Trust Mechanisms and Moral Hazard Mitigation in Procurement

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March 31, 2019

Abstract
Product quality is often unverifiable by third parties and high quality can be costly to provide. It becomes impossible to condition purchasing contracts on the realized quality that a seller provides to the buyer. This moral hazard problem renders price-based reverse auctions inefficient. We use laboratory experiments with human subjects to investigate how switching the burden of trust in procurement affects the outcomes of transactions allocated by reverse auction. To do this, we embed a retainage structure into a fixed-price contract. Retainage is a commonly used incentive mechanism to insure against low quality in the construction industry. Crucially, it does not impose a requirement to condition price on quality. We observe that retainage can induce an economically significant improvement in product quality, as predicted by a theoretical analysis based on fairness. This improvement, however, is realized at the cost of increased profit inequalities. Informal procurement arrangements, characterized by high retainage, undermine auction success. Our results imply that an appropriable retainage mechanism can help overcome the tension between competition and cooperation that arises from reverse auctions but is unable to yield a Pareto improvement.

Keywords: Trust, Procurement Auction, Retainage, Moral Hazard, Hold-up

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1. Introduction

Technological advance since the 1990's has greatly increased procurement through auctions that foster competition via improved market access for suppliers. Regulations in the United States now require the allocation of most public-sector procurement projects via competitive tender processes (Bajari et al. 2014). The implied cost-savings for buyers are in the region of 10-40% (Elmaghraby 2007). Yet price competition can erode trust in the buyer-seller relationship. Emiliani and Stec (2005), for example, observed that auctions encourage unethical cost-cutting behavior by suppliers to preserve profit margins. Trust issues arise because it is difficult - if not impossible - for a buyer to write complete contracts that account for every contingency. Over 1,100 suppliers are involved in construction of the high frequency and high capacity United Kingdom railway service Crossrail, Europe’s largest infrastructure project.¹ In complex procurement projects, a moral hazard problem arises with two components. First, a supplier has limited financial incentive to restore product quality with costly action. Second, a rational buyer will anticipate delivery of the lowest quality and adjust their willingness-to-pay accordingly. This dynamic is likely to result in inefficiency. Thus, we see preferences for incumbent suppliers, market interactions contained within close social networks, and the development of reputation mechanisms.

In this paper, we use laboratory experiments with human subjects to conduct the first test of a contractual structure aimed at facilitating trust when allocation is via price-based auctions: retainage. A retainage provision, or retention as it is known outside the US, is a percentage of the fixed contractual price withheld from a seller by the buyer. The buyer in this context might be a client, main contractor or sub-contractor withholding money from a lower tier. Retainage has its origins in nineteenth-century British railway construction, when it was set at 20% of contractual value (Bausman 2004). Today, typical arrangements range from 5-10%. A construction sector consultation in 2017 by the UK’s Department of Business, Energy & Industrial Strategy (BEIS 2017) estimated the size of retainage monies held in England alone at £4.5 billion. Three-quarters of contractors in England had experienced retainage at some point during the preceding three years, whilst such provisions were included in 65% of ongoing contracts.

If operating as intended, retainage is a useful mechanism to mitigate moral hazard by guaranteeing high quality work and incentivizing timely completion. Yet where sellers deliver a relationship-specific product prior to receiving compensation, they accept vulnerability to uncertain

¹ http://www.crossrail.co.uk/supply-chain/.
behavior during trade. Retainage is generally due on substantial completion of a project, at which point half of the money is released immediately and the remainder is released after the expiration of a defects liability period. Substantial completion is difficult to verify and measures to safeguard cash retainage vary by country. Over half of contractors surveyed by BEIS had experienced full or partial non-repayment of retainage monies, which acted as a financial constraint and generated a counter-productive increase in procurement costs. This hold-up problem is particularly acute for small and medium-sized enterprises. In the US, retainage practices differ according to state statutory requirements. Buyer recognition of the hidden cost of retainage has driven a recent downward trend in the maximum retainage rate permitted by some states (ASA 2018).

