Trade Contingencies in Procurement Interactions*

Matthew J. Walker†

December 10, 2020

[JOB MARKET PAPER]

[LATEST VERSION HERE]

Abstract

It is difficult to write a perfect contract. Contracts are often incomplete and parties to a contract may understand their obligations differently. When these differences are important, disputes over buyer and seller non-performance arise. This paper addresses the problem of seller moral hazard in procurement which arises when the contract price cannot be conditioned on outcomes. I develop a flexible price contract structure that contains an arbitration clause and embed this structure into a procurement interaction, where the contract price bounds are determined via a competitive bidding process. The theoretical results suggest that there exists a contingent contract, defined by the degree of price flexibility and probability of arbitration, for which trade is efficient. This contract relies only on the regard of each party to their own interest. I test the predictions of the model in a laboratory experiment and find support for several comparative statics in the data. Under the shadow of arbitration, bidding is more aggressive and high quality is the more profitable seller strategy. However, the arbitrator also crowds out buyer reciprocity and so a contingent contract does not increase trade efficiency relative to a contract that contains only implicit incentives. The findings have managerial implications for the establishment of trust and procurement efficiencies driven by competition.

Keywords: Procurement Auction, Contingent Contract, Arbitration, Moral Hazard, Fairness

JEL classifications: D44, D86, J52, C92

---

* This paper would not have been possible without the guidance and support of my advisor, Jason Shachat, to whom I am very grateful. I thank Daniel Zizzo, Kenju Kamei and Kyle Hyndman for invaluable feedback on earlier drafts. I also thank Timo Heinrich, Matthew Embrey, participants of the ESA 2020 Global Conference and the SABE 2020 Annual Conference for helpful discussions. Funding from the Economic and Social Research Council Award No. ES/R500963/1 is gratefully acknowledged.

† Durham University Business School, Millhill Ln, Durham DH1 3LB; email: matthew.j.walker@durham.ac.uk.

1. Introduction

It is difficult to write a perfect contract. Contracts are often incomplete, and the contract price must be flexible to adjust to unforeseen contingencies during trade. Therefore, procuring relation-specific (or "non-standardized") goods poses contractual challenges. Parties to the contract may understand their performance obligations differently, leading to liability risks and moral hazard issues. When these differences are important, disputes over non-performance arise. A common source of payment adjustments in the construction industry, for example, are deductions (see Bajari et al. 2014). Deductions reduce the seller's final compensation. The buyer may deduct liquidated damages in response to seller negligence, which the seller may dispute. The value of such contractual disputes can be large. A global industry report estimated the average value of construction disputes in 2019 at US $30.7 million (Arcadis 2020).

In this paper, I propose a contractual solution to the problem of seller non-performance in procurement, by developing a flexible price structure that contains an arbitration clause. This structure is a type of contingent contract, in which the contingency is the arbitrator's decision.[1] It is robust in that it relies only on the regard of each party to their own interest. Thus, it aligns incentives for responsible contractual behaviour when the contract price cannot be conditioned on outcomes and does not rely on other-regarding motives for its effectiveness.[2]

Arbitration is an alternative, and frequently less costly, dispute resolution method to litigation. The arbitrator is an independent third party, with the power to impose binding payment adjudication. Their role is "to remember who sunk costs in the past, and to ensure that future compensation is paid in a way that creates the *correct* incentives to make such investments" (Crawford 1985, p. 375).[3] Traditionally, the economics literature has examined the distributional implications of arbitration, under the assumption of a fixed surplus to divide (e.g. Farber and Katz 1979, Farber 1980, Crawford 1981, Ashenfelter and Bloom 1984). Gabuthy and Muthoo (2019) drop the fixed surplus assumption and show in a non-competitive environment that the mere presence of an arbitrator can improve the incentives of bilateral trade parties to make mutual relationship-specific investments.

---

[1] See Bazerman and Gillespie (1999).
[2] The importance of responsible contractual behaviour has gained renewed attention in the wake of the Covid-19 pandemic. The UK government has recently released specific guidance on this issue: "Responsible and fair behaviour in contracts now – in particular in dealing with potential disputes – will result in better long-term outcomes for jobs and our economy" (see https://tinyurl.com/y8f2vb4p).
fairly, support the response to Covid-19 and protect jobs and the economy"
[3] Arbitration finds varied applications for resolving disputes. Perhaps the most well-known is for the settlement of wage disputes in labour bargaining. Mandatory consumer arbitration clauses are also prevalent. For example, as of 2020, the eBay user agreement contains a requirement to submit dispute claims, e.g. due to an unpaid auction bid, to binding and final arbitration.

This paper considers the efficiency consequences of an exogenous arbitration mechanism in a quite different environment. Specifically, buyer seeks to procure a seller to deliver a contract via competitive bid process. After allocation of the contract, the seller receives some pre-agreed proportion of the winning bid up front and takes costly actions, before final payments – after compensation adjustments – are made. Where disputes arise on buyer or seller non-performance, an arbitrator is invoked to provide binding resolution, through a pre-agreed clause written into the contract. The arbitrator must *ex-post* verify the claims and adjudicate on how best to compensate the trade parties. Such arrangements are common in construction and engineering projects.[4] Standard building contracts in the UK are produced by the Joint Contracts Tribunal, which provides model rules for the resolution of payment disputes by arbitration. Until 2007, arbitration was the preferred dispute resolution method in standard US construction contracts by default, while construction case filings at the American Arbitration Association continue to increase, up six percent in 2019, with complex new cases rising at twice this rate. [5]

The starting point for the model developed here is a first-price procurement auction. This is the dominant bidding mechanism in procurement – second-price mechanisms are rarely used (Engelbrecht-Wiggans et al. 2007). At date 0, potential sellers each submit a sealed bid to deliver a relation-specific product to the buyer. The seller submitting the lowest bid wins the auction. In a departure from standard auction setups, the winning bid determines the bounds of the contract price range, as opposed to the final trading price. The degree of price flexibility is a known and exogeneous parameter in the contract. If the buyer finds the outcome of the auction acceptable, a bilateral trade relationship forms and the parties to the contract proceed to date 1. At this date, the seller determines the product quality level, high or low. High quality is more costly for the seller to deliver but generates greater value for the buyer. After observing her value from trade, the buyer has discretion to propose a final price out of the agreed contract price range.

The main theoretical contribution of this paper is to introduce a contingency into the contracting environment, via a pre-specified arbitration clause. If the buyer's proposed final price is below some reference notion of a fair outcome, then the seller has the option to dispute the final price and call upon an arbitrator to adjudicate. No restriction is placed on what the arbitrator deems a fair settlement: the arbitrator's preferences are a known function of the trade surplus. This mirrors the arbitrator's role in real-world dispute resolution. The arbitrator is not always available to intervene; the probabilistic nature of the arbitrator reflects the reality that arbitration is not feasible in every trading scenario.

---

[4] Unlike litigation, there is generally no public record of arbitration proceedings.

[5] Since 2007, US construction contracts require trade parties to check a box specifying the preferred dispute resolution method (e.g. Document A101-2017 at https://www.aiacontracts.org/). The US case filings statistic is obtained from American Arbitration Association Annual Report at https://www.adr.org/annual-reports. Standard UK building contracts are obtained from https://www.jctltd.co.uk/.

The equilibrium analysis suggests that, in the absence of an arbitration clause, procurement in the baseline contracting environment is inefficient (i.e., low quality, see also Fugger et al. 2019). I show that there exists a contingent contract, defined by the combination of price flexibility and probability of arbitration, for which efficient (i.e., high quality) procurement is the unique equilibrium outcome. The intuition for this result is that the arbitrator changes the potential sellers' marginal bidding incentives: at a threshold bid level, a potential seller prefers to deliver high quality over low quality because he expects to be rewarded sufficiently by the arbitrator in relation to the associated delivery costs. The outcome is first-best in the absence of direct arbitration costs and is associated with more aggressive auction bids. A striking implication of the model is that the contingent contract benefits the buyer, but not the seller, in equilibrium. This is due to the competitive nature of bidding amongst potential sellers, who compete away their rents. Arbitration thereby serves an efficiency function but *not* a fairness function.

I test the predictions of the model using a laboratory experiment. The lab has found long-standing use as a test-bed for more general arbitration mechanisms, because it enables control over factors such as the arbitrator's preferences, costs, and valuations (e.g. Ashenfelter et al. 1992, Bolton and Katok 1998, Pecorino and Van Boening 2001, Deck and Farmer 2007, Deck et al. 2007, Gabuthy et al. 2008). These factors are unobserved in naturally occurring settings. To my knowledge, no prior experiment has analysed the effect of an arbitration mechanism in a procurement context, nor with relationship-specific investments.

The experimental data supports the robustness of the contingent contract in mitigating seller non-performance. In the shadow of arbitration, bidding is more aggressive and high quality is the more profitable seller strategy. Buyers earn significantly more than sellers, although more data is required to inform on whether a contingent contract can – in contrast to the theory – improve the seller's position. A contingent contract does not, however, significantly increase trade efficiency relative to the baseline contracting environment. This is because the arbitrator crowds out buyer reciprocity. Thus, this paper further contributes to a literature in experimental economics recognising the potential for explicit incentives to be counterproductive (for an early survey, see Fehr and Gächter 2000). A secondary experimental finding is that a significant fraction of buyers display reference-dependent fairness preferences (e.g. Kőszegi and Rabin 2006).

The paper continues in Section 2 with a discussion of related studies on incomplete contracting and procurement auctions with renegotiation. Section 3 outlines the model and equilibrium predictions, with and without a contingent contract. Section 4 describes the experiment and hypotheses to be tested. Section 5 summarizes the main experiment findings and presents a formal analysis of behaviour at the aggregate and individual levels. Section 6 concludes with a consideration of external validity of the model and empirics.

2. Related Literature

This study is related to an established economics literature on incomplete contracting in procurement. In a seminal contribution, Tirole (1986) discusses the implications of contract design for non-contractible relation-specific investments in a bilateral buyer-seller relationship. Relatively few papers address the issue of a buyer's inability to commit not to renegotiate in competitive procurement settings.[6] Waehrer (1995) permits sellers to renege on their auction bids after cost uncertainty is resolved. Anticipating this opportunity, bidding competition is more intense. Wang (2000) and Shachat and Tan (2015) also consider forms of renegotiation after a price-based procurement auction. A feature shared by these studies and the model presented here is that the auction institution allocates the contract but the initial price is non-binding.

Herweg and Schwarz (2018) consider the effects of renegotiation due to a contingency not specified in the initial procurement contract (cost overruns). Suppliers are endowed with a private cost type, which is observed by the buyer after the auction and before contract renegotiation. The buyer can specify one of two designs during the initial contracting stage, which differ according to their complexity. The cost advantage of the efficient supplier type is increasing in the design complexity and the generalized Nash bargaining solution implies that the buyer should minimise this cost differential by specifying the less complex design up front. The final price is higher if either the cost of the more complex design is higher for the winning supplier, or if the winning supplier is endowed with enough bargaining power. Since the low cost type always wins the auction, the outcome is efficient. Their finding of higher prices after auction renegotiation is consistent with Chang et al. (2016), who outline a model in which there is a common unknown cost component and suppliers are differentiated by wealth constraints. The ability to renegotiate favours those suppliers who can credibly threaten to default.

Consideration of unforeseen procurement contingencies is taken up by Herweg and Schmidt (2020). Using a mechanism design approach, they show that a two-stage auction process relying on an independent arbitrator to *ex-post* verify the payoff consequences of unforeseen events can implement an efficient procurement outcome, even when the set of all possible events is unknown. This stands in contrast to the usual assumption in the mechanism design literature that all model parameters are common knowledge when implementing an allocation *ex ante*. The assumption of *ex-post* verifiability enables the arbitrator to complete the mechanism by separating the problems of inducing truthful reporting of design flaws and truthful reporting of production costs. As in the present paper, this assumption is motivated by the established role that arbitrators have in real-world dispute resolution of complex goods.

[6] Che (1993) and Chen-Ritzo et al. (2005) consider the performance of procurement auctions with perfect commitment. Renegotiation may also arise for informational purposes (Onderstal and Yang 2020).

Procurement auctions with seller moral hazard have received attention in the behavioural operations literature (for an overview, see Elmaghraby and Katok 2018). Earlier studies focused on fixed-price contracts in which quality cannot be conditioned on price. These studies show that the moral hazard problem can be overcome via reputation (Brosig-Koch and Heinrich 2014) or an auction in which the buyer is not constrained to choose the lowest bidder (Fugger et al. 2019). An alternative solution to the seller moral hazard problem is suggested by Walker et al. (2020), who introduce the idea of retainage incentives – a fixed proportion of the winning auction bid withheld by the buyer from the seller until product delivery. Using lab experiments, they observe that retainage can mitigate the seller moral hazard problem in procurement auctions. This finding is explained using a model of payment norms, in which a known fraction of buyers in the population are trustworthy and engage in gift exchange behaviour. By restricting the bid space, they also show that arrangements in which the retainage level is set too high can lead sellers not to participate in the contracting process. The present paper builds on these studies, by incorporating a contingency into the contracting environment.

Finally, there are some similarities between the baseline contracting environment considered here and the more general contract-theoretic environment outlined in Hart and Moore (2008). First, the initial contract price range is determined under ex-ante competitive conditions. Second, *ex post* trade may be inefficient. Specifically, while it is possible to enforce a minimum contractual performance by both parties (delivery of low quality and payment of the lower bound contract price), it is not possible to enforce anything more than this (delivery of high quality or payment of a price above the lower bound). This contrasts with earlier incomplete contracting literature (e.g. Hart and Moore 1990) in which trade parties were always able to renegotiate to an efficient outcome. An important difference between the two environments lies in the seller's performance incentive. In Hart and Moore's (2008) setting, high quality may be no more costly for the seller to deliver than low quality, while the buyer does not have the option to withhold part of payment until after the transaction is complete. The baseline environment considered here is therefore closer in nature to the gift-exchange literature: the seller has implicit – but no explicit – incentive to take the efficiency-enhancing action in the absence of arbitration (e.g. Fehr et al. 1993, Brown et al. 2004, Fehr et al. 2007).[7]

3. Model and Theory

3.1 Baseline environment

I first outline the baseline contracting environment with no arbitration clause (a non-contingent contract). A single buyer seeks to purchase one unit of an indivisible product from a

---

[7]

pool of N potential sellers, indexed by i. Thus, sellers compete to deliver the unit. At date 0, the buyer can choose to purchase from the potential seller submitting the lowest priced (winning) bid or reject the opportunity to trade. A decision to purchase signals the beginning of a bilateral relationship with the winning potential seller (henceforth the seller). In that case, at date 1 the product quality is determined by the seller and the winning bid is renegotiable, before payoffs are realized. The buyer's payoff equals her valuation for the product v minus the final trading price p. The seller's payoff is given by the difference between the final price p and his delivery cost c. The seller's quality choice q maps directly to the valuation and cost schedules, which are common knowledge. The cost schedule is the same across potential sellers and so they are *ex-ante* homogeneous. Price cannot be conditioned on quality at date 0 but actions can be (costly) verified by third parties at date 1. *Ex-post* verifiability is not unrealistic: third-party arbitrators must be able to verify work to settle real-world disputes (Herweg and Schmidt 2020).

The payoffs of the buyer and seller are summarised as follows,

$$\pi_B = v(q) - p. \tag{1}$$

$$\pi_S = p - c(q). \tag{2}$$

A potential seller that loses the contract at date 0 earns zero payoff. A buyer that rejects the opportunity to purchase at date 0 ends the interaction with zero payoff to all agents.

If trade occurs, then at date 1 the seller can choose to deliver either low product quality ($q = q^L$) or high product quality ($q = q^H$). By discretizing the quality space, I simplify the analysis and restrict attention to contractual performance at the extensive margin. A seller's cost of delivering high quality is strictly greater than his cost of low quality, $c(q^H) > c(q^L)$. Trade is preferred to no trade and high quality maximises surplus, $v(q^H) - c(q^H) > v(q^L) - c(q^L) > 0$.

The seller's quality choice is taken before the final trading price p is determined, but after the *range* of contract prices is determined. The contract price range is given by the interval $[\underline{p}, \overline{p}]$. The upper bound contract price is equal to the winning bid at date 0, $\overline{p} = min\{b_1, \cdots, b_N\}$. The lower bound contract price is determined by the flexibility in the procurement contract, defined by an exogenous parameter $\lambda \in (0,1)$, with $\underline{p} = (1-\lambda)\overline{p}$. I exclude the boundary case of $\lambda = 0$, which constitutes a non-renegotiable contract, and $\lambda = 1$, for which bidding is uninformative cheap talk. This specification of the price bounds is without loss of generality. The bid might just as well correspond to the lower bound contract price, with a fixed interval above, and leave the model's predictions unaffected. The important thing is that there is flexibility in the contract price.

The structure of the sequential game proceeds as follows.

Date 0: Contracting.

Stage 1. The potential sellers each submit one sealed bid b_i at a first-price procurement auction. Bids can be greater than or equal to the seller's cost of delivering low product quality. The potential seller that submits the lowest priced bid wins the auction and becomes the seller. If two or more potential sellers submit the same bid, the tie is broken randomly. The winning bid determines the contract price range. The bid profile is public information before the next stage. Any potential seller that submits a losing bid is no longer considered in the interaction.

Stage 2. The buyer observes the contract price range and takes a decision from the action set $A \in \{a^0, a^1\}$, where a^0 represents a decision to reject and a^1 to accept the opportunity to purchase from the seller. If the buyer decides to reject, the interaction ends without a trade.

Date 1: Trade

Stage 3. The seller chooses the product quality level, either low (q^L) or high (q^H) and incurs his delivery cost $c(q)$.

Stage 4. The buyer observes her value for the product and proposes a final trading price from the contract price range.[8]

The trade is completed, and payoffs are realized.

Formally, a potential seller i's strategy has two components: a bid b_i from a discrete price grid $G = \{c(q^L), c(q^L) + \Delta, \dots\}$, where Δ is a small increment, and a quality choice function $q_i(b_i | b_i = \overline{p}, a = a^1)$. The use of a discrete price grid reflects that the discrete experiment implementation influences the point prediction when there are just two bidders. A buyer's strategy also has two components: a trade decision function, $a(\overline{p})$, and a price proposal function, $y\left([\underline{p}, \overline{p}], q \,|\, a = a^1\right)$.

The game can be analysed as an extensive-form game of complete information. The solution concept is subgame perfect Nash equilibrium (SPNE) in pure strategies and we can apply backward induction. As in standard Bertrand competition models with bounded demand, complete information, fixed marginal costs and zero fixed costs, there is no mixed strategy equilibrium (see e.g. Baye and Morgan 1999). We are interested in whether there exists a price at which high product quality is implementable.

Definition 1 *(Implementability).* A quality level is implementable if it is incentive compatible (preferred to the alternative quality level) as part of an equilibrium seller strategy.

[8] The analytical results would be unchanged by switching the order of stages 3 and 4.

For the baseline contracting environment, there is a unique and inefficient SPNE in which $b_i^* = c(q^L)/(1-\lambda) + \Delta$ for all i or $b_i^* = c(q^L)/(1-\lambda)$ for at least two i; $a^* = a^1$; $q_i^* = q^L$; and $y^* = \underline{p}$.

Proof. At Stage 4, the buyer uses her payment discretion to choose the lower bound contract price, independently of the seller's chosen quality level. The seller anticipates this and at Stage 3 delivers low quality to minimise his cost. At Stage 2, the buyer will accept to purchase at any bid less than or equal to $v(q^L)/(1-\lambda)$, in anticipation of a non-negative profit. At Stage 1, if two or more potential sellers submit a bid equal to $c(q^L)/(1-\lambda)$, i.e., the cost of low quality marked up in proportion to the degree of price flexibility, then every potential seller earns zero profit. Any deviation would also yield zero profit. If all potential sellers submit a bid equal to $c(q^L)/(1-\lambda) + \Delta$, then each makes a (small) positive expected profit equal to Δ/n. Any deviation would yield zero profit; thus, no potential seller has an incentive to deviate. All surplus accrues to the buyer. ■

The first proposition follows directly.

Proposition 1. With a non-contingent contract, high quality is not an implementable procurement outcome.

Conditional on expectations about population reciprocity, social preferences can rationalise high product quality with a non-contingent, but flexible-price, contract (see Walker et al. 2020 for a model). This will serve as the benchmark against which a contingent contract is assessed in the experiment.

3.2 Arbitration

I now write a contingency into the contract, via an arbitration clause that allows the seller to rely probabilistically on a third-party arbitrator to settle any dispute over the buyer's claim on the trade surplus. An additional stage is included at date 1 as follows.

Stage 5. The seller observes the buyer's price proposal and takes a decision from the action set $D \in \{d^0, d^1\}$, where d^0 represents a decision not to dispute and d^1 a decision to dispute via arbitration.

Seller i's strategy requires a third component: a dispute function $d_i\left(\left[\underline{p}, \overline{p}\right], q_i, y \mid a = a^1\right)$. If the seller opts not to dispute, he receives the buyer's proposed trading price and the buyer and seller payoffs are captured by equations (1) and (2). If a dispute is recorded, the arbitration clause is invoked. The probability of arbitration, σ, is pre-determined. With probability $(1-\sigma)$, the arbitrator is not called upon to adjudicate the dispute and the seller still receives the buyer's price proposal. With probability σ, the arbitrator is called upon and imposes a final trading price based on the following decision rule,

$$p^A(q, y|\mu) = max\{y, z^q(\mu)\}, \tag{3}$$

where $0 < \mu < 1$ and $z^q(\mu) = min\,\{\overline{p}, \mu v(q) + (1-\mu)c(q)\}$.

The parameter μ is common knowledge to both trade parties prior to date 0 and captures the arbitrator's preference over the share of transaction surplus due to the seller. This corresponds to what the arbitrator deems to constitute a fair settlement after completion of the fact-finding process. Consistent with the arbitration literature, μ is exogenous and a function of how an unbiased arbitrator reaches a decision (see Gabuthy and Muthoo 2019). I will abstract from the possibility that μ itself might be quality-specific. Such a formulation would not qualitatively change the arguments, so long as the arbitrator's preferences are commonly known.

