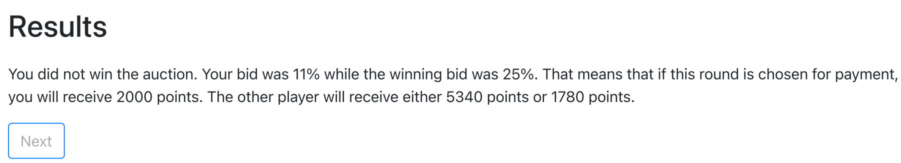


Figure 65: Losing result page for the second-price equity treatment.

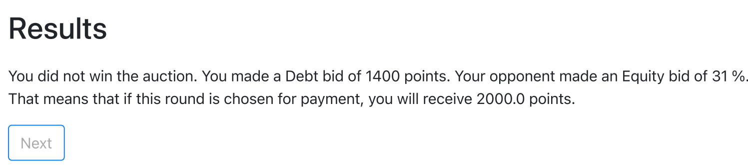


Figure 66: Losing result page for the informal treatment.

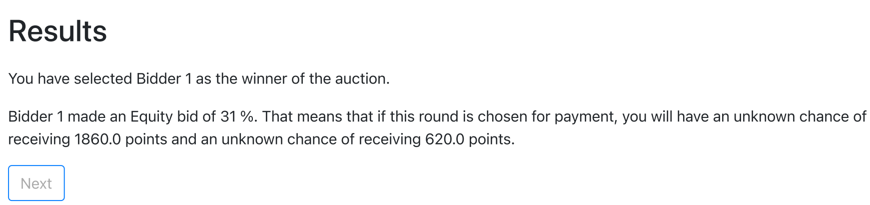


Figure 67: Seller result page for the informal treatment.

Instructions

PLEASE READ CAREFULLY AND DO NOT PRESS NEXT UNTIL INSTRUCTED TO DO SO.

In this part of the experiment, you will complete 10 rounds of an individual choice task. Every task has an interactive visual aid to assist with picking your preferred choice. In this part of the study, your payoffs will depend only on your choices, and not any other participants' choices.

In every task, you must choose among different options. Your choice will determine a monetary prize and its chance. All of your choices will involve some chance of a monetary prize, otherwise you will get the show-up fee of $20. As you move the slider to the right, the monetary prize will decrease but the chance you will receive the prize will increase. For each task you will have to determine your preferred combination of a positive prize and its chance. The size of the potential outcomes and how their chance changes with the slider will be different for different tasks.

Most choices involve some risk. For example, a choice could be between a 25 in 100 chance of 3000 points, and the corresponding 75 in 100 chance of 0 points. To aid with your choice, there will be a changing display for every possible choice. Therefore, for any choice you will always be able to see the chance of receiving a positive amount.

The next page contains an example to familiarize you with how this works. Take your time and make sure you understand how it works. We will not begin until everybody completes this example.

Very Important: For each task, the slider is a tool to help you decide the choice you like the best. Therefore, it is in your best interest to move it around to help you determine which choice you like better.

Next

Figure 68: Instructions for the Andreoni-Harbaugh task in all treatments.

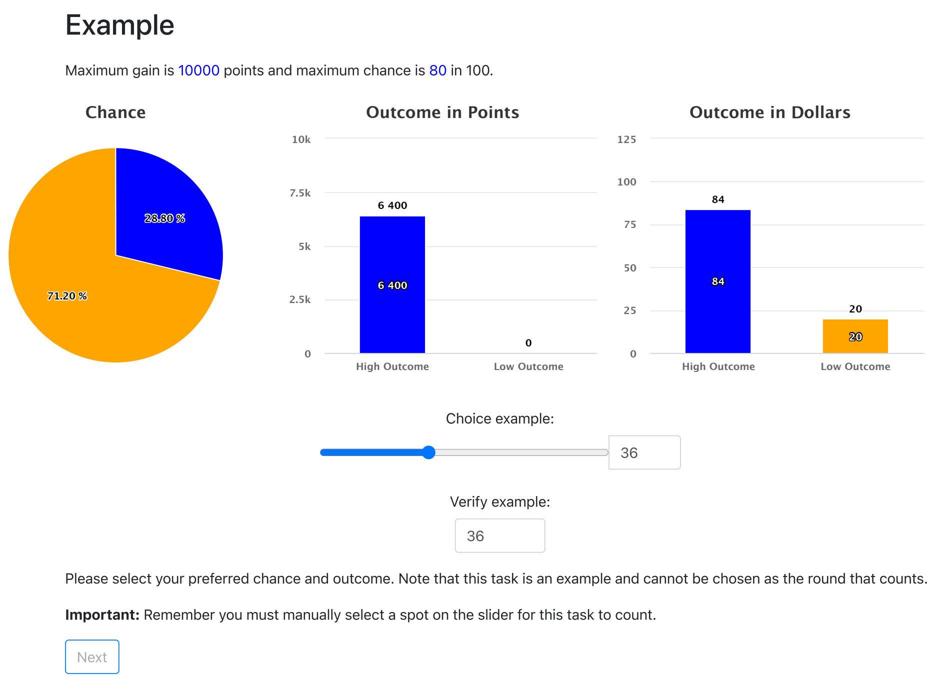


Figure 69: Examples for the Andreoni-Harbaugh task in all treatments.

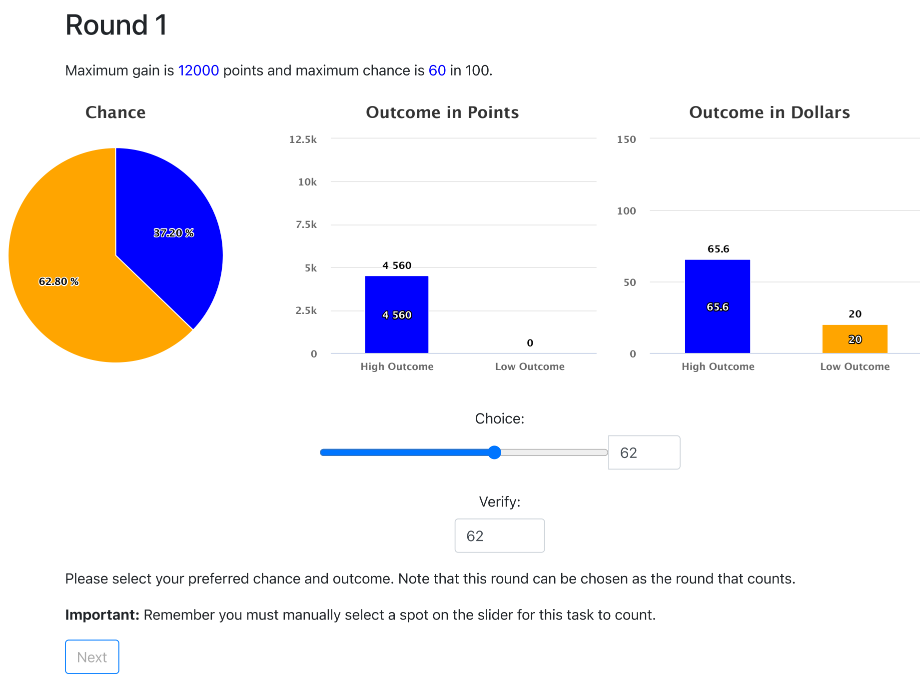


Figure 70: Round 1 of the Andreoni-Harbaugh task in all treatments.