Another mechanism observed in the construction sector that shares similarities with retainage as practiced is the letter of intent. This informal arrangement has an important role in keeping existing projects to schedule, but the use of letters of intent to initiate limited works without a legally binding agreement remains “widespread” (Wevill 2015, p 29). Early payments are exchanged, but with no guarantee over future payments to cover delivery costs incurred, and later disputes often outweigh any initial benefits from a reduced administrative burden. This is demonstrated by a notable English contract law case: In 2005, the German dairy manufacturer Müller commissioned RTS Systems to improve its food packaging. After repeated deferral in the execution of a binding contract, Müller alleged faults and refused to pay part of the non-binding price agreed up-front. A protracted legal battle ensued, during which RTS eventually brought a successful claim against Müller for monies due. The Supreme Court Justice pronounced on judgement day that “the moral of the story is to agree first and to start work later” (RTS Flexible Systems v Molkerei Alois Müller [2010]).

To capture the reciprocal trust issues underlying the procurement arrangements discussed, our research design integrates a new contractual gift-exchange game into a price-based reverse auction. In the seminal gift-exchange literature in experimental economics (Fehr et al. 1993), participants are assigned the role of either a Buyer or Seller and the game consists of two stages: a price-setting stage followed by a costly quality delivery stage. Unravelling arguments predict that, in the absence of reputations and with a preannounced and finite number of repetitions, the Seller

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2 Özer and Zheng (2017) define trust in the supply chain as a voluntary decision “to accept vulnerability due to uncertain behaviour of another (the trustee), based upon the expectation of a positive outcome” (p 495). They define trustworthiness as voluntary behaviour “in a way not to take advantage of the trustor’s vulnerable position when faced with a self-serving decision that conflicts with the trustor’s objective” (p 497).

3 The European Commission (2009, clause 41) prescribes that retainage monies “are not paid until the satisfaction of conditions specified in the contract for the payment of such amounts or until defects have been rectified.” In New Zealand, the 2015 Construction Contracts Amendment Bill provides additional protection for the payment of retainage monies to sub-contractors. In China, retainage applies to pre-specified defects liability periods and at the time of writing enjoy additional financial guarantees from the Agricultural Bank of China.
should deliver the minimum quality level and receive the lowest permitted price above cost. In contrast, studies typically observe a positive relationship between price and quality, enabling the emergence of a Pareto improvement relative to equilibrium. Evidence from labor contract experiments largely confirmed Akerlof’s (1982) original gift-exchange hypothesis (Anderhub et al. 2002, Fehr et al. 1998, Fehr et al. 2007).

The existence of positive and negative reciprocity is not in doubt and is robust in the laboratory to the imposition of demanding market institutions (Fehr and Falk 1999). This behavior can be rationalized with theories of social preferences (Bolton and Ockenfels 2000, Fehr and Schmidt 1999). Yet during binding first-price reverse auctions, in which sellers are on the long side of the market and trade proceeds only at the lowest price, competition forces bids down to minimum seller cost. High quality is then not an individually profitable strategy, even for sellers who would prefer to do so. The implied discontinuity in quality choice as a function of price is a direct result of the incomplete contracting model. Empirically the market collapses to a low efficiency outcome. By designing different price-setting institutions, it is possible to improve trust in the market. Brosig-Koch and Heinrich (2014) find that providing reputation information in a buyer determined auction format improves system performance. Fugger et al. (2018) report that giving buyers the option to select a supplier who did not bid place the lowest bid also significantly raises prices and quality levels. A model based on inequality aversion organizes their data well.

Research to date has not considered how contractual incentives are used to switch the burden of trust in procurement at binding price-based auctions with moral hazard.4 By varying a single retainage parameter, we bring together research on trust and competition into a single framework. We also contribute to a growing behavioral operations literature addressing how social preferences influence supply chain contracting (Beer et al. 2017, Cui et al. 2007, Davis and Hyndman 2018, Davis and Leider 2018, Hu et al. 2017, Katok and Pavlov 2013, Loch and Wu 2008). Our experimental results suggest that retainage can improve product quality on average in a competitive procurement environment, but to the detriment of suppliers who fail to fully adjust their bidding behavior. Suppliers are most vulnerable when forced to bear the full contractual trust burden, as witnessed during interactions based on intent.