If $z^q(\mu)$ is greater than y, the arbitrator settles in favour of the seller and awards a final trading price which is non-decreasing in both the buyer's valuation for the product and the seller's cost incurred. Under this scenario, a fixed and non-negative cost k of arbitration is borne by the buyer. I restrict k to be less than the trade surplus, since this is the only interesting case. If $z^q(\mu)$ is less than or equal to y, the arbitrator settles in favour of the buyer and awards the seller the buyer's proposed price. The cost of arbitration is then borne by the seller.[9]

Let events A and B represent settlement in favour of the buyer and seller respectively. The expected dispute payoffs of buyer and seller are as follows,

$$d_B = v(q) - (1-\sigma)y - \sigma(p^A + \mathbf{1}_B k). \tag{4}$$

$$d_S = (1-\sigma)y + \sigma(p^A - \mathbf{1}_A k) - c(q). \tag{5}$$

Risk neutrality is assumed primarily to simplify the notation. The results of the model are qualitatively unchanged by substituting into (4) and (5) a constant relative risk aversion (CRRA) utility function, $u(\pi) = \pi^{(1-r)}$ for $\pi \geq 0$ and $u(\pi) = -(-\pi)^{(1-r)}$ for $\pi < 0$, where r measures the degree of relative risk aversion, $r < 0$ implies risk seeking, $r = 0$ implies risk neutrality, and $r > 0$ implies risk aversion.[10] The expected dispute utilities remain monotonic over the discrete

[9] In practice, arbitration costs may be borne by the unsuccessful party or shared between the dispute parties. To simplify the exposition, we employ the former rule here, but for reasons that will become clear the main insights of the model are unchanged by using a shared cost allocation. Common knowledge about the arbitration cost has real-world application. The German Arbitration Institute, for example, makes its cost schedule publicly available and provides a cost calculator tool on its website (http://www.disarb.org/en/).

[10] When $r = 1$, the function is replaced by $\ln d$. When $r > 1$, the function must be divided by $(1-r)$ to preserve increasing utility.

price grid. I will show later that the model's predictions still hold in the experiment if we assume risk aversion. For the rest of this section, we stay with the risk neutral case.

At Stage 5, the quality level has already been chosen by the seller. It is never in the interest of a seller to dispute if the buyer proposes a price greater than or equal to $z^q(\mu)$, because he would bear the direct cost of employing the arbitrator if called upon at no monetary gain. In that case, $d_i = d^0$. For any lower price proposal, the seller should dispute since the buyer would bear the direct cost. In this case, $d_i = d^1$. Therefore, we can assign conditional probability zero to event A and conditional probability one to event B (conditional on dispute).

At Stage 4, the buyer anticipates this outcome and, having observed the delivered quality, proposes a trading price as follows,

$$y = \begin{cases} \underline{p}, & if\ k < \frac{(1-\sigma)}{\sigma}\left(z^q(\mu) - \underline{p}\right) \\ max\left\{\underline{p}, z^q(\mu)\right\}, & if\ k > \frac{(1-\sigma)}{\sigma}\left(z^q(\mu) - \underline{p}\right). \end{cases} \tag{6}$$

At high costs of arbitration k, the buyer prefers to propose a price according to the arbitrator's preferences. At low such costs, she proposes the lower bound price $\underline{p}$. Since the buyer's dispute payoff is strictly decreasing in p, it is never in her interest to propose a price between $\underline{p}$ and $z^q(\mu)$.

At Stage 3, the seller chooses the quality level. If the winning bid is high enough that $z^H(\mu)$ is less than or equal to $\underline{p}$, then the arbitrator has no influence on the analysis and high quality is not incentive compatible. The incentive compatibility constraint for high quality is composed of the union of three cases (a proof is contained in Appendix A):

Case (i) $k \geq \frac{(1-\sigma)}{\sigma}(z^H(\mu) - \underline{p})$: *High quality is incentive compatible if* $z^H(\mu) - max\left\{\underline{p}, z^L(\mu)\right\} > c(q^H) - c(q^L)$. *Case (ii)* $\frac{(1-\sigma)}{\sigma}\left(z^L(\mu) - \underline{p}\right) < k < \frac{(1-\sigma)}{\sigma}\left(z^H(\mu) - \underline{p}\right)$: *High quality is incentive compatible if* $\sigma > \frac{c(q^H)-c(q^L)+max\left\{\underline{p}, z^L(\mu)\right\}-\underline{p}}{z^H(\mu)-\underline{p}}$. *Case (iii)* $k \leq \frac{(1-\sigma)}{\sigma}(z^L(\mu) - \underline{p})$: *High quality is incentive compatible if* $\sigma > \frac{c(q^H)-c(q^L)}{z^H(\mu)-z^L(\mu)}$.

We infer the following insight: at high arbitration costs, above the threshold defined by case (*i*), incentive compatibility does not depend on the arbitration probability; at lower arbitration costs, as defined by cases *(ii)* and *(iii)*, high quality satisfies the incentive compatibility constraint if and only if the probability of arbitration is large enough.

At Stage 2, having observed the contract price range, the buyer anticipates the seller's quality choice and accepts to purchase whenever her own expected payoff is non-negative. Since the arbitrator cannot award a price below the buyer's proposal, the buyer will accept any winning bid that does not exceed $v(E[q;\overline{p}])/(1-\lambda)$, where the expectation of quality is determined by the incentive compatible quality level given the probability of arbitration σ and the arbitrator's preference parameter μ. The buyer will reject any bid above this.

Let us turn to the bidding incentives at Stage 1. The benchmark for payoff comparison is zero, which is a losing seller's payoff at auction. From (3), the arbitrator's award is constrained by the upper bound contract price $\overline{p}$. At a high enough arbitration cost k, as defined by the cost threshold in (6), a potential seller always has an incentive to marginally undercut his competitor at auction and increase his probability of winning from $1/n$ to one. When the upper bound contract price $\overline{p}$ is less than $z^q(\mu)$, the seller is guaranteed a trading price equal to $\overline{p}$. In this cost case, by standard Bertrand arguments, the winning auction bid equals the cost of low quality, or one increment above. High quality is not incentive compatible, and we return to the inefficient outcome analogous to that obtained with a non-contingent contract.

Corollary 1. At high enough arbitration cost, high quality is not an implementable outcome.

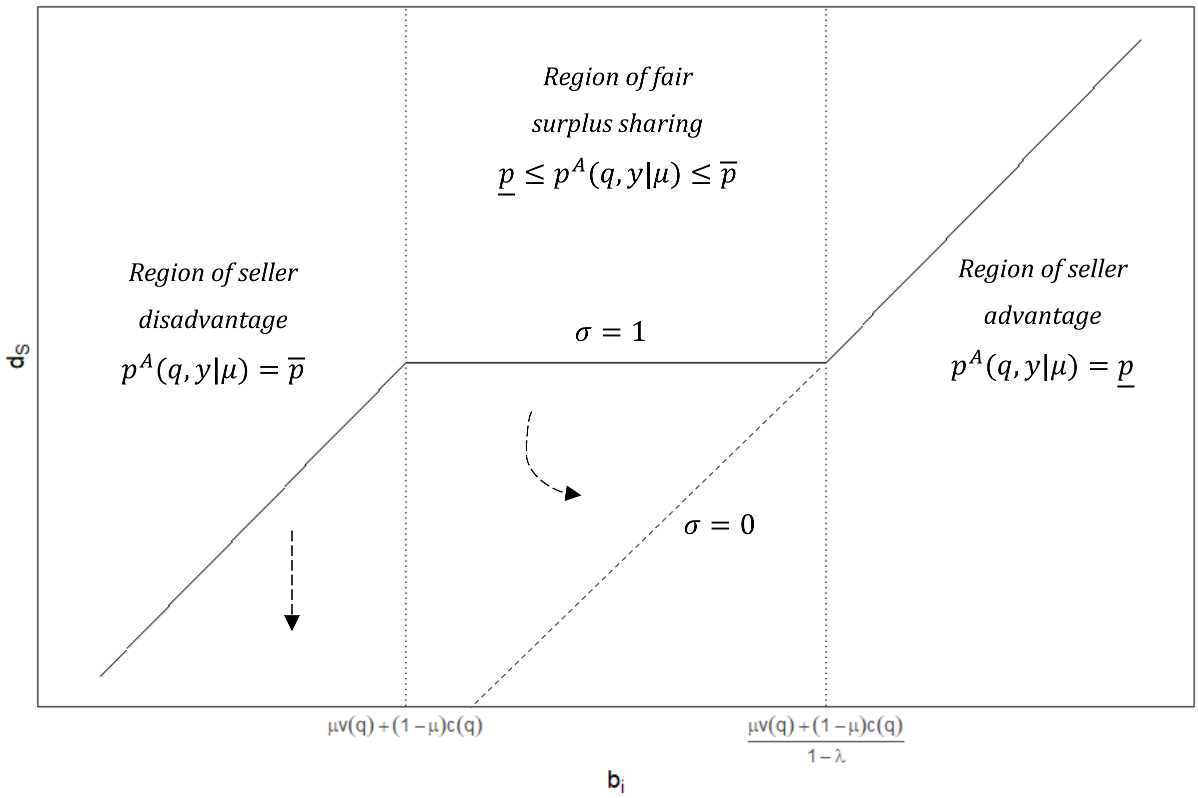
Suppose now that the arbitration cost k is low enough to ensure that the buyer proposes a trading price equal to $\underline{p}$. Without loss of generality, we can normalize the arbitration cost to zero. In Figure 1, I sketch the seller dispute payoff $d_S(q)$, as a function of seller i's bidding strategy. The solid line in the figure corresponds to the payoff function given certain arbitration ($\sigma = 1$). This payoff function is quality specific and has two pivot points. The lower pivot point is at $\mu v(q) + (1-\mu)c(q)$. As bids fall below this level, the arbitrator's preferred settlement cannot be implemented. From (3), the arbitrator imposes a final price equal to the upper bound contract price $\overline{p}$. I denote this the *region of seller disadvantage*.

The upper pivot point is at $[\mu v(q) + (1-\mu)c(q)]/(1-\lambda)$. A bid above this level is high enough to guarantee the seller a greater share of the surplus than the arbitrator deems fair. The arbitrator imposes a final price equal to the lower bound contract price $\underline{p}$. Thus, the arbitrator has no influence on the interaction in this region. I denote this the *region of seller advantage*.

For bids between the two pivot points, the preferred settlement is located within the price range and so the arbitrator can impose a final trading price to achieve this settlement. I denote this the *region of fair surplus sharing*.

We can examine comparative statics for μ, λ and σ. At larger values of μ, the pivot points in Figure 1 shift to the right. Intuitively, a higher bid is required to allocate the seller a greater share of the surplus and the dispute payoff in the *region of fair surplus sharing* is located at a higher level. At larger values of λ, there is a wider contract price range. The payoff function shifts down in all regions, due to the larger potential for seller losses if the arbitrator is not available. The upper pivot point shifts right and the *region of fair surplus sharing* incorporates more bids.

Figure 1. Seller i's dispute payoff as a function of bid.



Notes: The solid line is seller i's dispute payoff d_S as a function of bid b_i given certain arbitration ($\sigma = 1$). The dashed line extension is the equivalent payoff given no arbitration ($\sigma = 0$). The arbitrator's preferred price p^A, as a function of the product quality q, the price proposal y and conditional on the arbitrator's preference μ. The price flexibility in the contract is denoted by λ. The buyer's valuation v and seller's cost c are functions of q. The lower and upper bounds of the contract price range are denoted by $\underline{p}$ and $\overline{p}$.

Let us turn to the probability of arbitration σ. We know from the analysis of Stage 3 that high quality is only incentive-compatible if σ is large enough. As σ decreases below one, the payoff function in the *region of seller disadvantage* shifts downwards and the payoff function in the *region of fair surplus sharing* pivots anti-clockwise. Thus, σ determines the slope of the payoff function in this region. Incentive compatibility corresponds to regions in which the seller dispute payoff to high quality is above the payoff to low quality.

For $\sigma = 0$, the two segments form a straight line and the *region of fair surplus sharing* collapses to a single price. This scenario is shown by the dashed line in Figure 1. The two quality-specific payoff functions never intersect and the payoff to low quality is strictly above the payoff to high quality. This led us to the inefficient outcome described in *Proposition 1*.

For $\sigma > 0$, the two quality-specific payoff functions either never intersect or they intersect at two points in the price grid G. For high quality to be incentive compatible, we require the latter. Due to monotonicity of the dispute payoff function, the low quality payoff must be strictly less than zero for some non-empty price subset G'. For high quality to be implementable, there must exist at least one bid in G' for which a seller strategy with high quality component yields a non-negative expected payoff.

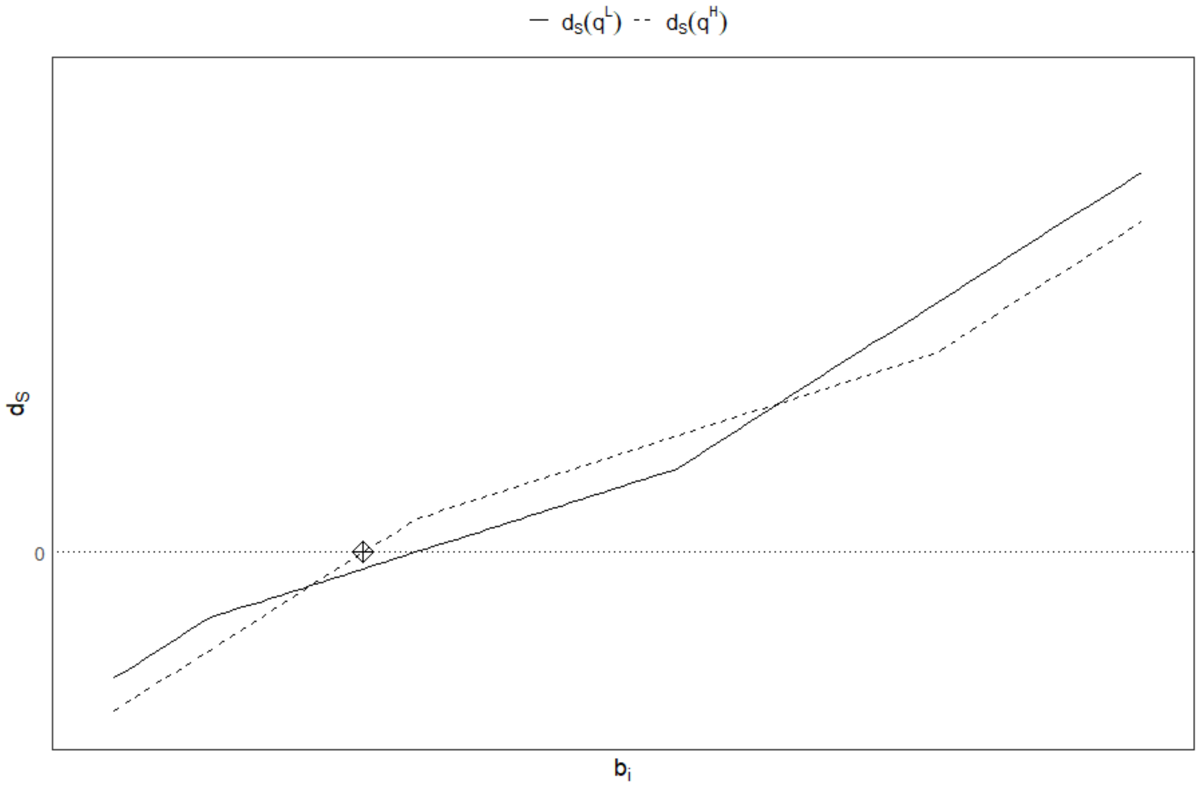
Definition 2 *(Equilibrium Implementability Condition).* $\exists b_i \in G$: $d_S(q^L) < 0 \leq d_S(q^H)$.

At any bid in G', the arbitrator would settle in favour of the seller. The lowest bid in G' must be:

$$\underline{b}^H = \frac{c(q^H) - \sigma z^H(\mu)}{(1-\lambda)(1-\sigma)}, \tag{7}$$

which is obtained by setting the seller's dispute payoff to high quality equal to zero. The potential sellers' no deviation incentives during bidding are the same as described in the baseline environment, except that now the breakeven bid depends on the cost of high quality and accounts for the arbitration probability and arbitrator's preferences. An example of this condition is contained in Figure 2, with $\underline{b}^H$ marked by a diamond plus.

Figure 2. *Equilibrium Implementability Condition*.



Notes: The solid (dashed) line is seller i's dispute payoff to low (high) quality, as defined in (5). The equilibrium bid level $\underline{b}^H$ is marked on the figure by a diamond plus.

The *Equilibrium Implementability Condition* is sufficient for the existence of a unique SPNE associated with high quality. In each SPNE, we have $b_i^* = \underline{b}^H + \Delta$ for all i or $b_i^* = \underline{b}^H$ for at least two i; $a^* = a^1$; $q_i^* = q^H$; $y^* = \underline{p}$; and $d_i^* = d^1$.

Proof. The equilibrium actions are described above. Uniqueness follows from monotonicity of the seller dispute payoff function. The buyer achieves the full (larger) surplus in expectation, although her payoff is reduced by the arbitration cost. Seller payoffs are unchanged (in expectation) from the baseline contracting environment. ∎

For zero arbitration cost, the first-best outcome can be achieved. For any non-zero cost, a pareto-improving second-best outcome can be achieved when the arbitration cost is less than the gain from trading a high quality product.[11] A second proposition follows directly.

Proposition 2. Probabilistic arbitration can mitigate the seller moral hazard problem. There exists a contingent contract defined by $\lambda \in (0,1)$ and $\sigma \in (0,1)$ for which high quality is the unique implementable outcome.

Since the equilibrium bid $\underline{b}^H$ is at the point where the payoff function to high quality crosses the zero profit line and the slope of the payoff function is least steep in the *region of fair surplus sharing*, we can state the following corollary.

Corollary 2. Any contingent contract that implements a high quality outcome is associated with lower equilibrium bids than the equivalent contract with $\sigma = 0$.

As σ approaches one, the buyer's claim on the surplus becomes irrelevant. The seller dispute payoff to low quality remains greater than or equal to zero at all acceptable bids and so the *Equilibrium Implementability Condition* is never satisfied. For any bid strictly above $c(q^L) + \Delta$, each seller has an incentive to marginally undercut his competitor. We obtain a final corollary.

Corollary 3. Certain arbitration cannot mitigate the seller moral hazard problem; for $\sigma = 1$, high quality is not an implementable outcome.

4. Experiment Setup

I design a controlled lab experiment to test the main predictions of the model. In the experimental setting, one buyer faces two potential sellers. The degree of price flexibility λ is set exogenously at 0.75. This permits substantial flexibility in the contract.

---

[11] If the seller were to share in a fixed proportion α of the arbitration cost, then she would only dispute at Stage 5 if the expected gain from doing so exceeds αk. The seller dispute payoff function intercept would shift upwards and the breakeven bid would adjust accordingly. Sufficiency of the *Equilibrium Implementability Condition* still applies.

4.1 *Treatments and parameters*

There are three experimental conditions (Table 1), which vary according to the probability of arbitration σ – using a between-subjects design – and the arbitrator's preference parameter μ – using a within-subjects design. The first condition simulates the baseline contracting environment, and so the probability of arbitration is zero (the "*Voluntary*" treatment). In this treatment, any payment to the seller above one-quarter of the winning bid is made by the buyer voluntarily. In the second and third conditions, the probability of arbitration is one-half (collectively, the "*Arbitrator*" treatment). This treatment is split into two sub-treatments, in which the arbitrator either prefers to award one-third or two-thirds of the trade surplus to the seller. By varying the arbitrator's preference parameter within subjects, we conduct a less restrictive test of the arbitration model and consider trade relationships in which the arbitrator favours the buyer and seller. I deliberately avoid invoking the fairness norms associated with an equal split, which have been observed in prior bargaining studies (e.g. Andreoni and Bernheim 2009).[12] The cost of arbitration is deliberately set low, at two (further details below).

Table 1 – Treatment matrix.

Treatment	*Voluntary*	*Arbitrator*	
Sub-treatment		$\mu = 1/3$	$\mu = 2/3$
Probability of arbitration	$\sigma = 0$	$\sigma = 0.50$	
Price flexibility	$\lambda = 0.75$		

The cost and valuation schedules are common knowledge to all subjects in the experiment (Table 2). Low quality generates a trading surplus of twenty and high quality generates a trading surplus of sixty. Low quality costs the seller thirty to deliver and is valued by the buyer at fifty. High quality costs the seller forty to deliver and is valued by the buyer at one-hundred. Consistent with the investment game literature in experimental economics, the surplus multiplier is three. The bid increment Δ is set at one, the minimum bid at thirty and the maximum at two-hundred. The maximum bid is high enough to ensure that potential sellers can always submit a profitable bid associated with either low or high quality. The maximum bid is low enough to ensure that there is no winning bid at which a self-interested buyer would reject the opportunity to purchase.

[12] Aside from the normative appeal of the equal split, there is no obvious reason why subjects should behave differently for values of μ other than 1/3 or 2/3 (so long as the relevant theoretical proposition applies).

Table 2 – Cost and valuation schedules.

Quality level q	$q = q^L$	$q = q^H$
Buyer's valuation: $v(q)$	50	100
Seller's cost: $c(q)$	30	40

4.2 Session protocol

All subjects participated in a sequence of thirty trade interactions. Each interaction was divided into distinct phases. There were two phases of every interaction in the *Voluntary* treatment and three phases of every interaction in the *Arbitrator* treatment. The first two phases were the same across treatments. In the first phase, the potential sellers in a group simultaneously submitted bids at a first-price procurement auction. At the same time as choosing a bid, each potential seller also chose a quality level, high or low, to be delivered conditional on submitting the winning bid. This variant on the strategy method enabled twice as many quality observations to be collected, without changing the strategic nature of the game.[13] The potential seller submitting the lower bid in the first phase won the auction, with ties broken at random. The winning and losing bids and the contract price range were then revealed in the group. The lower bound contract price was one-quarter of the winning bid and the upper bound price equal to the winning bid. The auction winner became the seller for the interaction. The potential seller that submitted the losing bid waited for the interaction to conclude, earning a profit of zero.

In the second phase, the buyer observed the seller's chosen quality level and proposed a price to pay the seller from the contract price range. Since there was no bid available at which the lower bound contract price could exceed the buyer's valuation for low quality, the buyer's acceptance decision was automated in the experiment. In *Voluntary*, the buyer's chosen price was the final price by assumption and the interaction ended at the conclusion of this phase.

In *Arbitrator*, there was a third (non-decision) phase in which an appeal to the arbitrator could be triggered. The arbitrator's price was the amount from between the buyer's proposed price and the winning bid that provided the seller with closest to the arbitrator's preferred surplus division, defined by μ. To provide a clean test of the theory, the seller's appeal decision was automated. If and only if the buyer's proposed price was strictly below the arbitrator's price, an appeal was triggered. In other words, optimal use of the arbitrator was assumed. Following an appeal, the arbitrator was not always available to intervene. Specifically, the arbitrator could only

[13] Further benefits were that it helped to preserve anonymity of the winning seller and buyers did not have to wait for the completion of two stages before deciding. A complete strategy method in *Arbitrator* would have required sellers to specify a quality choice conditional on their bid and a decision over whether to invoke the arbitration clause, for every possible price. Such an approach was not practical.

set a final price on one-half of appeals, determined at random. If no appeal was triggered, or if the arbitrator was unavailable, then the outcome remained the same as in *Voluntary*. If an appeal was triggered and the arbitrator available, then the buyer had to pay the cost of arbitration. This cost was not factored into the arbitrator's surplus division calculations.

To illustrate, suppose the winning bid is 128 and the seller chooses high quality. The contract price range is from thirty-two to 128. The buyer proposes a price of sixty-five. In *Voluntary*, the final price is sixty-five. The buyer's profit is thirty-five and the seller's profit is twenty-five. In *Arbitrator*, if $\mu = 1/3$, the arbitrator's price is sixty. No appeal is triggered, and the profit outcomes are the same as in *Voluntary*. If $\mu = 2/3$, the arbitrator's price is eighty and so an appeal is triggered. If the arbitrator is unavailable, profit outcomes are the same as in *Voluntary*. If the arbitrator is available, a fee of two points is levied on the buyer. The buyer's profit is eighteen and the seller's profit is forty.

4.3 Hypotheses

The *Equilibrium Implementability Condition* is satisfied in *Arbitrator* for all levels of risk aversion (see Appendix B). The cost of arbitration is low enough to ensure that the buyer's equilibrium proposal is always the minimum amount in the contract price range. The parameter choices are without loss of generality and in Appendix B I demonstrate the implementable quality levels for the full set of contracts. The subset of contracts for which high quality is implementable is decreasing in the seller's risk aversion. The point predictions are presented in Table 3. In *Voluntary*, low quality is the unique implementable outcome (cf. **Proposition 1)**. In *Arbitrator*, high quality is the unique implementable outcome (cf. **Proposition 2**). To within an increment, equilibrium bids are 120 in *Voluntary*, 80 in *Arbitrator* ($\mu = 1/3$) and 64 ($\mu = 2/3$); buyers propose the lower bound price and earn the full surplus; sellers earn zero in expectation.

Table 3 – Equilibrium point predictions.

Treatment	*Voluntary*	*Arbitrator*	
Sub-treatment		$\mu = 1/3$	$\mu = 2/3$
Measure			
b_i	120	80	64
q	Low quality	High quality	High quality
y	30	20	16
π_B	20	60	60
π_S	0	0	0

Notes: A potential seller's bid is b_i; the product quality level chosen by the auction winner is q; the buyer's price proposal is y. The buyer's expected profit is π_B and the seller's expected profit is π_S. Numbers are to within one increment due to discreteness of the experimental price grid.

The comparative hypotheses to be tested are summarised as follows:

Hypothesis 1. Bidding. (a) Winning bids are lower in *Arbitrator* than in *Voluntary*; and (b) winning bids are higher when $\mu = 1/3$ than when $\mu = 2/3$.

Hypothesis 2. Efficiency. The realised trade surplus net of the arbitration cost is greater in *Arbitrator* than in *Voluntary*.

Hypothesis 3. Reciprocity. In both *Voluntary* and *Arbitrator*, the buyer proposes the lower bound contract price.

Hypothesis 4. Profits. Buyer profits are higher in *Arbitrator* than in *Voluntary*; and seller profits are unchanged between *Arbitrator* and *Voluntary*.

4.4 Implementation

The total number of subjects recruited for the experiment was 108. Subjects were recruited using the web-based software hroot (Bock et al. 2014) and allocated at random to one of the two treatments, *Voluntary* or *Arbitrator*. Each treatment included six independent cohorts and no subject participated in more than one treatment. Every cohort had nine human subjects, three buyers and six sellers, who were matched into groups of one buyer and two sellers using a stranger matching protocol for thirty trade interactions. An algorithm ensured no subject played with the same two players in consecutive interactions, and subjects were informed of this. In procurement, firms typically compete for contracts within a fixed pool of potential sellers. While buyers and potential sellers vary between interactions, they often meet again at some future date. Thus, this matching protocol is preferable to perfect stranger matching. There were two cohorts (18 subjects) of the same treatment in every session.[14] To minimize the possibility of tacit collusion, subjects were not informed about the cohort size.

In *Arbitrator*, the sequence of trade interactions was broken into two blocks of fifteen interactions, which constituted the two sub-treatments. To control for order effects, the block sequence in this treatment followed a crossover design, with one half of the subjects in a session assigned to the sequence $\mu = \{1/3, 2/3\}$ and one half of the subjects in a session assigned to the sequence $\mu = \{2/3, 1/3\}$.

To facilitate understanding, the task was presented using a cover story. A shipping company sought to procure an engine for its cargo ship. The choice of a shipping company was deliberate. Subjects are less likely to have experience from daily life with a shipping company

[14] The first cohort of the *Voluntary* treatment had to be re-run, with nine (new) subjects in the session, after discovery of a comprehension issue. Data for the excluded cohort is available on request.

than say, an airline (see Alekseev et al. 201, on the merits and pitfalls of using a meaningful frame). One-third of subjects assumed the role of a shipping company (buyer). Two-thirds assumed the role of a supplier (seller). At the beginning of every interaction, each buyer was matched with two sellers. The seller that won the auction delivered the engine to the buyer. The engine quality depended on the winning seller's choice. The losing seller earnt zero profit for the interaction.

The probabilistic nature of the arbitrator was explained using a die roll. Subjects were informed that if an appeal to the arbitrator were triggered, the computer would roll a fair six-sided die. If the die came up one to three, the arbitrator would be unavailable, and the seller would receive the buyer's proposed price. If the die came up four to six, the arbitrator would be available, and the seller would receive the arbitrator's price instead.[15] A fee of two points would be levied on the buyer. The arbitrator's preferred surplus division was explained to subjects in terms of a two-to-one buyer (seller) to seller (buyer) profit ratio.

In *Arbitrator*, sellers were informed about the arbitrator's price associated with each combination of bid and quality level. Buyers were informed about the arbitrator's price associated with each proposal and whether an appeal would be triggered. At the end of each interaction, feedback was provided about the outcomes of a subject's own interaction group only, including on bids, quality, price proposal, arbitration process (in *Arbitrator*), final price and profits. This feedback was provided to all groups simultaneously, to prevent subjects inferring the identities of others in their interaction group. Private feedback remained available in a history table to facilitate learning. The losing seller only observed the auction outcome.

The experiments were computerised and programmed in oTree (Chen et al. 2016). To aid replicability and ensure common knowledge, video instructions were created and played at the start of an experimental session.[16] Subjects had to answer a set of comprehension questions correctly before proceeding to two trial rounds, in which they were guided through the decision screens specific to their role. Roles were assigned randomly before the trial rounds and remained fixed. Each seller had their own auction in the trial rounds and these rounds were non-incentivised. The main experiment followed immediately. At the end of a session, subjects completed a survey to elicit demographic information, risk attitudes and trust attitudes.[17]

Subjects received money for their participation, which was paid in private and in cash at the end of a session. As is common in auction experiments, there is the potential for losses. Subjects assigned a buyer (seller) role therefore began each interaction with an endowment of

---

[15] This randomization was implemented successfully: the arbitrator was available on 49.3 percent of appeals in the experiment, which is not significantly different from 50 percent (p-value = 0.690, two-tailed binomial test).

[16] A copy of the instructions and links to the video recordings can be found in Appendix E.

[17] Since the predictions do not depend on risk preferences, we do not employ an incentivized elicitation. Summary statistics from the post-experiment survey can be found in Appendix F.

five (ten) points.[18] Any profit or loss was added to or subtracted from the endowment. Sessions lasted sixty to seventy-five minutes. The total points from all rounds were multiplied by a pre-determined exchange rate of forty points per one British pound. Subjects were informed that the minimum amount they could leave the session with was £4.[19] Approximate average earnings for buyers were £28 and for sellers £10. This payoff inequality is not important theoretically, because the model assumes standard preferences. Empirically, however, social preferences may influence behaviour (e.g. Fehr and Schmidt 1999, Bolton and Ockenfels 2000). I return to this when analysing the experimental results.

5. Experimental Results

This section presents the findings of the lab experiment. First, I conduct an aggregate analysis. The cohort is the independent observation and is used for all statistical comparison tests in this sub-section. Second, I analyse the individual bidding strategies pursued by sellers, in relation to the theory. Third, I estimate a mixture model to demonstrate how observed buyer behaviour might be rationalized with reference-dependent preferences.

5.1 Aggregate findings

The main results of the experiment are summarised in Table 4. Median cohort averages are provided for winning bids, the relative frequency of high quality, the buyer's proposed price as a share of trade surplus and profits. An overall trade efficiency measure is provided, which captures the realised percentage of attainable trade surplus net of the arbitration cost incurred.

Bidding. The theory predicts that winning bids are lower when the contract contains a contingency and that the equilibrium bid is a function of the arbitrator's preferences. The data strongly supports the first prediction, but not the second.

Both bids and winning bids (the lower-order bidding statistic) differ between the two treatments. In *Voluntary*, the average bid submitted in the auction is 115.77 and in the pooled *Arbitrator* data, 78.55. The average winning bids are 105.64 and 69.24, respectively. Both differences are statistically significant in the direction predicted by Hypothesis 1 (p-value < 0.01 for both comparisons, Wilcoxon-Mann-Whitney tests, one-tailed).[20] Pairwise comparisons between the *Voluntary* treatment and the *Arbitrator* sub-treatments yield similar statistical differences.[21] The cumulative bid distribution functions are presented in Appendix B. The

[18] The relative endowment sizes compensate for the expectation that, on average, each seller participates in half as many transactions as the buyer.

[19] One subject encountered a limited liability problem. The results are qualitatively unchanged by inclusion or exclusion of the cohort in which this subject participated. For completeness, we include this cohort.

[20] I report p-values from one-tailed statistical comparison tests where the theory predicts a direction.

[21] *Voluntary* vs. $\mu = 1/3$, p-value < 0.01 for both; *Voluntary* vs. $\mu = 2/3$, p-value = 0.021 and p-value < 0.01.

distribution of bids in *Voluntary* is stochastically larger than in *Arbitrator* (p-value < 0.001, Kolmogorov-Smirnov test, one-tailed). In *Voluntary*, bids are not significantly different from the point prediction of 120 (p-value = 0.563, one-sample Wilcoxon Signed-Rank test, two-tailed).

Result 1(a). We find support for Hypothesis 1(a). A contingent contract results in significantly lower winning bids than a non-contingent contract.

The theory is less successful at explaining bidding behaviour within-subjects in *Arbitrator*. When the arbitrator favours the buyer ($\mu = 1/3$), rather than the seller ($\mu = 2/3$), we expect sellers to adjust their bids upwards to compensate for the lower expected price in the event of winning the auction and the arbitrator being available. This is not observed in the data.

Table 4 – Summary of experiment outcomes.

Treatment / Sub-treatment / Measure	*Voluntary*	*Arbitrator* $\mu = 1/3$	*Arbitrator* $\mu = 2/3$
Winning bid	105.64	65.29***	72.96***
Product quality	0.45	0.43	0.53
Proposal / surplus	0.13	-0.18***	-0.05**
Low quality	0.13	-0.23***	-0.13***
High quality	0.13	-0.11**	-0.05
Buyer profit	33.85	33.8	32.32
Low quality	17.32	18.35	13.93
High quality	52.41	52.83	48.21
Seller profit	4.79	3.35	8.01
Low quality	2.68	0.78	5.24
High quality	7.59	6.51	11.11
Efficiency	63%	61%	67%

Notes: The table summarises the main outcomes of the lab experiment. All values are median cohort averages, based on six independent cohorts per treatment. *Winning bid* is the lowest bid submitted by potential sellers in the auction phase; *Product quality* measures the relative frequency that high quality is chosen for delivery by the winning seller; *Proposal / surplus* measures the buyer's price proposal as a share of trade surplus; *Buyer profit* is the trade profit per round for the buyer; *Seller profit* is the trade profit per round for the winning seller; and *Efficiency* measures the realised percentage of attainable trade surplus net of any arbitration cost incurred.
*** p < 0.01, ** p < 0.05, * p < 0.1 [based on two-tailed nonparametric Wilcoxon-Mann-Whitney test versus the *Voluntary* treatment, taking each cohort as one independent observation]

Average bids are 74.71 when $\mu = 1/3$ and 81.06 when $\mu = 2/3$. Winning bids are 65.29 and 72.96, respectively. Neither difference is significant (p-value = 0.563 and p-value = 0.313, Wilcoxon Signed-Rank tests, two-tailed). The failure to adjust bids as expected in response to a change in μ is not concealed by learning. If we restrict attention to experienced sellers only – classified as periods 11 to 15 and 26 to 30 – neither the bids nor winning bids are significantly different (p-value = 1.00 and p-value = 0.563, Wilcoxon Signed-Rank tests, two-tailed). The finding is also not a consequence of behavioural spillover effects. Spillover effects are possible in *Arbitrator* because μ is varied within subjects between the first and second half of the experiment (see Bednar et al. [2012] for a discussion of the importance of accounting for spillovers in economic experiments). The results in this section are qualitatively unchanged if we only consider data from periods one to fifteen and so only consider between-subjects variation.[22] This suggests that any spillover effects, if present, did not significantly alter subject behaviour.

Result 1(b). We reject Hypothesis 1(b). Potential sellers fail to adjust their bids based on expected values in response to a change in the contractual contingency.

Efficiency. The theory predicts that high quality trading relationships are more likely with a contingent contract. This prediction is independent of the arbitrator's preferences. There is no systematic evidence for this in the data.

High quality trades are observed across the winning bid distributions in both treatments. The relative frequencies of high product quality delivered by the winning seller in the *Voluntary* and *Arbitrator* treatments are forty-five and forty-eight percent, respectively. This difference is not significant (p-value = 0.350, Wilcoxon-Mann-Whitney test, one-tailed). There is no significant difference in quality between the *Arbitrator* sub-treatments (p-value = 0.313, Wilcoxon Signed-Rank test, two-tailed).

Consistent with the theory, the relative frequency of dispute is high at around 80 percent in both *Arbitrator* sub-treatments. After taking the resulting arbitration cost into account, average trade efficiency is sixty-three percent in *Voluntary* and sixty-four percent in *Arbitrator*. The difference is not statistically significant (p-value = 0.531, Wilcoxon-Mann-Whitney test, one-tailed). There is no significant pairwise difference between *Voluntary* and either of the *Arbitrator* sub-treatments (*Voluntary* vs. $\mu = 1/3$, p-value = 0.803 and vs. $\mu = 2/3$, p-value = 0.294, Wilcoxon-Mann-Whitney tests, one-tailed).

Result 2. We reject Hypothesis 2. A contingent contract does not significantly increase trade efficiency relative to a non-contingent contract.

Reciprocity. The model assumes standard preferences and so predicts that buyers always propose the minimum price in the contract price range. Given the vast experimental economics

[22] Summary statistics for the spillover analyses can be found in Appendix B.

literature documenting social preferences, it is unsurprising that this assumption is falsified behaviourally. Interestingly, however, buyer reciprocity is significantly lower when the contract contains a contingency.

In *Voluntary*, the buyer on average proposes a price equal to 37.6 percent of the winning bid. In *Arbitrator*, the average proposal is forty-two percent, but of a lower average price. Both rates are significantly above the minimum required one-quarter (p-value = 0.016 for both comparisons, one-sample Wilcoxon Signed-Rank tests, one-tailed) and attest to the existence of social preferences in the buyer population.[23] There is a sustained gap between lower bound contract price and the average buyer proposal in the experiment over time (see the time-series plot in Appendix B). The average final price in *Arbitrator* is 40.78, which coincides nearly exactly with the equilibrium prediction of compensation equal to the seller's delivery cost of high quality. By contrast, in *Voluntary* the average final price is 38.93, significantly above the cost of low quality (p-value = 0.031, one-sample Wilcoxon Signed-Rank test, two-tailed).

The level of buyer reciprocity differs between the treatments. Average price proposals in *Voluntary* imply a seller profit equal to 13.26 percent of the transaction surplus. The picture is very different in *Arbitrator*, where proposals imply a seller loss equal to 14.65 percent of the transaction surplus. The difference is highly significant (p-value < 0.01, Wilcoxon-Mann-Whitney test, two-tailed). The arbitration clause was triggered on four out of five transactions. Revealingly, while in *Voluntary* buyers propose that the seller receives a similar share of the surplus independently of the quality level, in *Arbitrator* buyers offer significantly less in exchange for low product quality than for high quality (p-value = 0.031, Wilcoxon Signed-Rank test, two-tailed). This is not driven by differences in bids accompanying the two quality levels (see next sub-section) and implies that buyers are less forgiving of a seller's reluctance to deliver high quality with a contingent contract.

Result 3. We reject Hypothesis 3. A contingent contract crowds out buyer reciprocity and the arbitrator acts as a partial substitute for reciprocity in the determination of final prices.

Profits. The standard theory predicts that sellers compete away trading profits and the buyer appropriates the trade surplus, ruling out a fairness function of arbitration. To some extent, this prediction is borne out in the data.

In both the *Voluntary* and *Arbitrator* treatments, buyers earn significantly higher profits than sellers (p-value = 0.016 for both comparisons, Wilcoxon Signed-Rank tests, one-tailed). The gains from high quality trading relationships are also apparent. Buyers and sellers each earn roughly three times as much from high quality trades as low quality trades, in line with the

---

[23] Since proposals cannot be below one-quarter of the winning bid, we use a one-tailed test.

surplus multiplier. Yet buyers do not benefit from the presence of an arbitrator. In fact, buyer profits are remarkably stable across experimental conditions, at 33.85 in *Voluntary*, 33.80 in *Arbitrator* when $\mu = 1/3$ and 32.32 when $\mu = 2/3$. Neither pairwise difference is significant.[24]

The average seller profit is 4.79 in *Voluntary* and 6.42 in *Arbitrator*. This increase is not significant (p-value = 0.818, Wilcoxon-Mann-Whitney test, two-tailed). It does, however, mask underlying differences between the *Arbitrator* sub-treatments. Whereas seller profits are 3.35 when $\mu = 1/3$, they are 8.01 when $\mu = 2/3$, although the latter is not significantly different from the *Voluntary* treatment level (p-value = 0.310, Wilcoxon-Mann-Whitney test, two-tailed). I cannot rule out that this is due to a lack of statistical power – see the robustness check below. More data is required to make concrete inferences on whether, and the conditions under which, an arbitration mechanism serves a fairness function in competitive procurement interactions.

Result 4. We find partial support for Hypothesis 4. Buyers earn significantly more than sellers, but neither trade party significantly benefit from a contingent contract.

Robustness check: Since the number of independent observations per treatment is small, low statistical power might be a concern for any null result in the hypothesised direction. We have disaggregated data from 540 matching groups in each treatment, which yields greater statistical power to detect effects than the more conservative mean comparison tests used above. Results 1 to 4 are qualitatively unchanged if we conduct a regression analysis on the matching group level data, accounting for intra-cohort dependencies and small-sample considerations using the wild cluster bootstrap method (Cameron et al. 2008). The results of this exercise are contained in Appendix C.

5.2 Seller bidding strategies

In this sub-section, I analyse seller bidding strategies formulated during the auction phase of the experiment. There is data from 1,070 strategies submitted in *Voluntary* and 1,059 strategies submitted in *Arbitrator*.[25] High quality is a component of forty-two percent of bidding strategies in *Voluntary*. In *Arbitrator*, this is true of forty-six percent of seller strategies when $\mu = 1/3$, and fifty-five percent of seller strategies when $\mu = 2/3$. The latter is a significant increase over *Voluntary* (p-value = 0.066, Wilcoxon-Mann-Whitney test based on cohort averages, one-tailed). Thus, whereas a contingent contract is not able to significantly improve the winning product

[24] *Voluntary* vs. $\mu = 1/3$, p-value = 0.758 and vs. $\mu = 2/3$, p-value = 0.758 (Wilcoxon-Mann-Whitney tests, one-tailed); $\mu = 1/3$ vs. $\mu = 2/3$, p-value = 1.00 (Wilcoxon Signed-Rank test, two-tailed).

[25] The difference is due to the use of a hard time-out protocol in the experimental sessions. In the event of timing out, the default bid was 200, the quality level was decided at random and the price proposal was set equal to the winning bid. The rate of data loss is less than one percent, which seems a reasonable trade-off given the benefits of the protocol for minimizing delays during a session.

quality delivered, it does promote higher quality among the pool of potential sellers, particularly when the arbitrator is known to favour the seller.

As a first step, it is instructive to examine average bids that accompany the respective quality levels at the cohort level. In *Voluntary*, the median bid for low quality strategies is 118.35, very close to the equilibrium point prediction. The median bid for high quality strategies is significantly lower at 109.71 (p-value = 0.031, Wilcoxon Signed-Rank test, two-tailed). This suggests that, with a non-contingent contract, deviation to a lower bid may have been driven by a belief that buyers view high quality as a "gift" that they are more likely to reciprocate.

In *Arbitrator*, by contrast, the median bid for high quality strategies – at 81.86 – is significantly higher than for low quality strategies – at 74.46 (p-value = 0.063, Wilcoxon Signed-Rank test, two-tailed). Similar qualitative differences are observed in both the *Arbitrator* sub-treatments (see summary statistics in Appendix B). This suggests that potential sellers anticipated the lower levels of buyer reciprocity with a contingent contract and adjusted their bid–quality combinations to reflect the implied difference in delivery cost. Conditional on bids, potential sellers chose the incentive compatible quality level in fifty-six percent of auction decisions in *Arbitrator*.[26] This measure of incentive compatibility is based on the expectation of strictly self-interested buyers. If sellers expect some degree of buyer reciprocity, the delivery of high quality might be justified. Nevertheless, in *Arbitrator* buyer reciprocity is attenuated and so the assumption of self-interested buyers is more appropriate. To check the implications of sub-optimal seller bidding strategies for the efficiency Hypothesis 2, in Figure 3 I compare *actual* versus *predicted* seller profits per quality level, as a function of the winning bid. The SPNE point in each experimental condition is marked with a red diamond plus.

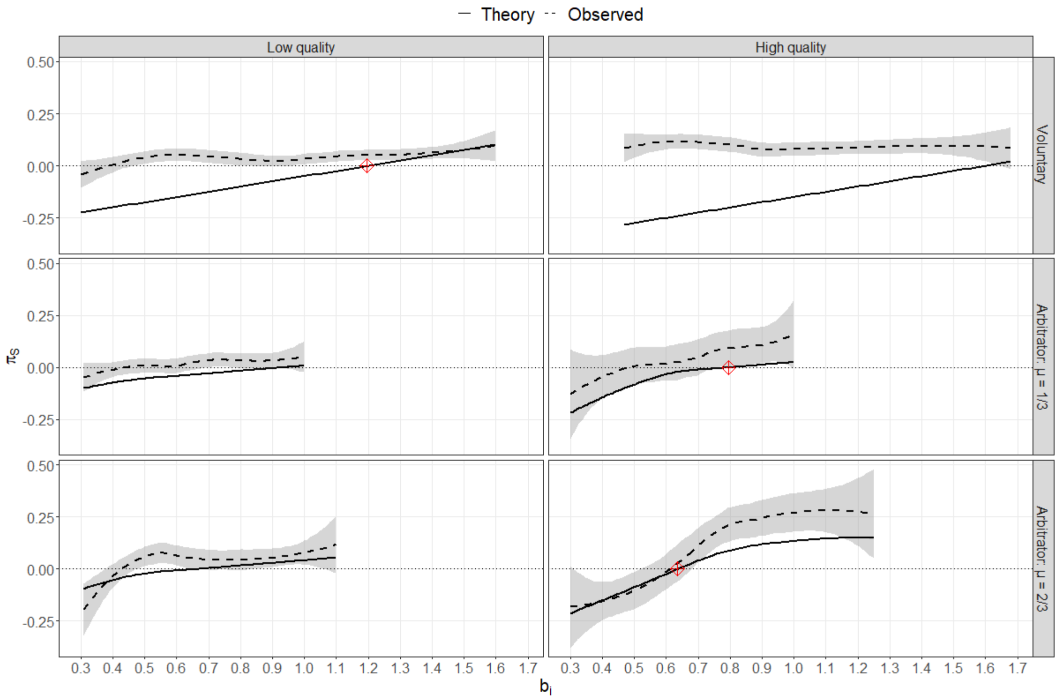
Consistent with the earlier results, buyer reciprocity is stable across bids in *Voluntary*. On average, observed seller profits remain flat above the break-even level, independent of the bid and quality choice. In *Arbitrator*, seller profits track the prediction as a function of the winning bid, at a level weakly above the theory. For the median winning bid in each *Arbitrator* sub-treatment, high quality is incentive compatible (see Appendix B).

As a further investigation into the determinants of bidding strategies, I employ two complementary parametric methods (Table 5). First, to examine the factors affecting seller bids *independently* of quality, I use random effects regressions with three levels of dependencies and controlling for a range of covariates (columns 1 and 2, adapted from Moffatt 2015, Chapter 4.7). The dependent variable is the bid of subject i in cohort j in period t. To account for intra-session correlation, the variance is estimated at subject and cohort levels.[27] We observe a positive

[26] This calculation assumes risk neutrality. In *Voluntary*, incentive-compatible choice is always low quality.
[27] The exact regression specification is $y_{ijt} = \beta_0 + \beta_1 x_{ijt} + \beta_2 z_i + \beta_3 o_j + \beta_4 t + u_i + \upsilon_j + \varepsilon_{ijt}$, with variances $V(u_i) = \sigma_u^2$, $V(\upsilon_j) = \sigma_\upsilon^2$ and $V(\varepsilon_{ijt}) = \sigma_\varepsilon^2$. The three levels are $i = 1, \ldots, 36$ (sellers), $j = 1, \ldots, 6$

dependency of current bids on the once-lagged competitor's bid, which captures the strategic complementarities of Bertrand competition. This effect is enough to largely offset the negative time trend in *Voluntary*, although in *Arbitrator* bids trend downwards (see also the time-series plot of winning bids in Appendix B).

Figure 3. Seller profits as a function of the winning bid: Actual versus predicted.



Notes: The lines are loess smoothers and the shaded regions for the observed data are 95% confidence intervals. The red diamond plus is the equilibrium bid level.

Second, to examine the factors affecting seller quality choices, I estimate instrumental variable probit regressions in which quality is the dependent variable and bid is the endogenous regressor, which is instrumented for by the once-lagged bid (columns 3 and 4). The instrumental variable estimator is used to mitigate the issue of simultaneity between bids and quality choices inherent in the strategy method application. The instrument passes recognised strength tests – see Appendix B for diagnostic statistics. Standard errors are adjusted using the Huber-White sandwich estimator of variance at the subject level. Cohort fixed effects are included in these regressions, based on a test of their joint significance (for both treatments, p-value < 0.001, two-tailed Wald test). We find support for the earlier observation that lower bids are more likely to be accompanied by high quality in *Voluntary*, but that this relationship breaks down with the

(cohorts) and $t = 1, \dots, 30$ (periods). Independent variables are specific to the subject-cohort-period (x_{ijt}), subject only (z_i) or cohort only (o_j).

introduction of an arbitrator. Reassuringly, the order in which the values of μ are presented to sellers in *Arbitrator* has no significant effect on either bid or quality decisions.[28]

Table 5 – Determinants of seller bidding strategies.

Dependent variable	Bid		Prob. High Quality	
Estimation method	*Multilevel*		*IV*	
Treatment	*Voluntary*	*Arbitrator*	*Voluntary*	*Arbitrator*
Competitor's bid $_{t-1}$	0.222***	0.075***		
	(0.024)	(0.024)		
Bid			-0.016**	0.002
			(0.006)	(0.007)
Period	-0.302***	-0.510***	0.007	0.002
	(0.063)	(0.077)	(0.009)	(0.010)
$\mu = 2/3$		1.44		0.149
		(1.28)		(0.159)
OrderHL		8.37		0.178
		(9.38)		(0.490)
Constant	87.62***	85.38***	1.415*	-2.71
	(13.58)	(19.95)	(0.859)	(1.79)
Control variables	Yes	Yes	Yes	Yes
Cohort fixed effects	No	No	Yes	Yes
Observations	1,037	990	1,028	970
Subjects	36	36	36	36
Cohorts	6	6	6	6
Wald χ^2	149.8	85.08	51.53	45.57
χ^2 p-value	0.000	0.000	0.000	0.000
σ_v	15.01	11.08		
σ_u	9.60	5.44		
σ_ε	16.68	20.05		

Notes: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. The models in columns 1 and 2 are estimated using multilevel mixed effects linear regression and include two random effects intercepts that capture intra-session correlation at the subject and cohort levels, respectively. Coefficient estimates are presented, with standard errors in parentheses. The models in columns 3 and 4 are estimated using instrumental variable (IV) probit regression. Coefficient estimates are on the z-score scale, with robust standard errors clustered at the subject level. *Bid* is the continuous endogenous regressor and the excluded instrument is the once-lagged bid. The IV first stage is reported in Appendix B. The following control variables (not shown) are included: dummy for being female; dummy for being an economics and finance major; two Likert scales for self-reported willingness to take risks in general and in financial matters; dummy for reporting trust in strangers; and a generalised trust index. *OrderHL* is a dummy variable to indicate that the cohort followed the sequence μ = {2/3, 1/3} in the *Arbitrator* treatment. Period 1 is excluded from the models in column 1 and 3; periods 1 and 16 are excluded from the models in columns 2 and 4 due to the within-subjects design.

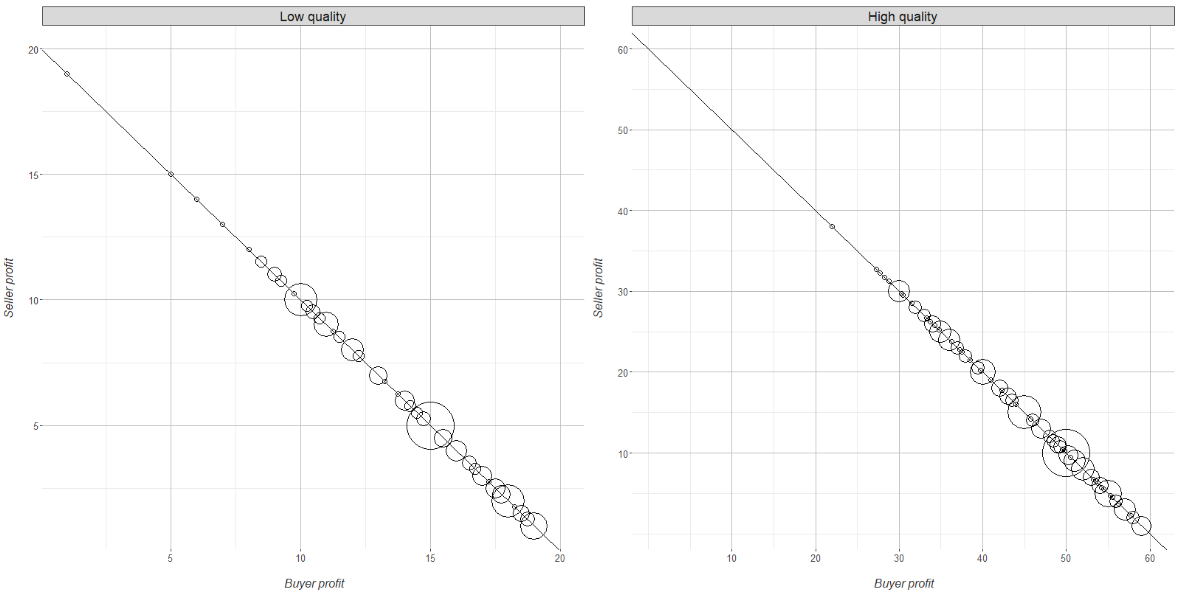
[28] No significant order effects are found for buyer behaviour either (see Appendix B).

5.3 *Reference-dependent buyers*

In this sub-section, I analyse buyer behaviour during the price proposal phase of the experiment. There are eighteen buyers in each treatment, each of whom is observed over thirty trading periods. We have data from 535 price proposal decisions in each treatment.

In *Voluntary*, only 23.7 percent of buyer choices are of the lower bound price. This varies by product quality, at 31.4 percent for low quality and less than fifteen percent for high quality. In Figure 4, I plot the range of surplus allocations in *Voluntary*, for all transactions in which the seller earns non-negative profit (423 out of 535). A further three transactions are excluded in which the buyer incurred a loss (these occurred early on and likely due to learning). The sizes of the open circles are weighted by the number of observations. The left (right) panel corresponds to low (high) quality trades. In both, there are concentrations at the salient fifty-fifty split. The most common allocations are found at three-to-one and five-to-one buyer to seller ratios.

Figure 4. Buyer surplus allocations in the *Voluntary* treatment.



Notes: Based on individual buyer decisions over the course of the experiment. The sizes of the open circles are weighted by the number of surplus allocations at the coordinate.

In *Arbitrator*, proposals of the lower bound price are observed more frequently: 46.8 percent of choices when $\mu = 1/3$, and 50.8 percent of choices when $\mu = 2/3$. These frequencies are stable across quality levels. Thus, a seller in this treatment could expect to encounter a strictly self-interested buyer on roughly one-half of transactions. Around one in five buyer choices in *Arbitrator* are "mimicking". That is, the buyer proposes the arbitrator's interim preferred price $p_{it}^{A\prime}$, given the winning bid and quality level delivered. Note that the arbitrator's interim preferred price does not necessarily coincide with the arbitrator's final price, because the arbitrator is constrained to award at least the buyer's proposal - equation (3) in the model. The frequency of mimicking choices was stable across quality levels. Most of the remaining price proposals are in the region between the lower bound price and the arbitrator's preferred price. Less than four percent of proposals awarded the seller more than what the arbitrator deemed a fair surplus split.

In both treatments, buyers learn to follow the equilibrium strategy as the experiment progresses. Non-parametric bootstrap tests of a positive time trend in the number of lower bound price proposals show strong significance across conditions.[29] The standard theory cannot, however, explain the persistence of mimicking choices in *Arbitrator*. When $\mu = 1/3$, no time trend is observed in the average number of such choices (p-value = 0.499). When $\mu = 2/3$, there is a significant *positive* time trend (p-value = 0.015).

One explanation for the persistence of mimicking choices is that some buyers have reference-dependent social preferences over outcomes. In the experiment, subjects are informed in advance about the arbitrator's preferred surplus allocation and when this would change. Buyers with a concern for fairness may have anchored their proposals on the arbitrator's interim preferred price $p_{it}^{A\prime}$ and perceived this as the fair reference point. If the reference point is determined by recently held expectations (e.g. Kőszegi and Rabin 2006), then we expect the proportion of mimicking choices to be stable across the *Arbitrator* sub-treatments. I refer to this as the *reference-dependent argument*. Its plausibility is suggested by the raw choice data: 22.3 percent of choices are mimicking when $\mu = 1/3$ and 20.7 percent when $\mu = 2/3$, respectively.

To test the reference-dependent argument, I separate buyers in *Arbitrator* into two behavioural types, self-interested (*Self*) or fair (*Fair*). I then estimate the parameters underlying each type's price proposal function using a finite mixture model. This structural approach will help us to identify the determinants of buyer behaviour in the experiment. The mixture model estimation procedure is adapted from Moffatt (2015) and full details are contained in Appendix D. The observation that buyers in *Arbitrator* tend to either offer the lower bound contract price or mimic the arbitrator's interim preferred price $p_{it}^{A\prime}$ is used to define the type strategies. Self-interested buyers propose the lower bound contract price. For fair buyers, I specify a latent model in which price proposals anchor on $p_{it}^{A\prime}$ with a normally distributed error term of variance s^2. The estimate on $p_{it}^{A\prime}$ for this type is expected to be close to one. An implicit assumption is that subjects do not switch between types.[30] A two-limit tobit model is appropriate, where the limits

[29] Based on 999 replications, *Voluntary*: Mean = 0.365, S.E. = 0.187, p-value = 0.027; *Arbitrator*, $\mu = 1/3$: Mean = 0.763, S.E. = 0.271, p-value < 0.001; *Arbitrator*, $\mu = 2/3$: Mean = 0.553, S.E. = 0.271, p-value = 0.026.

[30] Preliminary evidence to support these type definitions is obtained from raw strategy count data, which are presented in Appendix B. Buyers appear to gravitate towards one strategy during the experiment, rather than mixing between different strategies.

correspond to the lower and upper bounds of the contract price range and are specific to each buyer and period. The two buyer types are represented by the mixing fractions fr_{self} and fr_{fair}.

Maximum likelihood estimates obtained from this procedure are summarized in Table 6. Bootstrapped standard errors are calculated, with resampling clusters at the cohort level. The estimated fraction of self-interested buyers in *Arbitrator* is 0.611 and of fair buyers is 0.389 (p-value < 0.001). Consistent with the reference-dependent argument, the coefficient estimate on $p_{it}^{A\prime}$ at 0.971 is not significantly different from one (p-value = 0.853, two-sided Wald test).

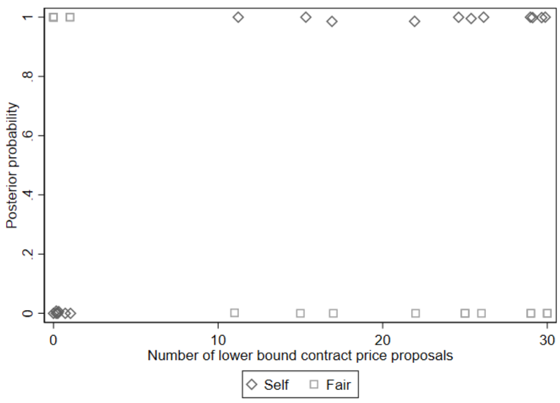
Table 6 – Maximum likelihood estimates from the finite mixture two-limit Tobit model of buyer behaviour in the *Arbitrator* treatment.

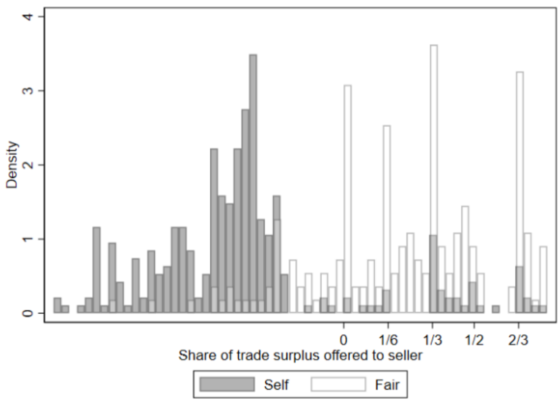
Fair buyers	
$p_{it}^{A\prime}$	0.971 (0.158)***
Constant	-3.64 (5.76)
s	8.51 (6.54)
Mixing fractions	
fr_{self}	0.611 (0.084)***
fr_{fair}	0.389 (0.084)***
Observations	535
Wald χ^2	37.97
χ^2 p-value	0.000
(Subjects, Periods)	(18, 30)

Notes: *** p < 0.01, ** p < 0.05, * p < 0.1. Bootstrapped standard errors in parentheses, clustered at the cohort level, based on 999 bootstrap replications.

In Figure 5, panel (a), I display the posterior type probabilities obtained from estimation of the mixture model, as a function of the number of lower bound proposals. The model fully separates buyers into the two types. A large cluster of buyers in *Arbitrator* never choose the lower bound price and these subjects fall naturally into the fair type category. Self-interested types are identified as choosing the equilibrium (minimal) price on more than ten transactions. Panel (b) of the figure presents the histogram of price proposals by type, as a share of the trade surplus. For fair types, the largest densities can be found at proposals equal to 1/3 and 2/3 of the surplus. I exclude any proposal equal to the winning bid (35 observations) because these do not necessarily reflect a buyer's true preference. If we include these observations, the mass at 1/3 of the surplus increases.

Figure 5. Finite mixture model validation.





(a) Posterior type probabilities. (b) Histogram of buyer type proposals.

Notes: Panel (a) contains a jittered scatter plot of posterior type probabilities from the finite mixture two-limit Tobit model. Panel (b) contains a histogram of buyer price proposals as a share of the trade surplus, excluding upper censored price proposals and one outlying observation in which a buyer offered more than the full trade surplus to the seller.

6. Conclusion

Arbitration is a common method of alternative dispute resolution in procurement interactions characterised by moral hazard. By embedding a contingency into the contract, trade parties can avoid the prohibitive costs of lengthy court proceedings and align incentives to maximise the gains from trade. I use a combination of theory and lab experiments to analyse the effect of a contractual contingency in such an environment. The seller is determined by a price-based procurement auction and the contract price is renegotiable. In theory, with a non-contingent contract, trade is inefficient. A contingent contract, meanwhile, can establish welfare-enhancing trust, with increased bidding competition and improved product quality.

A notable implication of the equilibrium analysis is that, in a broad sense, arbitration does not benefit the seller – expected seller profits are zero, with or without a contingent contract. Buyers, who hold the balance of market power, do benefit. The model can rationalize why powerful corporations may favour the use of arbitration agreements, from simple profit-maximizing behaviour. Another interesting implication arises from the finding that uncertainty is a necessary condition for the effectiveness of a contingent contract. That is, if the auction selection rule is price-based, then making an arbitrator available with 100 percent probability is (i) always inefficient and (ii) welfare-decreasing if there exists an efficient contingent contract with a probabilistic arbitrator. Since the total arbitration cost increases in the relative frequency with which an arbitrator is employed, any industry scheme guaranteeing the availability of an arbitrator during trade may incur an unnecessary and counter-productive expense. Potential sellers can use such information to lower their bids and increase their probability of winning the contract. That sellers may lower their bids, in expectation of recovering costs through a dispute mechanism, was recognised in a recent survey of industry practitioners.[31]

The experiment results demonstrate that the contingent contract is robust in the sense that it relies only on the regard of each party to their own interest: high quality remains incentive compatible on average, despite a significant fall in buyer reciprocity. This crowding out effect is consistent with prior evidence from labour market experiments on the demotivating effects of explicit incentives (e.g. Fehr and Gächter 2000, Fehr et al. 2007), and with principal-agent literature on the hidden costs of incentive devices (e.g. Falk and Kosfeld 2006). There is also evidence of reference-dependency in buyers' payment decisions (e.g. Kőszegi and Rabin 2006), which enables the contingent contract to weakly improve the position of sellers in the experiment.

Both the flexible price contract structures tested in the lab imply large efficiency gains over a rigid, fixed-price contract, which performs poorly in procurement auctions with seller moral hazard (Brosig-Koch and Heinrich 2014, Fugger et al. 2019). There are, of course, alternative mechanisms to mitigate the seller moral hazard problem, such as buyer-determined auctions and systems of reputation. Since there is a cost involved in organising an arbitration scheme, these mechanisms may be complementary and/or preferable in certain settings.

An optimal dispute resolution mechanism was employed in the experiment, as implemented by a computer program. Whether or not trade parties make optimal use of dispute resolution is an interesting question for future work. An alternative avenue would be to assess how payment norms emerge endogenously if a human arbitrator(s) were introduced into the experiment. Third-party punishment behaviours have been observed to serve a useful function in enforcing distributional norms (e.g. Fehr and Fischbacher 2004). Whether social norms emerge in a competitive procurement environment, and whether the incentives offered by third parties are enough to promote efficient trade relationships, is a question best answered empirically.

A consequence of the competitive bidding environment is that the buyer appropriates most of the surplus from trade. Small supplier profit margins are characteristic of many procurement settings. For example, publicly traded highway construction firms in the sample of Bajari et al. (2014) report profit margins of less than three percent. It would, however, be interesting to extend the analysis to more balanced market environments or those in which the seller holds market power. The assumption that buyers are endowed with full bargaining power is often used in the contract-theoretic literature to create the most severe hold-up problem (e.g. Hart and Moore 1999, Hoppe and Schmitz 2011). The model might also be extended to allow for an investigation of a seller's relative bargaining power in determining the final price. A further

[31] Pinsent Masons (2019, p 7): "Some interviewees noted that they had observed project participants bidding a lower price upon the expectation of recovering sums through variation orders which, if disputed, could be arbitrated."

assumption is that the arbitrator's preferred settlement is a known and deterministic function of the transaction price and quality. In practice, this decision is likely to involve some noise, especially when the facts of the case are difficult to verify. This *caveat* should be kept in mind if drawing policy implications, which may overstate the effects of an arbitrator in real-world dispute resolution. Introducing a stochastic component into the arbitrator's preference set would be a useful extension in future work.

References

Alekseev, A., Charness, G., & Gneezy, U. (2017). Experimental methods: When and why contextual instructions are important. *Journal of Economic Behavior & Organization, 134*, 48-59.

Allison, J. R. (1990). Five ways to keep disputes out of court. *Harvard Business Review, 68*(1), 166-177.

Andreoni, J., & Bernheim, B. D. (2009). Social Image and the Fifty-Fifty Norm: A Theoretical and Experimental Analysis of Audience Effects. *Econometrica, 77*(5), 1607-1636.

Arcadis (2020). *Global Construction Disputes Report*. Retrieved from: https://www.arcadis.com/en/united-states/our-perspectives/global-construction-disputes-report-2020/.

Ashenfelter, O., Currie, J., Farber, H. S., & Spiegel, M. (1992). An Experimental Comparison of Dispute Rates in Alternative Arbitration Systems. *Econometrica, 60*(6), 1407-1433.

Ashenfelter, O. C., & Bloom, D. E. (1984). Models of Arbitrator Behavior: Theory and Evidence. *American Economic Review, 74*(1), 111-124.

Bajari, P., Houghton, S., & Tadelis, S. (2014). Bidding for incomplete contracts: An empirical analysis of adaptation costs. *American Economic Review, 104*(4), 1288-1319.

Bartling, B., & Schmidt, K. M. (2015). Reference points, social norms, and fairness in contract renegotiations. *Journal of the European Economic Association, 13*(1), 98-129.

Baye, M. R., & Morgan, J. (1999). A Folk Theorem for One-Shot Bertrand Games. *Economics Letters, 65*(1), 59-65.

Bazerman, M. H., & Gillespie, J. J. (1999). Betting on the future: The virtues of contingent contracts. *Harvard Business Review, 77*, 155-162.

Bednar, J., Chen, Y., Liu, T. X., & Page, S. (2012). Behavioral spillovers and cognitive load in multiple games: An experimental study. *Games and Economic Behavior, 74*(1), 12-31.

Bock, O., Baetge, I., & Nicklisch, A. (2014). hroot: Hamburg registration and organization online tool. *European Economic Review, 71*, 117-120.

Bolton, G. E., & Katok, E. (1998). Reinterpreting Arbitration's Narcotic Effect: An Experimental Study of Learning in Repeated Bargaining. *Games and Economic Behavior, 25*(1), 1-33.

Bolton, G. E., & Ockenfels, A. (2000). ERC: A theory of equity, reciprocity, and competition. *American Economic Review, 90*(1), 166-193.

Brandts, J., Ellman, M., & Charness, G. (2015). Let's talk: How communication affects contract design. *Journal of the European Economic Association, 14*(4), 943-974.

Brosig-Koch, J., & Heinrich, T. (2014). Reputation and mechanism choice in procurement auctions: An experiment. *Production and Operations Management, 23*(2), 210-220.

Brown, M., Falk, A., & Fehr, E. (2004). Relational contracts and the nature of market interactions. *Econometrica, 72*(3), 747-780.

Cameron, A. C., Gelbach, J. B., & Miller, D. L. (2008). Bootstrap-Based Improvements for Inference with Clustered Errors. *Review of Economics and Statistics, 90*(3), 414-427.

Chang, W.-S., Salmon, T. C., & Saral, K. J. (2016). Procurement auctions with renegotiation and wealth constraints. *Economic Inquiry, 54*(3), 1684-1704.

Che, Y.-K. (1993). Design competition through multidimensional auctions. *RAND Journal of Economics, 24*(4), 668-680.

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

Chen-Ritzo, C.-H., Harrison, T. P., Kwasnica, A. M., & Thomas, D. J. (2005). Better, Faster, Cheaper: An Experimental Analysis of a Multiattribute Reverse Auction Mechanism with Restricted Information Feedback. *Management Science, 51*(12), 1753-1762.

Crawford, V. P. (1981). Arbitration and Conflict Resolution in Labor-Management Bargaining. *American Economic Review, 71*(2), 205-210.

Crawford, V. P. (1985). The role of arbitration and the theory of incentives. In A. E. Roth (Ed.), *Game-Theoretic Models of Bargaining*. Cambridge, MA: Cambridge Univ. Press.

Davis, A. M., & Leider, S. (2018). Contracts and Capacity Investment in Supply Chains. *Manufacturing & Service Operations Management, 20*(3), 403-421.

Deck, C., Farmer, A., & Zeng, D.-Z. (2007). Amended Final-Offer Arbitration over an Uncertain Value: A Comparison with CA and FOA. *Experimental Economics, 10*(4), 439-454.

Deck, C. A., & Farmer, A. (2007). Bargaining over an Uncertain Value: Arbitration Mechanisms Compared. *Journal of Law, Economics, and Organization, 23*(3), 547-579.

Elmaghraby, W., & Katok, E. (2018). Behavioral research in competitive bidding and auction design. In K. Donohue, E. Katok, & S. Leider (Eds.), *The Handbook of Behavioral Operations*. Hoboken, NJ: Wiley.

Falk, A., & Kosfeld, M. (2006). The hidden costs of control. *American Economic Review, 96*(5), 1611-1630.

Farber, H. S. (1980). An analysis of final-offer arbitration. *Journal of Conflict Resolution, 24*(4), 683-705.

Farber, H. S., & Katz, H. C. (1979). Interest Arbitration, Outcomes, and the Incentive to Bargain. *Industrial and Labor Relations Review, 33*(1), 55-63.

Fehr, E., & Fischbacher, U. (2004). Third-party punishment and social norms. *Evolution and Human Behavior, 25*(2), 63-87.

Fehr, E., & Gächter, S. (2000). Fairness and retaliation: The economics of reciprocity. *Journal of Economic Perspectives*, *14*(3), 159-181.

Fehr, E., Hart, O., & Zehnder, C. (2011). Contracts as reference points—experimental evidence. *American Economic Review, 101*(2), 493-525.

Fehr, E., Hart, O., & Zehnder, C. (2015). How do informal agreements and revision shape contractual reference points? *Journal of the European Economic Association, 13*(1), 1-28.

Fehr, E., Kirchsteiger, G., & Riedl, A. (1993). Does fairness prevent market clearing? An experimental investigation. *Quarterly Journal of Economics, 108*(2), 437-459.

Fehr, E., Klein, A., & Schmidt, K. M. (2007). Fairness and contract design. *Econometrica, 75*(1), 121-154.

Fugger, N., Katok, E., & Wambach, A. (2019). Trust in procurement interactions. *Management Science, 65*(11), 5110-5127.

Gabuthy, Y., Jacquemet, N., & Marchand, N. (2008). Does Resorting to Online Dispute Resolution Promote Agreements? Experimental Evidence. *European Economic Review, 52*(2), 259-282.

Gabuthy, Y., & Muthoo, A. (2019). Bargaining and Hold-Up: The Role of Arbitration. *Oxford Economic Papers, 71*(1), 292-308.

Hart, O., & Moore, J. (1999). Foundations of Incomplete Contracts. *Review of Economic Studies, 66*(1), 115-138.

Hart, O., & Moore, J. (2008). Contracts as reference points. *Quarterly Journal of Economics, 123*(1), 1-48.

Herweg, F., & Schmidt, K. M. (2020). Procurement with Unforeseen Contingencies. *Management Science, 66*(5), 2194-2212.

Herweg, F., & Schwarz, M. A. (2018). Optimal Cost Overruns: Procurement Auctions with Renegotiation. *International Economic Review, 59*(4), 1995-2021.

Hoppe, E., & Schmitz, P. (2011). Can contracts solve the hold-up problem? Experimental evidence. *Games and Economic Behavior, 73*(1), 186-199.

Kőszegi, B., & Rabin, M. (2006). A model of reference-dependent preferences. *Quarterly Journal of Economics, 121*(4), 1133-1165.

Moffatt, P.G. (2015) Experimetrics: Econometrics for Experimental Economics. Palgrave Macmillan.

Onderstal, S., & Yang, Y. (2020). Cheap-talk Communication in Procurement Auctions: Theory and Experiment. Tinbergen Institute Discussion Paper 2020-013/VII. http://dx.doi.org/10.2139/ssrn.3542737.

Pecorino, P., & Van Boening, M. (2001). Bargaining and Information: An Empirical Analysis of a Multistage Arbitration Game. *Journal of Labor Economics, 19*(4), 922-948.

Pinsent Masons (2019). *International Arbitration Survey – Driving Efficiency in International Construction Disputes*. Retrieved from:

https://www.pinsentmasons.com/thinking/special-reports/international-arbitration-survey.

Shachat, J., & Tan, L. (2015). An experimental investigation of auctions and bargaining in procurement. *Management Science, 61*(5), 1036-1051.

Tirole, J. (1986). Procurement and Renegotiation. *Journal of Political Economy, 94*(2), 235-259.

Waehrer, K. (1995). A Model of Auction Contracts with Liquidated Damages. *Journal of Economic Theory, 67*(2), 531-555.

Walker, M. J., Katok, E., & Shachat, J. (2020). Trust and trustworthiness in procurement contracts with retainage. ESI Working Paper 20-34.

Wang, R. (2000). Bidding and Renegotiation in Procurement Auctions. *European Economic Review, 44*(8), 1577-1597.

Appendix A: Incentive compatibility constraint with a contingent contract.

There are three cases to consider for the incentive compatibility of high quality at Stage 3 of the competitive procurement interaction, which depend on the cost of arbitration k in relation to the arbitration probability σ, the arbitrator's preferences μ and the lower bound contract price $\underline{p}$. The arbitrator's decision rule z^q is defined in equation (3) of the main text.

Case (i): $k \geq \frac{(1-\sigma)}{\sigma}(z^H(\mu) - \underline{p})$.

High quality is incentive compatible if $z^H(\mu) - max\left\{\underline{p}, z^L(\mu)\right\} > c(q^H) - c(q^L)$.

Proof. The buyer proposes a trading price equal to $z^H(\mu)$ in exchange for high quality and $max\left\{\underline{p}, z^L(\mu)\right\}$ in exchange for low quality. The seller opts not to invoke the arbitration clause at Stage 5 and so incentive compatibility follows directly from the associated delivery costs $c(q)$. ■

Case (ii): $\frac{(1-\sigma)}{\sigma}\left(z^L(\mu) - \underline{p}\right) < k < \frac{(1-\sigma)}{\sigma}\left(z^H(\mu) - \underline{p}\right)$.

High quality is incentive compatible if $\sigma > \frac{c(q^H)-c(q^L)+max\left\{\underline{p}, z^L(\mu)\right\}-\underline{p}}{z^H(\mu)-\underline{p}}$.

Proof. The buyer proposes a trading price equal to $\underline{p}$ in exchange for high quality and $max\left\{\underline{p},\ z^L(\mu)\right\}$ in exchange for low quality. The seller opts to invoke the arbitration clause at Stage 5 only if he delivers high quality. In that scenario, the buyer bears the direct cost of arbitration. The incentive-compatibility condition follows directly from the associated delivery costs $c(q)$ and the probability of arbitration σ. ■

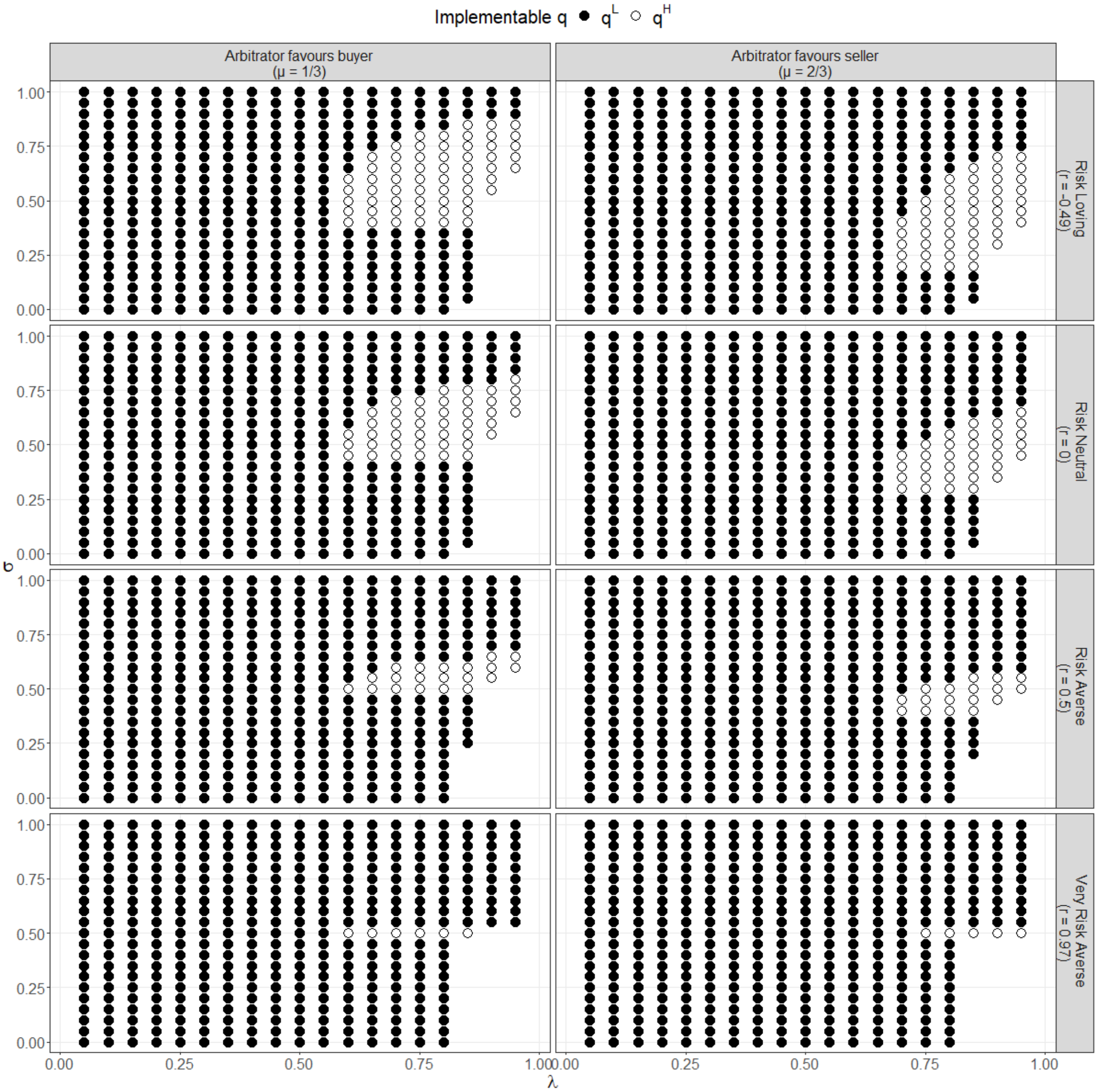
Case (iii): $k \leq \frac{(1-\sigma)}{\sigma}(z^L(\mu) - \underline{p})$.

High quality is incentive compatible if $\sigma > \frac{c(q^H)-c(q^L)}{z^H(\mu)-z^L(\mu)}$.

Proof. This case exists if and only if $z^L(\mu) \geq \underline{p}$. The buyer proposes a trading price equal to $\underline{p}$ both in exchange for high quality and low quality. The seller opts to invoke the arbitration clause at Stage 5 regardless of the quality level. The buyer again bears the direct cost of arbitration and the incentive-compatibility condition follows directly. ■

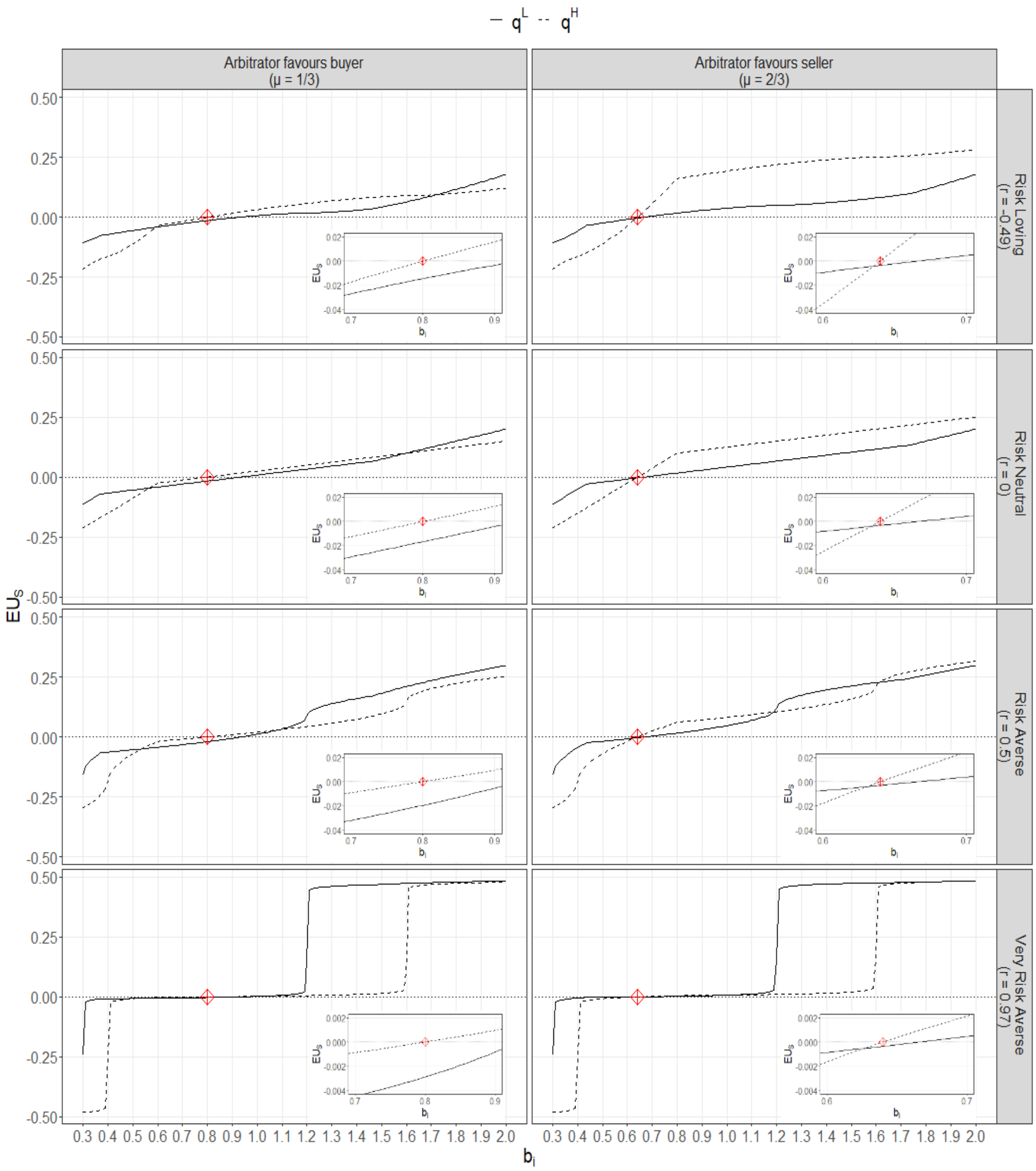
Appendix B: Additional figures and tables.

Figure A. 1. Implementable quality level by contract for the CRRA utility case (experiment parameters are without loss of generality).



Notes: The figure assumes that potential sellers formulate their bidding strategies based on the CRRA utility function $u(\pi_S) = \pi_S{}^{(1-r)}/(1-r)$ for $\pi_S \geq 0$ and $u(\pi) = -(-\pi_S)^{(1-r)}/(1-r)$ for $\pi_S < 0$, where r measures the degree of relative risk aversion. A contract is defined by the probability of arbitration σ and the degree of flexibility λ. The empty regions correspond to contracts for which no profitable bidding strategy exists, given the maximum bid limit in the experiment.

Figure A. 2. Expected seller dispute utilities conditional on submitting the winning bid (*Equilibrium Implementability Condition* is satisfied in *Arbitrator* for all levels of risk aversion).



Notes: The figure assumes that potential sellers formulate their strategies based on the CRRA utility function $u(\pi_S) = \pi_S{}^{(1-r)}/(1-r)$ for $\pi_S \geq 0$ and $u(\pi) = -(-\pi_S)^{(1-r)}/(1-r)$ for $\pi_S < 0$, where r measures the degree of relative risk aversion. The red diamond plus is the equilibrium bid level. Inset in each panel is the subset of the discrete price grid in which the *Equilibrium Implementability Condition* is satisfied.

Figure A. 3. CDFs of seller auction bids in the experiment (supports Results 1(a) and1(b)).

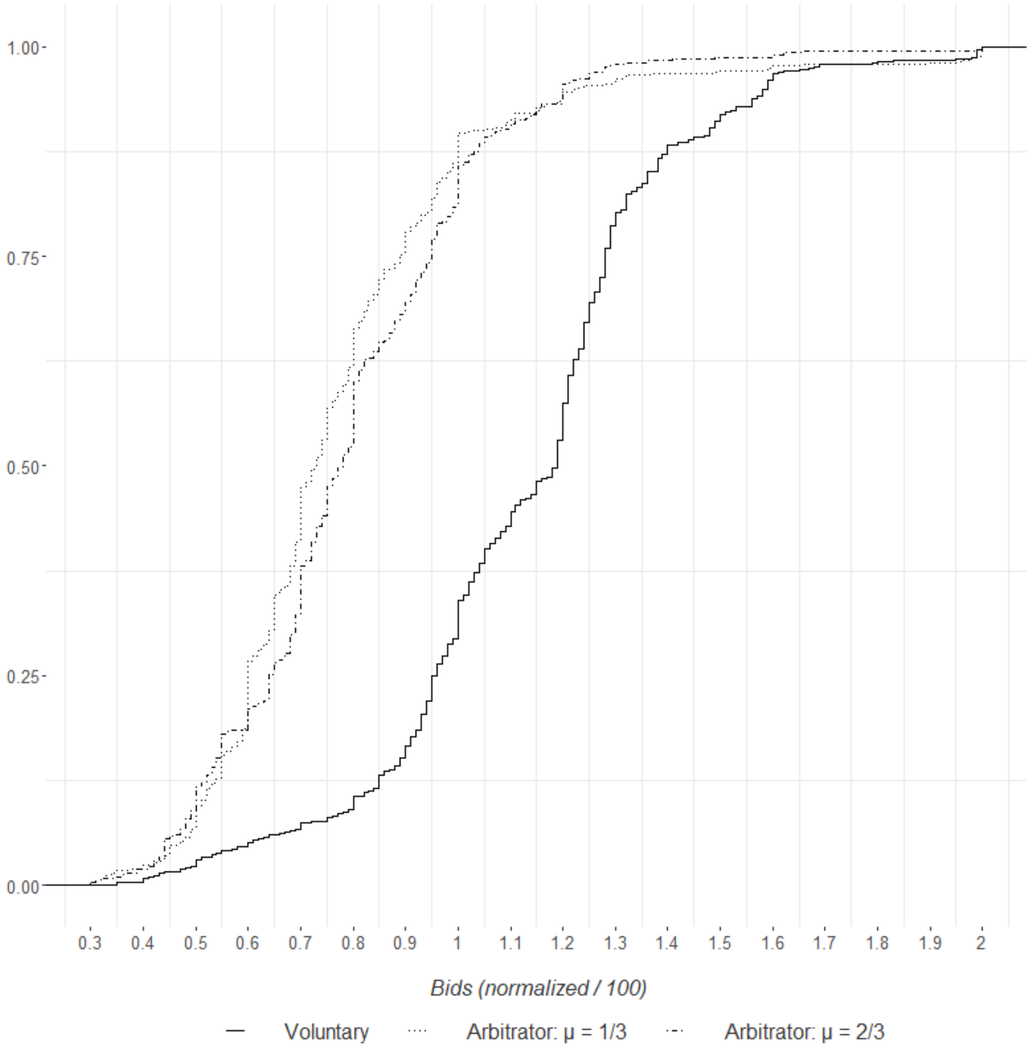
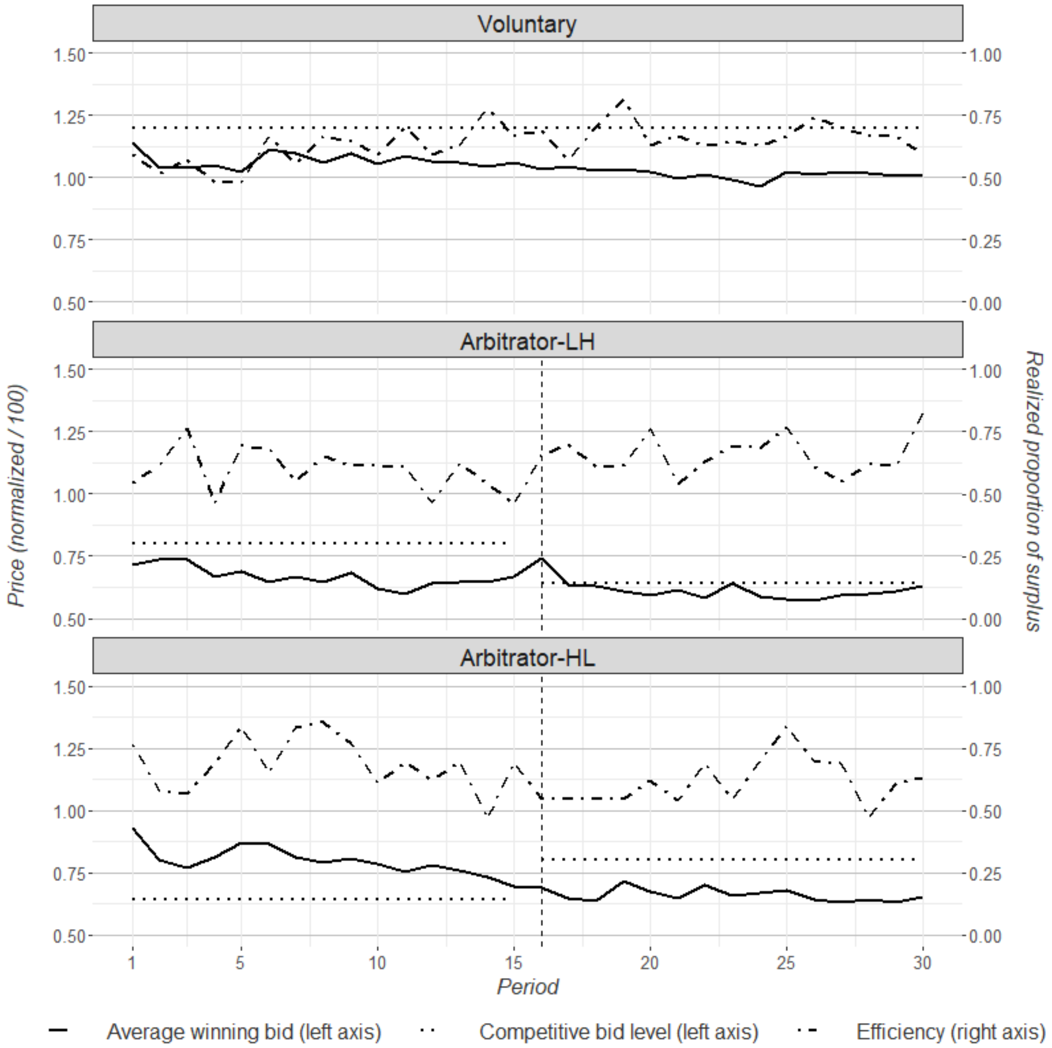
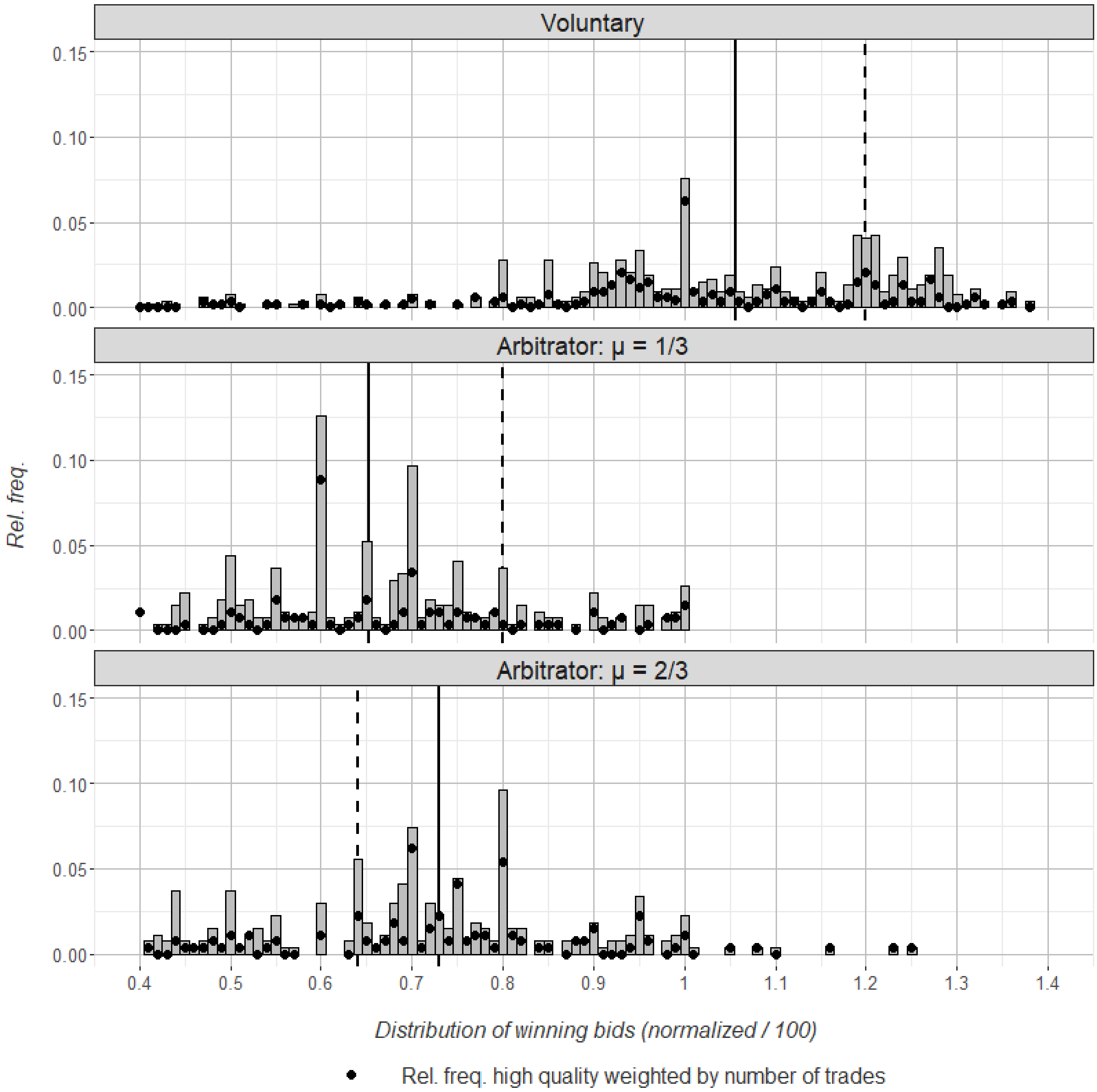


Figure A. 4. Winning bids and trade efficiency over time.



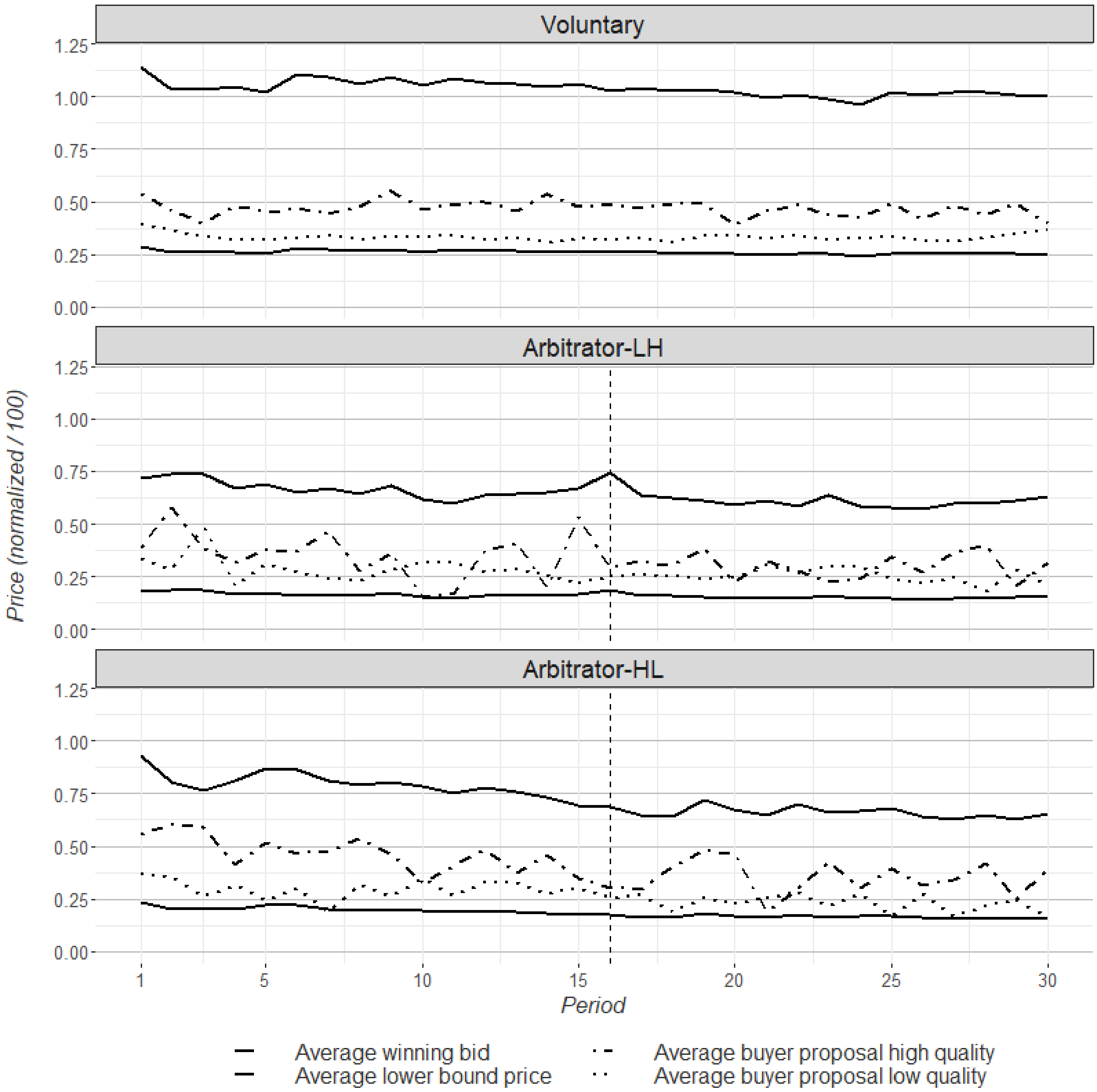
Notes: The vertical dashed line in the *Arbitrator* treatment panels represents the change in the arbitrator's preference parameter μ after period fifteen. *Arbitrator-LH* corresponds to those cohorts assigned to the sequence $\mu = \{1/3, 2/3\}$ and *Arbitrator-HL* to those cohorts assigned to the sequence $\mu = \{2/3, 1/3\}$.

Figure A. 5. Distribution of winning bids and the relative frequency of high quality in the experiment.



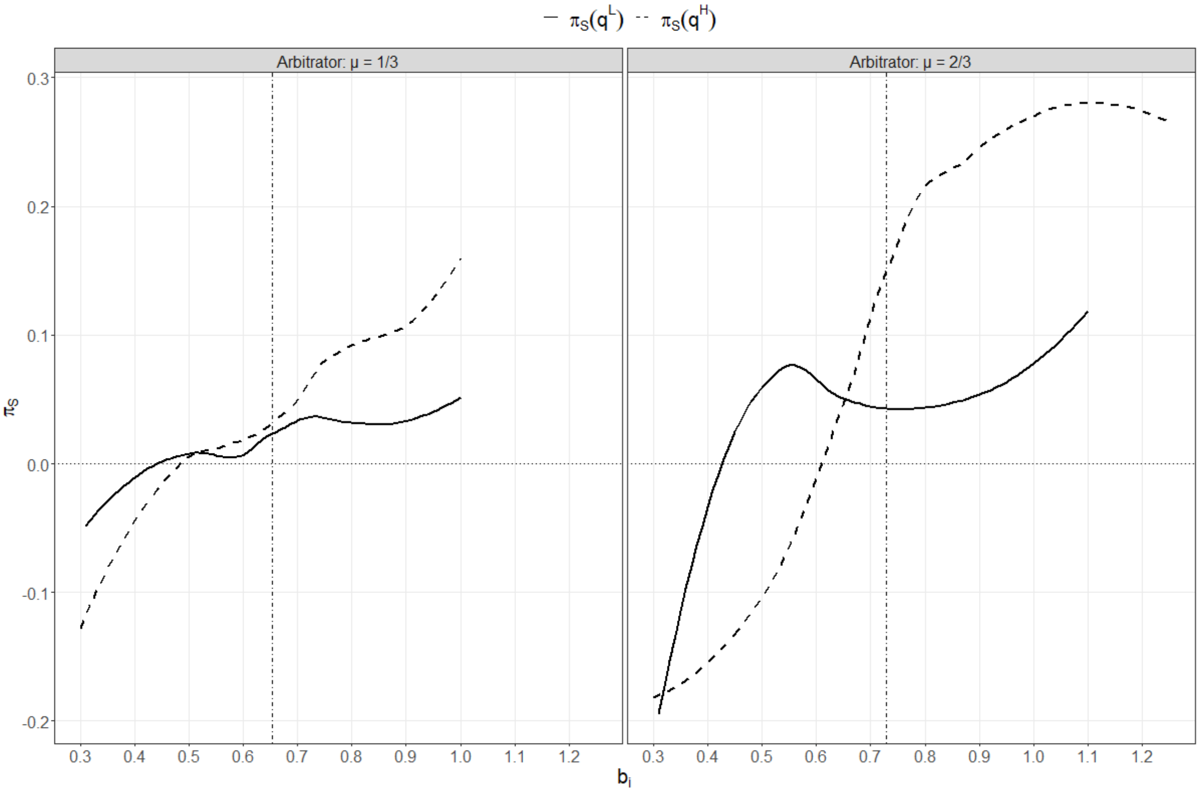
Notes: The vertical dashed line is the equilibrium bid level. The vertical solid line is the median winning bid observed in the experiment.

Figure A. 6. Contract price ranges and buyer reciprocity over time in the experiment.



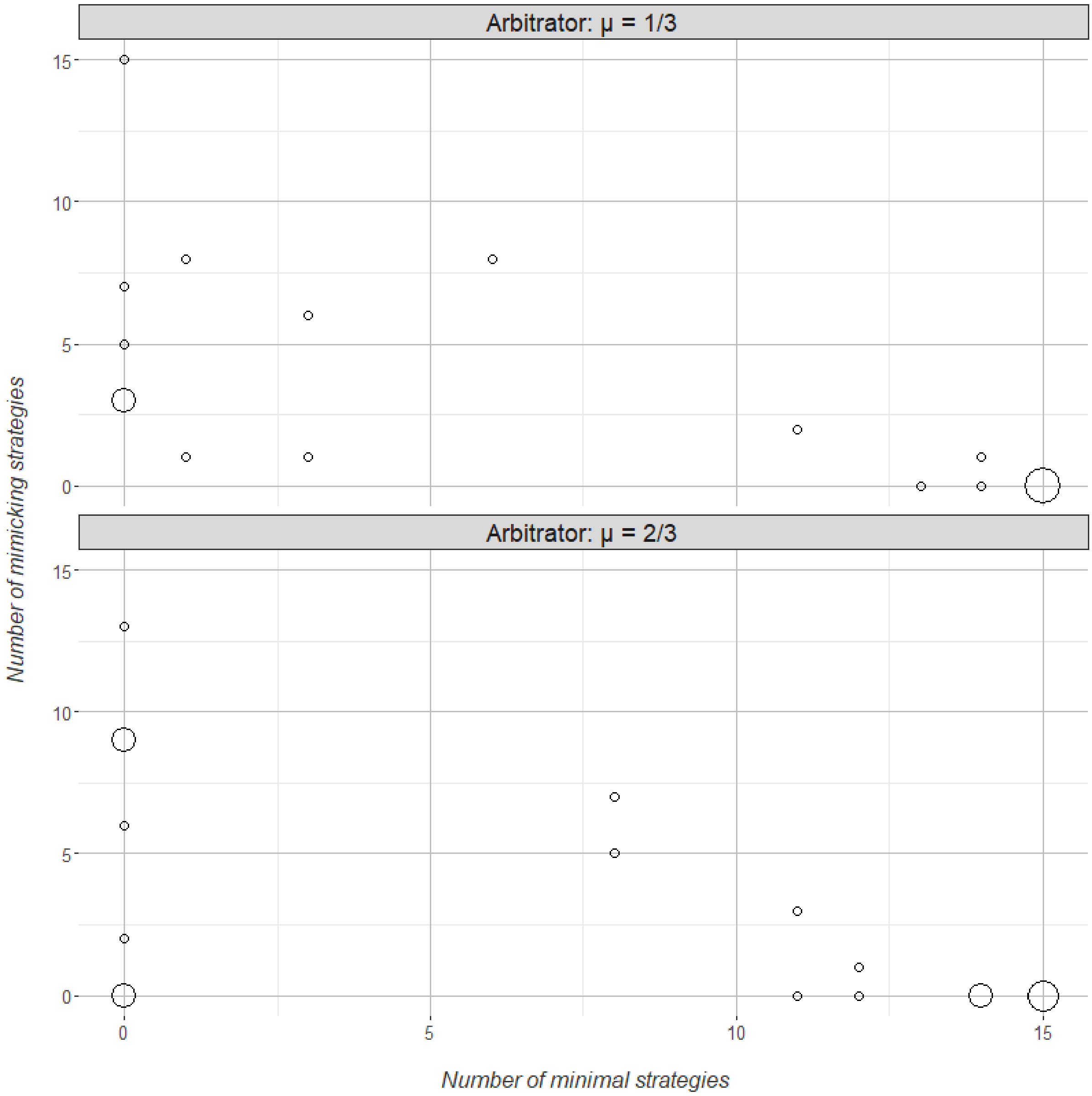
Notes: The vertical dashed line in the *Arbitrator* treatment panels represents the change in the arbitrator's preference parameter μ after period fifteen. *Arbitrator-LH* corresponds to those cohorts assigned to the sequence $\mu = \{1/3, 2/3\}$ and *Arbitrator-HL* to those cohorts assigned to the sequence $\mu = \{2/3, 1/3\}$.

Figure A. 7. Seller profits as a function of the winning bid observed in the *Arbitrator* treatment: High quality is incentive compatible on average.



Notes: The vertical dot-dash line is the median winning bid observed in the respective experiment condition.

Figure A. 8. Individual buyer strategy counts in the *Arbitrator* treatment.



Notes: Based on individual buyer decisions over the course of the experiment. The size of the open circles is weighted by the number of buyers at the coordinate. Minimal strategies are defined as buyer choices to propose the lower bound contract price. Mimicking strategies are defined as buyer choices to propose the arbitrator's interim preferred price $p_{it}^{A\prime}$ +/- 2. We permit a tolerance of two points either side of the arbitrator's interim preferred price to reflect the granularity of the buyer's price proposal slider. This slider was set at increments of 0.25 points, which did not always permit the arbitrator's preferred price to be selected exactly.

Table A. 1 – Summary of experiment outcomes from periods one to fifteen only in the *Arbitrator* treatment (relates to behavioural spillover analysis in Section 5.1).

Measure / Treatment	*Arbitrator-LH* ($\mu = 1/3$)	*Arbitrator-HL* ($\mu = 2/3$)
Winning bid	71.16	75.00
Product quality	0.42	0.56
Proposal / surplus	-0.16	0.01
Low quality	-0.19	0.04
High quality	-0.12	-0.04
Buyer profit	31.80	23.19
Low quality	14.50	12.09
High quality	55.04	38.56
Seller profit	4.78	16.01
Low quality	4.86	7.24
High quality	4.12	20.35
Efficiency	60%	69%

Notes: The table summarises the main outcomes of the *Arbitrator* treatment based on data from periods one to fifteen only. *Arbitrator-LH* corresponds to those cohorts assigned to the sequence $\mu = \{1/3, 2/3\}$ and *Arbitrator-HL* to those cohorts assigned to the sequence $\mu = \{2/3, 1/3\}$. This precludes the possibility of behavioural spillover effects between the first and second half of the experiment. All values are median cohort averages, based on three independent cohorts per treatment. *Winning bid* is the lowest bid submitted by potential sellers in the auction phase; *Product quality* measures the relative frequency that high quality is chosen for delivery by the winning seller; *Proposal / surplus* measures the buyer's price proposal as a share of trade surplus; *Buyer profit* is the trade profit per round for the buyer; *Seller profit* is the trade profit per round for the winning seller; *Efficiency* measures the realised percentage of attainable trade surplus net of any arbitration cost incurred.

Table A. 2 – Average seller bids by quality level in the experiment.

Treatment	*Voluntary*	*Arbitrator*	
Sub-treatment		$\mu = 1/3$	$\mu = 2/3$
Low quality strategies	118.35	73.29	78.95
High quality strategies	109.71	78.66	85.38

Notes: The table presents seller bids from the strategy method data, by the quality level selected. All values are median cohort averages, based on six independent cohorts per treatment.

Table A. 3 – Frequencies of buyer choices in the *Arbitrator* treatment.

Sub-treatment	$\mu = 1/3$	$\mu = 2/3$
Minimal	0.468	0.508
Low quality	0.471	0.496
High quality	0.465	0.518
Mimicking	0.223	0.207
Low quality	0.232	0.216
High quality	0.211	0.199

Notes: The table displays relative frequencies of buyer choices to propose the lower bound contract price (minimal) and the arbitrator's interim preferred price $p_{it}^{A\prime}$ +/- 2 (mimicking). We permit a tolerance of two points either side of the arbitrator's interim preferred price to reflect the granularity of the buyer's price proposal slider. This slider was set at increments of 0.25 points, which did not always permit the arbitrator's preferred price to be selected exactly. The missing categories are price proposals between minimal and mimicking, and price proposals above mimicking.

Table A. 4 – IV first stage estimates: Determinants of quality level in seller bidding strategies (relates to Section 5.2 in the main text).

Dependent variable	*Bid*	
Estimation method	*IV*	
Treatment	*Voluntary*	*Arbitrator*
Bid $_{t-1}$	0.603***	0.412***
	(0.050)	(0.066)
Period	-0.129	-0.279**
	(0.082)	(0.120)
$\mu = 2/3$		0.654
		(1.411)
OrderHL		-5.712**
		(2.618)
Constant	39.004***	68.752***
	(6.646)	(11.402)
Control variables	Yes	Yes
Cohort fixed effects	Yes	Yes
Observations	1,028	970
Subjects	36	36
Cohorts	6	6
F test of excluded instruments	142.04***	38.44***
Cragg-Donald Wald F statistic	615.13	181.72

Notes: *** p < 0.01, ** p < 0.05, * p < 0.1. Coefficient estimates, with robust standard errors clustered at the subject level. Cohort fixed effects are included. The following control variables (not shown) are included: dummy for being female; dummy for being an economics and finance major; two Likert scales for self-reported willingness to take risks in general and in financial matters; dummy for reporting trust in strangers; and a generalised trust index. *OrderHL* is a dummy variable to indicate that the cohort followed the sequence μ = {2/3, 1/3} in the *Arbitrator* treatment. Periods 1 and 16 are excluded due to the within-subjects design.

Table A. 5 – Determinants of buyer price proposals (no significant order effects).

Dependent variable	Price proposal	
Estimation method	*Multilevel*	
Treatment	*Voluntary*	*Arbitrator*
Lower bound contract price	0.493***	1.347***
	(0.077)	(0.168)
Product quality	13.168***	9.389***
	(0.649)	(0.988)
Period	-0.037	-0.263***
	(0.036)	(0.062)
$\mu = 2/3$		1.428
		(0.978)
OrderHL		8.940
		(6.475)
Constant	45.201***	-62.141**
	(17.029)	(25.577)
Control variables	Yes	Yes
Observations	535	535
Subjects	18	18
Cohorts	6	6
Wald χ^2	454.6	287.7
χ^2 *p*-value	0.000	0.000
σ_v	0.000	0.000
σ_u	6.881	9.549
σ_ε	7.118	11.09

Notes: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. The models are estimated using mixed effects linear regression and include two random effects intercepts that capture intra-session correlation at the subject and cohort levels, respectively. Coefficient estimates are presented, with standard errors in parentheses. The following control variables (not shown) are included: dummy for being female; dummy for being an economics and finance major; two Likert scales for self-reported willingness to take risks in general and in financial matters; dummy for reporting trust in strangers; and a generalised trust index. *OrderHL* is a dummy variable to indicate that the cohort followed the sequence μ = {2/3, 1/3} in the *Arbitrator* treatment.

Appendix C: Robustness check of aggregate experiment findings.

In this section of the appendix, I validate Results 1 to 4 (see Section 5.1 of the main text) using an OLS regression procedure based on disaggregated data at the matching group level. There are 540 matching groups in each treatment. Data from all periods are included and I incorporate a time trend. There are dummies for each of the *Arbitrator* sub-treatments. The *Voluntary* treatment is omitted. Robust standard errors are clustered at the cohort level to control for intra-cohort dependencies – matching groups are randomly reconstituted each round within a cohort. Since the number of clusters is small (six), standard asymptotic inference is liable to over-reject (Cameron et al. 2008). Thus, I also present p-values using wild cluster bootstrap tests of linear hypotheses (Roodman et al. 2019). The results are contained in Table A. 6.

Column 1 of the table supports Results 1(a) and 1(b). On average, winning auction bids are 34 to 38 points lower in the respective *Arbitrator* sub-treatments than in the *Voluntary* treatment (both p-values < 0.01, cluster bootstrap-t tests). There is some evidence of a decreasing trend in bids over time (p-value = 0.098, cluster bootstrap-t test). The difference in winning bids between the *Arbitrator* sub-treatments is not in the direction predicted by the theory.

Result 2 states that there is no significant difference in trade efficiency between a contingent and non-contingent contract. Since this insight is based on a null finding, it is important to check whether the null result still obtains in the matching group data. This is of particular interest for the comparison between *Voluntary* and *Arbitrator* when $\mu = 2/3$. Indeed, a power calculation suggests that this pairwise comparison at the cohort-level only has around 13 percent power to detect an effect size of the magnitude observed in the data.[1] Column 2 of the table supports Result 2. There is no significant increase in trade efficiency with a contingent contract than without ($\mu = 1/3$, p-value = 0.399; $\mu = 2/3$, p-value = 0.699; score bootstrap-t tests). This does not change significantly over time in the experiment (p-value = 0.518, score bootstrap-t test). We fail to reject a linear hypothesis test that the coefficient estimates on the *Arbitrator* sub-treatment dummies are equal (p-value = 0.404, score bootstrap-t test).

Column 3 of the table supports Result 3. Buyer price proposals as a proportion of trade surplus are significantly lower with a contingent contract, both when $\mu = 1/3$ (p-value < 0.01, cluster bootstrap-t test) and when $\mu = 2/3$ (p-value = 0.011, cluster bootstrap-t test). This is consistent with a crowding out of buyer reciprocity. The period indicator in column 3 is also negative and significant (p-value < 0.01, cluster bootstrap-t test), indicating decreasing levels of buyer reciprocity over time.

[1] Mean (sd) in *Voluntary* of 0.639 (0.096) and in *Arbitrator* $\mu = 2/3$ of 0.674 (0.098). All power calculations are based on 1000 replications and assume a normal distribution.

Table A. 6 – Regression analysis of matching group data.

Dependent variable	*Winning bid*	*Trade efficiency*	*Proposal / surplus*	*Buyer Profit*	*Seller Profit*
Validation of Result	1	2	3	4	4
$Arbitrator\ (\mu = 1/3)$	-37.63***	-0.151	-0.308***	-0.431	-1.70
	(7.56)	(0.162)	(0.039)	(2.32)	(1.05)
	[0.009]	[0.399]	[0.006]	[0.870]	[0.153]
$Arbitrator\ (\mu = 2/3)$	-33.52***	0.157	-0.215***	-1.84	3.96
	(8.28)	(0.335)	(0.039)	(3.33)	(2.53)
	[0.013]	[0.699]	[0.011]	[0.597]	[0.230]
Period	-0.46	0.008	-0.008***	0.373**	-0.258**
	(0.28)	(0.103)	(0.001)	(0.108)	(0.097)
	[0.081]	[0.518]	[0.005]	[0.007]	[0.077]
Constant	111.26***	0.440***	0.262***	27.48***	9.050***
	(3.51)	(0.085)	(0.050)	(1.58)	(1.89)
Observations	1,080	1,070	1,070	1,070	1,070
Wald test statistic	41.61***	26.97***	51.76***	9.40**	4.50*

Notes: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Coefficient estimates are presented, with robust standard errors in parentheses clustered at the cohort level to correct for intra-cohort correlation. The omitted experimental condition is the *Voluntary* treatment. In square brackets are wild cluster bootstrap p-values after imposing the zero null on the bootstrap data generating process, with 999 bootstrap samples drawing from the six-point Webb distribution – which is preferred to alternative distributions when the number of clusters is less than ten – obtained using the *boottest* command in Stata (Roodman et al. 2019). The models in columns 1, 3, 4 and 5 are estimated using OLS regression. The model in column 2 was estimated using fractional logistic regression and coefficient estimates are on the logit scale. The Wald test statistic is based on a test of joint regression significance (F-statistics except for column 2, which is a chi-squared statistic). The number of observations is higher in the first column because we have auction data from all matching groups, whereas trade data from 10 matching groups was lost due to a hard time-out protocol.

Columns 4 and 5 of the table are in line with Result 4. Buyer profits do not differ significantly with a contingent contract than without and there is no significant difference between the *Arbitrator* sub-treatments (p-value = 0.625, cluster bootstrap-t test). Of more interest is the comparison in seller profits between *Voluntary* and *Arbitrator* when $\mu = 2/3$. There is little statistical evidence at the aggregate level to suggest that the contingent contract increases seller profits under these conditions, but this test only has around 23 percent power to detect an effect size of the magnitude observed.[2] At the matching group level, the evidence for a positive effect is stronger but still not significant at conventional thresholds (p-value = 0.230, cluster bootstrap-t test). We also fail to reject a linear hypothesis test that the coefficient estimates on the dummy variables for the *Arbitrator* sub-treatments are equal in column 5 (p-value = 0.163, cluster bootstrap-t test). The buyer-seller profit differential widens over the course of the experiment, with a significant positive time trend in the specification for buyer profits (p-value < 0.01, cluster bootstrap-t test) and a significant negative time trend in the specification for seller profits (p-value = 0.077, cluster bootstrap-t test).

[2] Mean (sd) in *Voluntary* of 5.09 (3.85) and in *Arbitrator* $\mu = 2/3$ of 9.06 (9.27).

Appendix D: Mixture model estimation procedure (relates to Section 5.3 in the main text).

The finite mixture model estimation procedure used here is adapted from Moffatt (2015). There are 18 buyers in the *Arbitrator* treatment, each of whom has been observed over 30 trading periods. Buyer i's price proposal in period t is given by y_{it}. The variable y_{it} is bounded by the contract price range, $[\underline{p}_{it}, \overline{p}_{it}]$, which is determined in the auction phase of the period and is observed before the buyer makes her decision. The arbitrator's interim preferred price is given by:

$$p_{it}^{A\prime} = max\left\{\underline{p}_{it}, min\,\{\overline{p}_{it},\ \mu_t v(q_{it}) + (1 - \ \mu_t)c(q_{it})\}\right\}. \tag{A.1}$$

This price is determined by the seller's product quality choice q_{it}, the arbitrator's exogeneous preference parameter μ_t, which varies during the experiment, and the cost and valuation schedules. It is constrained by the bounds of the contract price range. The experiment parameter values are described in the main text.

The buyer's preferred price is y_{it}^*, which depends on her type. I assume that there are two buyer types: self-interested (*self*) and fair (*fair*). The model precludes subjects from switching between types. Self-interested buyers propose the lower bound contract price, $\underline{p}_{it}$. This type consists of strictly self-interested economic agents. Fair buyers are assumed to exhibit reference-dependent fairness preferences. For this type, I specify the following latent model:[3]

$$y_{it}^* = \beta_0 + \beta_1 p_{it}^{A\prime} + \varepsilon_{it,fair} \tag{A.2}$$

$$i = 1, \ldots, 18, \qquad t = 1, \ldots, 30, \qquad \varepsilon_{it,fair} \sim N(0, s^2).$$

Where the arbitrator's interim preferred price is the fair reference point in a trading period. We expect the parameter β_1 to be close to one for fair buyers. The error term is assumed to be normally distributed, with variance s^2.

A two-limit tobit model (Nelson 1976) is appropriate, where the limits correspond to the lower and upper bounds of the contract price range and are specific to each buyer and period. The relationship between the buyer's preferred price proposal and actual price proposal is determined by the following censoring rules:

For self-interested buyers:

$$y_{it} = \underline{p}_{it} \ \ \forall t \tag{A.3a}$$

[3] A period indicator was found not to be a significant contributor to the latent model and so was dropped from the equation.

For fair buyers:

$$y_{it} = \begin{cases} \underline{p}_{it} & if\ y_{it}^* \leq \underline{p}_{it} \\ y_{it}^* & if\ \underline{p}_{it} < y_{it}^* < \underline{p}_{it} \\ \overline{p}_{it} & if\ y_{it}^* \geq \overline{p}_{it} \end{cases} \tag{A.3b}$$

I further incorporate the possibility that buyers deviate on occasion from their preferred price by incorporating a tremble parameter ω. In any given period, with probability ω a buyer may lose concentration and choose a price proposal at random. The price proposal increment in the experiment was set at 0.25 points and so the cardinality of the set of possible price proposals is $|Y_{it}| = 1 + (\overline{p}_{it} - \underline{p}_{it})/0.25$. The importance of this parameter is likely decreasing during the experiment as subjects gain experience in the decision-making environment and so I employ the specification:

$$\omega_{it} = \omega_0 \exp\,[\omega_1(Period)] \tag{A.4}$$

where ω_0 is the initial tremble probability and ω_1 is the rate of decline, which we expect to be negative. These tremble parameter estimates, however, turn out not to be statistically different from zero and so I do not report on them further here.

The likelihood contributions for a single price decision are as follows, where $\Phi(.)$ and $\phi(.)$ are the standard normal cumulative distribution and probability density functions respectively:

$\boldsymbol{y} = \underline{\boldsymbol{p}}$:

$$P\left(y_{it} = \underline{p}_{it} \middle| i = self\right) = 1 - \frac{\omega_{it}}{|Y_{it}|}$$

$$P\left(y_{it} = \underline{p}_{it} \middle| i = fair\right) = (1 - \omega_{it})\Phi\left(-\frac{\beta_0 + \beta_1 p_{it}^{A'}}{s}\right) + \frac{\omega_{it}}{|Y_{it}|} \tag{A.5a}$$

$\underline{\boldsymbol{p}} < \boldsymbol{y} < \overline{\boldsymbol{p}}$:

$$f(y_{it}|i = self) = \frac{\omega_{it}}{|Y_{it}|}$$

$$f(y_{it}|i = fair) = (1 - \omega_{it})\frac{1}{s}\phi\left(\frac{y_{it} - \beta_0 - \beta_1 p_{it}^{A'}}{s}\right) + \frac{\omega_{it}}{|Y_{it}|} \tag{A.5b}$$

$\boldsymbol{y} = \overline{\boldsymbol{p}}$:

$$P(y_{it} = \overline{p}_{it} | i = self) = \frac{\omega_{it}}{|Y_{it}|}$$

$$P(y_{it} = \overline{p}_{it} | i = fair) = (1 - \omega_{it}) \left[1 - \Phi\left(\frac{\overline{p}_{it} - \beta_0 - \beta_1 p_{it}^{A'}}{s}\right)\right] + \frac{\omega_{it}}{|Y_{it}|} \tag{A.5c}$$

The two buyer types are represented in the model by the mixing fractions fr_{self} and fr_{fair}. The likelihood contribution for a buyer i is:

$$L_i = fr_{self} \prod_{t=1}^{30} P\left(y_{it} = \underline{p}_{it} \middle| self\right)^{I_{y_{it}=\underline{p}}} f(y_{it}|self)^{I_{\underline{p}<y_{it}<\overline{p}}} P(y_{it} = \overline{p}_{it}|self)^{I_{y_{it}=\overline{p}}}$$
$$+ fr_{mimic} \prod_{t=1}^{30} P\left(y_{it} = \underline{p}_{it} \middle| fair\right)^{I_{y_{it}=\underline{p}}} f(y_{it}|fair)^{I_{\underline{p}<y_{it}<\overline{p}}} P(y_{it} = \overline{p}_{it}|fair)^{I_{y_{it}=\overline{p}}} \tag{A.6}$$

Where $I(.)$ is an indicator function for the subscripted expression and the conditional probabilities/densities are substituted from (A.5).

Finally, the sample log-likelihood is obtained as follows:

$$Log\ L = \sum_{i=1}^{18} \log(L_i) \tag{A.7}$$

on maximization of which we obtain maximum likelihood estimates for the five parameters $\beta_0, \beta_1, s, \omega_0, \omega_1$ and one of the two mixing fractions (from which the other is deduced using the delta method).

Posterior probabilities for the two types can then be calculated as:

$$P(i = self|y_{i1,\dots,i30}) = \frac{fr_{self} \prod_{t=1}^{30} P\left(y_{it} = \underline{p}_{it} \middle| self\right)^{I_{y_{it}=\underline{p}}} f(y_{it}|self)^{I_{\underline{p}<y_{it}<\overline{p}}} P(y_{it} = \overline{p}_{it}|self)^{I_{y_{it}=\overline{p}}}}{L_i} \tag{A.8a}$$

$$P(i = fair|y_{i1,\dots,i30}) = \frac{fr_{fair} \prod_{t=1}^{30} P\left(y_{it} = \underline{p}_{it} \middle| fair\right)^{I_{y_{it}=\underline{p}}} f(y_{it}|fair)^{I_{\underline{p}<y_{it}<\overline{p}}} P(y_{it} = \overline{p}_{it}|fair)^{I_{y_{it}=\overline{p}}}}{L_i} \tag{A.8b}$$

The estimation is conducted in Stata 16, using the d0 estimator to account for the panel structure of the data. A starting value for the mixing fraction is obtained from the frequency table of buyer choices in Table A. 3. Starting values for the five parameters are (0, 1, 4, 0.11, -0.05), obtained from a process of trial and error. Bootstrapped standard errors are calculated, clustered at the cohort level based on 999 bootstrap replications.

Appendix E: Experiment instructions.

The experiment video instructions can be found online at the [external link: project repository]. A written version is provided below. Note: Horizontal sliders were used for the suppliers' bidding decision and the shipping company's price proposal. The initial values of these sliders were set at random in each interaction to avoid anchoring bias.

You are now participating in an experiment in the economics of decision making. Based on your decisions and the decisions of other participants in the experiment, you can earn money which will be paid to you in private and in cash. Read these instructions carefully.

Please turn to silent mode your cell phone or any other electronic device that you have brought with you. These electronic devices must be stored out of sight and not used for the duration of the experiment. Please do not communicate with other participants. If at any point you have a question, raise your hand and we will answer you as soon as possible.

<u>How you earn money</u>

The experiment today consists of **30 decision-making rounds**. You will be paid for all these rounds. You earn money during the experiment by accruing points in each round. All the points that you earn during the experiment are converted to pounds sterling at the following rate:

40 points = £1

At the end of the experiment, you will be asked to complete a short questionnaire. Upon completion, you will immediately receive the monetary amount that you earned. The minimum amount that you will leave today's session with is £4.

<u>Summary of the experiment procedure</u>

For today's session, one third of you will be randomly assigned to the role of a **shipping company**, and two thirds of you assigned to the role of a **supplier**. You will be informed to which role you are assigned before the first round. You remain in the same role for the entire experiment.

In each of the 30 rounds, a shipping company is matched with two suppliers in the room. This is called a matching group. The shipping company is looking to buy an engine from **one** of the two suppliers in his/her matching group.

Note: Your matching group changes in each round. You are not matched with the same persons in consecutive rounds.

All subjects assigned to a shipping company role begin each round with an endowment of 5 points. All subjects assigned to a supplier role begin each round with an endowment of 10 points.

----*Voluntary*----

There are two phases in each round:

1. Auction phase
2. Price-setting phase

----*Arbitrator*----

There are three phases in each round:

1. Auction phase
2. Price proposal phase
3. Arbitration phase.

In the <u>auction phase</u>, it is decided which supplier delivers the engine. Each supplier submits a bid. The **lower** bid wins the auction. The winning supplier at the auction delivers the engine. The losing supplier at the auction exits the round.

The engine delivered to the shipping company can be of **high or low quality**. This is decided by the winning supplier during the auction and determines the shipping company's value for the engine and the winning supplier's delivery cost (see Table 1).

Table - 1: Engine value and cost schedule

	Low quality	High quality
Shipping company's value	50	100
Winning supplier's cost	30	40

----*Voluntary*----

In the <u>price-setting phase</u>, the shipping company observes the engine quality delivered. Then, the shipping company chooses a final price to pay the winning supplier. This price can be any amount from **one quarter** of the winning auction bid up to and including the winning auction bid.

At the end of the round, the points earned are calculated as follows:

Shipping company earns 5 + Profit, where Profit = value – final price

Winning supplier earns 10 + Profit, where Profit = final price – cost

Losing supplier earns 10 (Profit = 0)

Note: Profit can be negative. Make your decisions carefully.

We now explain the experiment procedure in detail.

<u>Auction phase:</u>

- The two suppliers in a matching group each submit a bid at an auction.
- This bid can be any whole number from 30 up to and including 200.
- Neither of the two suppliers can see the other's choice of bid.
- The supplier that submits the **lower** bid wins the auction. In the event of a tie, the computer chooses the winner at random.
- The winning bid is not necessarily the final price paid by the shipping company. Instead, the winning bid determines the **price range** that the winning supplier can receive:
  - ➔ the **minimum price** in this range is one quarter of the winning bid.

➔ the **maximum price** in this range is the winning bid.

- At the same time as submitting a bid, each supplier also selects an engine quality (high or low) to be delivered in the event of winning the auction.
- The winning supplier at the auction proceeds to the next phase and incurs his/her engine delivery cost.
- The losing supplier at the auction exits and earns the round endowment of 10 points (a profit of zero).

Computer interface:

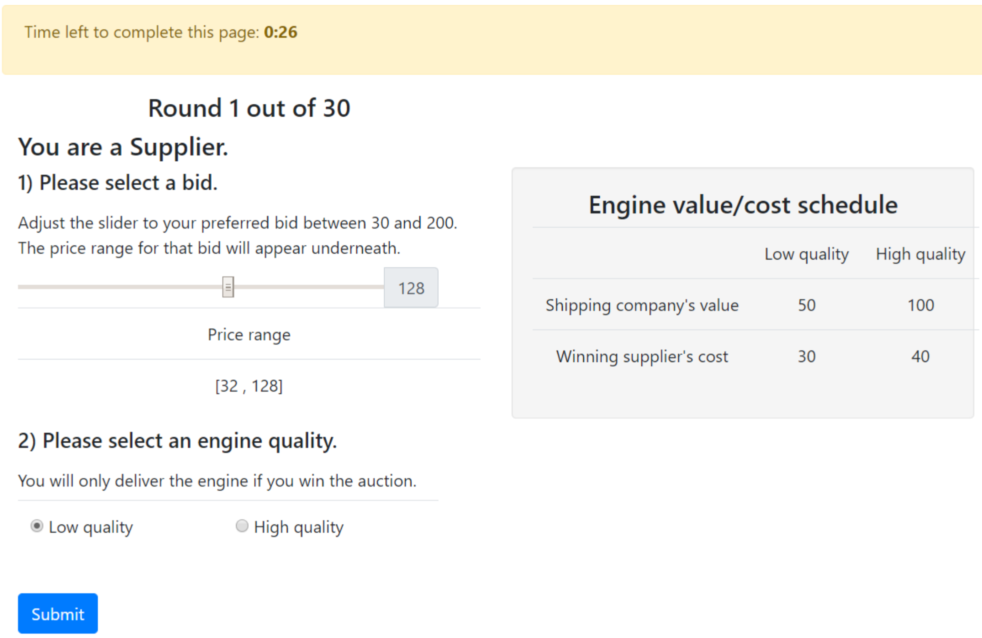
In the auction phase, each supplier submits his/her bid by adjusting a slider in the upper part of the computer screen. As you adjust the slider, underneath you see the price ranges associated with the different possible bids. The first number in the brackets is the minimum price, which is one quarter of the selected bid. The second number is the maximum price, which is the bid itself.

A supplier submits his/her quality by selecting one of two options in the lower part of the screen.

On the right-hand side of the screen appears the engine value and cost schedule.

Suppliers should attempt to make their decisions in the prescriptive time. For the first five rounds, you have 60 seconds to make your decisions. After round five, you have 30 seconds to make your decisions. If you cannot make your decisions in time, the default bid is 200 and the engine quality is selected at random.

Auction phase computer screen:



Consider the following examples for the auction phase:

1. Supplier A bids 160 and selects low quality. Supplier B bids 170 and selects high quality.

➔ Supplier A wins the auction.

➔ The winning bid is 160.

- ➔ The price range is [40, 160].
- ➔ The engine is low quality

2. Suppliers A and B both bid 128. Supplier A selects high quality and B selects low quality.

- ➔ Suppliers A and B each have 50% probability of winning the auction.
- ➔ The winning bid is 128.
- ➔ The price range is [32, 128].
- ➔ If supplier A wins, the engine is high quality
- ➔ If supplier B wins, the engine is low quality.

<u>Price-setting phase:</u>

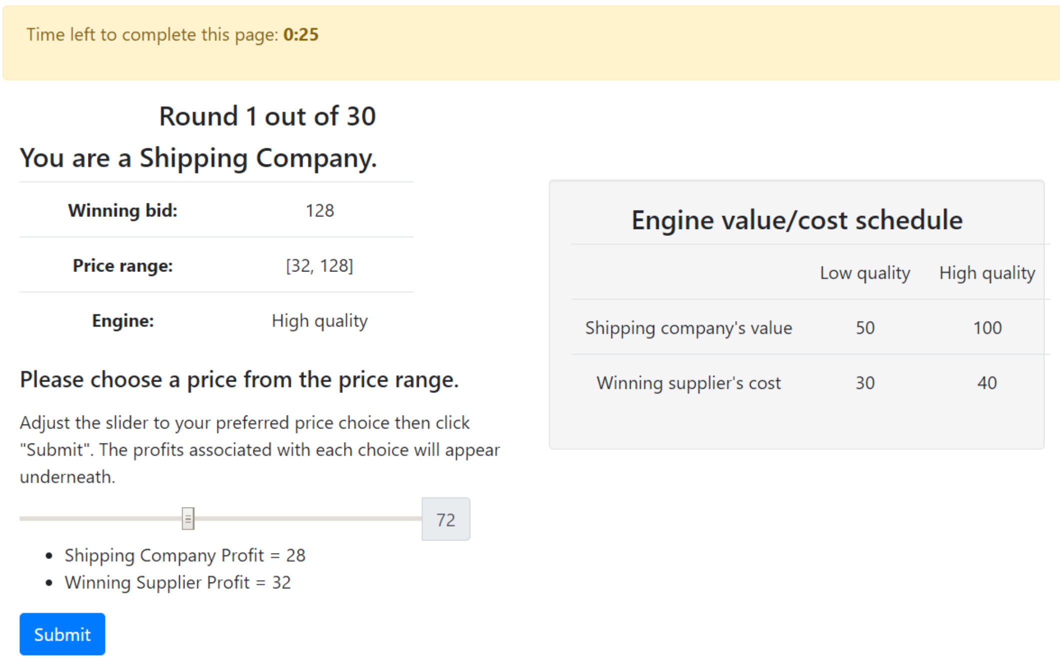
- The shipping company is informed about the price range and the engine quality selected by the winning supplier.
- The shipping company is not informed about the quality selected by the losing supplier.
- The shipping company receives his/her engine value.
- The shipping company chooses a final price from the price range to pay the winning supplier.

Computer interface:

In the price-setting phase, the shipping company's price choice is submitted by adjusting a slider. As you adjust the slider, underneath you will see the profits associated with each price.

The shipping company should attempt to make his or her decision in the prescriptive time. For the first five rounds, you have 60 seconds to make your decision. After round five, you have 30 seconds to make your decision. If you cannot make your decision in time, the default price choice is the maximum price in the price range.

Price-setting phase computer screen:



At the conclusion of the price-setting phase, the round ends and profits are realised.

Consider the following example scenarios:

1. The winning bid is 128 and so the price range is [32, 128].

   The winning supplier selected a low quality engine.

   If the shipping company chooses a final price of 45:

   - ➔ Shipping Company Profit = 50 – 45 = 5
   - ➔ Winning Supplier Profit = 45 – 30 = 15
   - ➔ Losing Supplier Profit = 0

2. The winning bid is 128 and so the price range is [32, 128].

   The winning supplier selected a high quality engine.

   If the shipping company chooses a final price of 65:

   - ➔ Shipping Company Profit = 100 – 65 = 35
   - ➔ Winning Supplier Profit = 65 – 40 = 25
   - ➔ Losing Supplier Profit = 0

<u>Information Display</u>

Much of the information displayed to you during the experiment is stored in a table in the lower portion of the computer screen. Here is an example of this table filled with made up numbers for demonstration purposes. The information shown is not from an actual experiment with people.

Round	Winning Bid	Losing Bid	Quality	Final Price	Profit	Balance
3	45	185*			0.00	56.00
2	75*	131	Low	34.00	4.00	56.00
1	128*	175	High	72.00	32.00	42.00

*Your Bid

The table provides detailed information for each round. Suppliers see the winning and losing auction bids and which of these is their own bid. The shipping company and winning supplier also see the winning supplier's engine quality delivered and the final price. All participants see their profit for the round and total accrued points balance.

Comprehension quiz

Please answer the questions below. Raise your hand if you require assistance. Once you answer all the questions correctly, you will be assigned your role and guided through two training rounds. The main part of the experiment then begins. Note: The comprehension questions and training rounds have no influence on your payment.

- Consider the following scenario.

  The winning auction bid is 140 and so the price range is [35, 140]. First, suppose the winning supplier selected a low quality engine, which is valued by the shipping company at 50 and costs the winning supplier 30. The shipping company chooses a final price of 44.

  1. What is the Shipping Company Profit? *6*

  2. What is the Winning Supplier Profit? *14*

  3. What is the Losing Supplier Profit? *0*

  Now suppose the winning supplier selected a high quality engine, which is valued by the shipping company at 100 and costs the winning supplier 40. The shipping company still chooses a final price of 44.

  4. What is the Shipping Company Profit? *56*

  5. What is the Winning Supplier Profit? *4*

---- *Arbitrator* ----

In the price proposal phase, the shipping company observes the engine quality delivered. Then, the shipping company proposes a final price to pay the winning supplier. The shipping company's proposed price can be any amount from **one quarter** of the winning auction bid up to and including the winning auction bid.

In the arbitration phase, an appeal is triggered if the shipping company's proposed price is below the price that an arbitrator would set. The arbitrator's price depends on its favoured profit ratio, which changes during the experiment. Whenever an appeal is triggered, the arbitrator is available with **50% probability**. If the arbitrator is available, the shipping company must pay the arbitrator's price instead of the price proposal. Precise details will be given below.

At the end of the round, the points earned are calculated as follows:

Shipping company earns 5 + Profit, where Profit = value – final price

Winning supplier earns 10 + Profit, where Profit = final price – cost

Losing supplier earns 10 (Profit = 0)

Note: Profit can be negative. Make your decisions carefully.

We now explain the experiment procedure in detail.

Auction phase:

- The two suppliers in a matching group each submit a bid at an auction
- This bid can be any whole number from 30 up to and including 200.
- Neither of the two suppliers can see the other's choice of bid.
- The supplier that submits the **lower** bid wins the auction. In the event of a tie, the computer chooses the winner at random.
- The winning bid is not necessarily the final price paid by the shipping company. Instead, the winning bid determines the **price range** that the winning supplier can receive:
  - ➔ the **minimum price** in this range is **one quarter** of the winning bid.
  - ➔ the **maximum price** in this range is the **winning bid**.
- At the same time as submitting a bid, each supplier also selects an engine quality (high or low) to be delivered in the event of winning the auction.
- The winning supplier at the auction proceeds to the next phase and incurs his/her engine delivery cost.
- The losing supplier at the auction exits and earns the round endowment of 10 points (a profit of zero).

Computer interface:

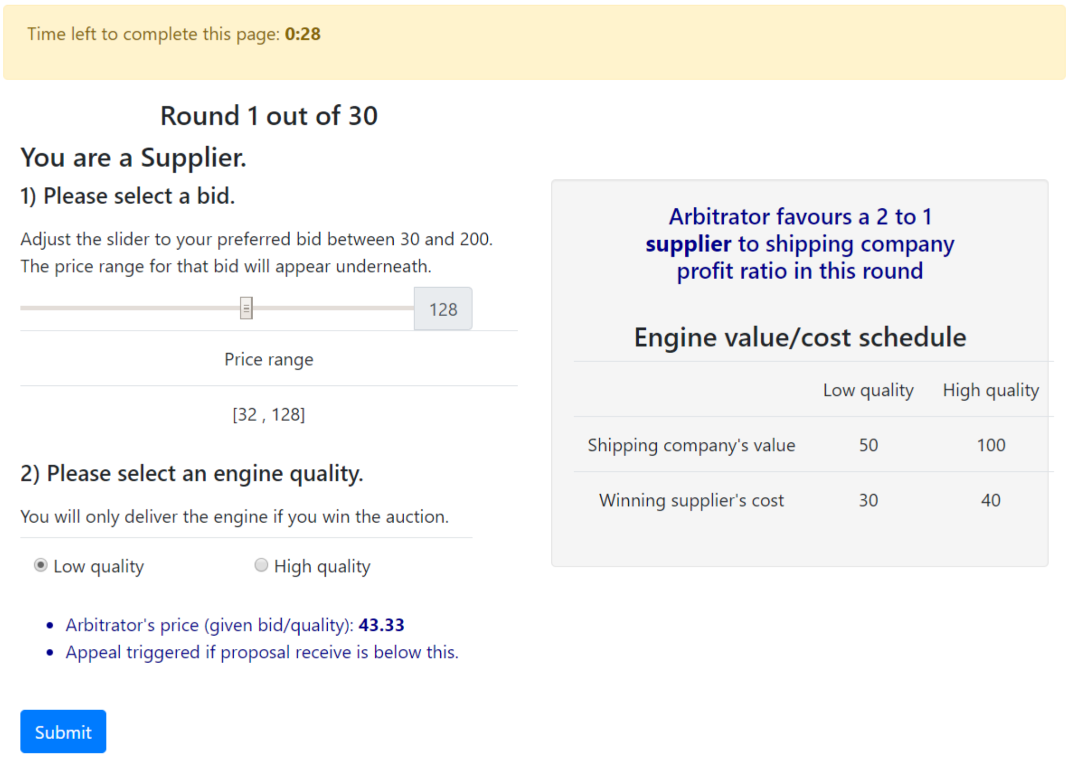
In the auction phase, each supplier submits his/her bid by adjusting a slider in the upper part of the computer screen. As you adjust the slider, underneath you see the price ranges associated with the different possible bids. The first number in the brackets is the minimum price, which is one quarter of the selected bid. The second number is the maximum price, which is the bid itself.

A supplier submits his/her quality by selecting one of two options in the lower part of the screen. As you click on each option, underneath you see the arbitrator's price associated with your combination of bid and quality level selected.

On the right-hand side of the screen appears the arbitrator's favoured profit ratio and the engine value and cost schedule.

Suppliers should attempt to make their decisions in the prescriptive time. For the first five rounds, you have 60 seconds to make your decisions. After round five, you have 30 seconds to make your decisions. If you cannot make your decisions in time, the default bid is 200 and the engine quality is selected at random.

Auction phase computer screen:



Consider the following examples for the auction phase:

1. Supplier A bids 160 and selects low quality. Supplier B bids 170 and selects high quality.

   ➔ Supplier A wins the auction.
   ➔ The winning bid is 160.
   ➔ The price range is [40, 160].
   ➔ The engine is low quality

2. Suppliers A and B both bid 128. Supplier A selects high quality and B selects low quality.

   ➔ Suppliers A and B each have 50% probability of winning the auction.

- ➔ The winning bid is 128.
- ➔ The price range is [32, 128].
- ➔ If supplier A wins, the engine is high quality
- ➔ If supplier B wins, the engine is low quality

<u>Price proposal phase:</u>

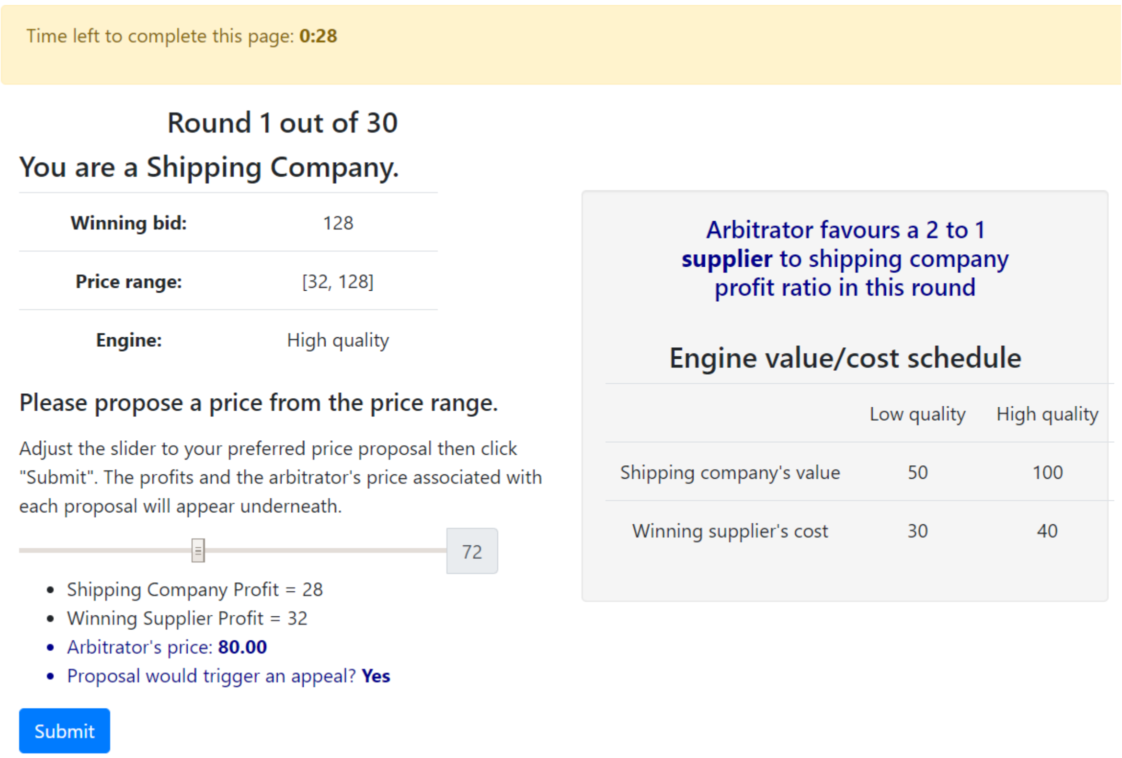
- The shipping company is informed about the price range and the engine quality selected by the winning supplier.
- The shipping company is not informed about the quality selected by the losing supplier.
- The shipping company receives his/her engine value.
- The shipping company proposes a final price from the price range to pay the winning supplier.

Computer interface:

In the price proposal phase, the shipping company's proposed price is submitted by adjusting a slider. As you adjust the slider, underneath you will see the profits associated with each price. You will also see the price that the arbitrator would set for each proposal and whether an appeal to the arbitrator would be triggered.

The shipping company should attempt to make his or her decision in the prescriptive time. For the first five rounds, you have 60 seconds to make your decision. After round five, you have 30 seconds to make your decision. If you cannot make your decision in time, the default price proposal is the maximum price in the price range.

Price proposal phase computer screen:



<u>Arbitration phase:</u>

- The outcome of the arbitration phase depends on the decisions taken in the first two phases.
- An arbitrator observes the winning bid, the shipping company's proposed price and the proposed shipping company and winning supplier profits.
- The arbitrator then sets its own price. The arbitrator cannot set any price, however. The arbitrator's price can be from between the shipping company's proposed price and the winning bid.
- The arbitrator's price is set to bring profits as close as possible to a favoured profit ratio, which varies between the first half and the second half of the experiment:
  - ➔ **EITHER** the arbitrator favours a 2 to 1 **shipping company** to supplier profit ratio, i.e., the arbitrator favours an outcome in which the shipping company's profit is double the winning supplier's profit.
  - ➔ **OR** the arbitrator favours a 2 to 1 **supplier** to shipping company profit ratio, i.e., the arbitrator favours an outcome in which the winning supplier's profit is double the shipping company's profit.
- You will be informed about the arbitrator's favored profit ratio immediately before the first round, and again when this ratio changes at the beginning of the sixteenth round.
- If the **shipping company's proposed price is below the arbitrator's price**, then an appeal to the arbitrator is automatically triggered. If no appeal is triggered, then the final price remains the shipping company's proposed price.
- Following an appeal, the computer rolls a standard six-sided die to determine whether the arbitrator is available:
  - ➔ If the die comes up **1, 2 or 3**, the arbitrator is **unavailable,** and the final price paid by the shipping company remains the shipping company's proposed price.
  - ➔ If the die comes up **4, 5 or 6**, the arbitrator is **available,** and the final price paid by the shipping company is the arbitrator's price. In this situation, a 2 point arbitrator fee is levied on the shipping company.

At the conclusion of the arbitration phase, the round ends and profits are realised.

Consider the following example scenarios:

1. The winning bid is 128 and so the price range is [32, 128].

   The winning supplier selected a low quality engine.

   The shipping company proposes a price of 39.

   If the arbitrator favours a 2 to 1 **shipping company** to supplier profit ratio, then the arbitrator's price is also 39, because the shipping company's proposed price already gives the winning supplier more than half the shipping company's profit. No appeal is triggered.

   - ➔ Shipping Company Profit = 50 – 39 = 11
   - ➔ Winning Supplier Profit = 39 – 30 = 9
   - ➔ Losing Supplier Profit = 0

2. The winning bid is 128 and so the price range is [32, 128].

The winning supplier selected a high quality engine.

The shipping company proposes a price of 65.

If the arbitrator favours a 2 to 1 **supplier** to shipping company profit ratio, then the arbitrator's price is 80, at which price the winning supplier would earn double the shipping company's profit. The shipping company's proposed price is below the arbitrator's price and so an appeal is triggered.

Suppose that the arbitrator is unavailable and so the final price remains 65:

- ➔ Shipping Company Profit = 100 – 65 = 35
- ➔ Winning Supplier Profit = 65 – 40 = 25
- ➔ Losing Supplier Profit = 0

Suppose instead that the arbitrator is available and so the final price is 80. An arbitrator fee of 2 points is subtracted from the shipping company's profit.

- ➔ Shipping Company Profit = 100 – 80 – 2 = 18
- ➔ Winning Supplier Profit = 80 – 40 = 40
- ➔ Losing Supplier Profit = 0

<u>Information Display</u>

Much of the information displayed to you during the experiment is stored in a table in the lower portion of the computer screen. Here is an example of this table filled with made up numbers for demonstration purposes. The information shown is not from an actual experiment with people.

Round	Bids Winning / Losing	Quality	Proposal	Arbitrator Appeal / Available	Final Price	Profit	Balance
3	45 / 131*					0.00	75.00
2	75* / 131	Low	45.00	No / -	45.00	15.00	75.00
1	128* / 175	High	72.00	Yes / Yes	80.00	40.00	50.00
	*Your Bid						

The table provides detailed information for each round. Suppliers see the winning and losing auction bids and which of these is their own bid. The shipping company and winning supplier also see the winning supplier's engine quality, the shipping company's proposed price, whether an appeal is triggered and the arbitrator's availability, and the final price. All participants see their profit for the round and total accrued points balance.

Comprehension quiz

Please answer the questions below. Raise your hand if you require assistance. Once you answer all the questions correctly, you will be assigned your role and guided through two training rounds. The main part of the experiment then begins. Note: The comprehension questions and training rounds have no influence on your payment.

- Consider the following scenario.

  The winning auction bid is 140 and so the price range is [35, 140]. First suppose the winning supplier selected a low quality engine, which is valued by the shipping company at 50 and costs the winning supplier 30. The shipping company proposes a price of 44.

  Let the arbitrator favour a 2 to 1 supplier to shipping company profit ratio. The arbitrator's preferred price is no higher than the shipping company's proposal (and remember it cannot be any lower), because a price of 44 already gives the winning supplier more than double the shipping company's profit. No appeal is triggered. The final price remains 44.

1. What is the Shipping Company Profit? *6*

2. What is the Winning Supplier Profit? *14*

3. What is the Losing Supplier Profit? *0*

   Now suppose the winning supplier selected a high quality engine, which is valued by the shipping company at 100 and costs the winning supplier 40. The shipping company still proposes a price of 44.

   Again, let the arbitrator favour a 2 to 1 supplier to shipping company profit ratio. The arbitrator's preferred price is now 80, which is higher than the shipping company's proposal and so an appeal is triggered.

   The die is rolled and the arbitrator turns out to be available. The final price is now 80. An arbitrator fee of 2 points should be subtracted from the shipping company's profit.

4. What is the Shipping Company Profit? *18*

5. What is the Winning Supplier Profit? *40*

Appendix F: Post-experiment questionnaire and subject pool characteristics.

Age: Interval variable.

Years.

Mean 22.71, Median 22, Standard deviation 4.03, Minimum 18, Maximum 39

Gender: Categorical variable.

Male 50.93%; Female 48.15%; Other 0.00%; Prefer not to Say 0.93%.

Field of studies: Categorical variable.

Arts and Education 16.67%; Economics and Finance 11.11%; Business and Management 13.89%; Social Sciences and Law 10.19%; Medicine and Health Sciences 14.81%; Engineering and Natural Sciences 33.33%; Not a Student 0.00%.

Nationality: Categorical variable:

Central and Eastern Asia 2.78%; Central and Western Africa 4.63%; Central, South America and the Caribbean 1.85%; Europe (excl. UK) 29.63%; Middle East and North Africa 2.78%; North America 1.85%; Oceania 0.00%; South and Eastern Africa 0.93%; South-East Asia 6.48%; Southern Asia 3.70%; UK 45.37%.

Income: Categorical variable.

When you were 16 years of age, what was the income of your parents in comparison to other families in your country?

Far below average 4.63%; Below average 15.74%; Average 37.04%; Above average 36.11%; Far above average 6.48%

Risk Indices:

Based on Dohmen et al. (2011). Likert scale from 0 “Completely unwilling to take risks” to 10 “Completely willing to take risks”.

1) Are you generally a person who is fully willing to take risks or do you try to avoid taking risks?

Mean 6.30, Median 7, Standard deviation 2.35, Minimum 0, Maximum 10

2) How would you rate your willingness to take risks in financial matters?

Mean 4.70, Median 5, Standard deviation 2.53, Minimum 0, Maximum 10

Trust Index: Average of three variables.

Questions taken from the "General Social Survey" consistent with the approach of Glaeser et al. (2000).

1) Generally speaking, would you say that most people can be trusted or that you can't be too careful in dealing with people?

"Most people can be trusted" 29.63% or "Can't be too careful" 70.37%

2) Do you think most people would try to take advantage of you if they got a chance, or would they try to be fair?

"Would try to be fair" 31.48% or "Would take advantage of you" 68.52%

3) Would you say that most of the time people try to be helpful, or that they are mostly just looking out for themselves?

"Try to be helpful" 38.89% or "Just look out for themselves" 61.11%

Trust Strangers: Dummy variable.

You can't count on strangers anymore.

"More or less disagree" 38.89% or "More or less agree" 61.11%

Additional references

Dohmen, T., Falk, A., Huffman, D., Sunde, U., Schupp, J., & Wagner, G. G. (2011). Individual risk attitudes: Measurement, determinants, and behavioral consequences. *Journal of the European Economic Association, 9*(3), 522-550.

Glaeser, E. L., Laibson, D. I., Scheinkman, J. A., & Soutter, C. L. (2000). Measuring Trust. *Quarterly Journal of Economics, 115*(3), 811-846.

Nelson, F. D. (1976). On a General Computer Algorithm for the Analysis of Models with Limited Dependent Variables. *Annals of Economic and Social Measurement, 5*(4), 493-509.

Roodman, D., Nielsen, M. Ø., MacKinnon, J. G., & Webb, M. D. (2019). Fast and wild: Bootstrap inference in Stata using boottest. *The Stata Journal, 19*(1), 4-60.