In the next section, we outline our model and the analytical results under self-interested and then social preferences. In section 3, we derive testable hypotheses and summarize the experimental

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4 Cox et al. (1996) conducted an early experimental analysis of cost-sharing contracts in procurement auctions with moral hazard. But such contracts were found to worsen, rather than attenuate, the strategic problem. In a non-competitive setting, Hoppe and Schmitz (2011) observed that renegotiable option contracts can help solve the hold-up problem if sellers have bargaining power.
design. In section 4, we examine the behavior observed in our experiment and conduct a formal statistical analysis. In section 5, we discuss the empirical findings in the context of our behavioral model. Finally, in section 6 we conclude by drawing implications for procurement contract design.

2. Model and Theory

The model that we propose both simplifies and extends the setting in Fugger et al. (2018). We consider a competitive one-shot procurement interaction in which one buyer faces $n$ potential suppliers. Bidding is over the right to deliver one unit of an indivisible product. Contracting is incomplete: monetary incentives cannot be tied to outcomes and quality is observable but non-verifiable by the courts (Hart 1995, Hart and Moore 1988). This assumption precludes the use of litigation to settle procurement payment disputes, which is often costly to pursue in practice. A retainage mechanism is used, such that an exogenous proportion $\rho \in [0,1)$ of the auction price $p$ is withheld from the winning supplier (seller) until after the product is delivered. The exogeneity of $\rho$ is analogous to a sector norm. This parameter regulates the trust burden that each party bears during a transaction: at low levels, the buyer possesses limited insurance against low quality outcomes; at high levels, the seller is more vulnerable to adverse payment decisions.

Figure 1 displays the sequence of events. In the Bidding Stage, each supplier $i \in \{1,2, \ldots n\}$ simultaneously submits one sealed bid at a first-price reverse auction or chooses to exit the auction without submitting a bid. Bid profiles are public information. In the Procurement Stage, the buyer observes any offers and decides whether to accept or reject the lowest price offer, if at least one Supplier submits a bid. The inclusion of a participation decision for both the buyer and supplier is necessary to ensure that trust is a voluntary decision. Our choice of a binding price-based format is motivated by our objective to isolate the impact of the contractual retainage level. A buyer that can choose the higher price may or may not interpret price as a signal of quality.

After the auction, and if the buyer accepts to trade, an initial payment of $(1 - \rho)p$ is made to the seller. In the Delivery Stage, the seller can provide either a low- or high-quality product, $q = \{q^L, q^H\}$. This simplification removes any ambiguity over performance given the set of individually profitable outcomes permitted by a contract. The buyer’s valuation $v(q)$ for the good depends deterministically on the product quality. This aspect permits us to analyze an agency problem without the confounding effects of risk preferences. Whilst the buyer benefits from high quality, it is associated with a higher seller delivery cost $c(q)$, which is homogeneous across potential suppliers.

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5 We exclude the special case of $\rho = 1$ because at this extreme a contract is purely “cheap talk”.
6 In real-world procurement, the winning bid is typically announced.
7 Houser et al. (2018) observe that buyers choose the higher price in 49.7% of buyer-determined auctions.
Figure 1. The sequence of events in our procurement model.

Notes: This is a sequential game in which suppliers \(1, \ldots, n\) move first and either submit a bid \(b_i\) at auction or choose to exit the market. If a market forms, the buyer can either accept to trade with the lowest bidder and make a guaranteed payment equal to \((1 - \rho)p\), or refuse the transaction. The winning supplier then selects to deliver a high quality \(q^H\) or low quality \(q^L\) product and incurs the cost \(c(q)\). The buyer realizes the product value \(v(q)\) and decides on a discretionary proportion \(r\) of the retainage money \(\rho p\) to pay to the winning supplier. The winning supplier earns a profit equal to the difference between total payment received and the cost incurred. The buyer earns a profit equal to the difference between value received and the total payment made. Non-trading parties earn zero profit.
The provision of quality is welfare increasing and $q^H > q^L$: $v(q^H) - c(q^H) > v(q^L) - c(q^L)$. Thus, the first-best outcome is obtained with a high quality product.

Finally, at the Payment Stage the buyer, having observed the delivered quality decides on which proportion $r \in [0,1]$ of the retainage money withheld to pay to the seller. If a transaction takes place, the profits of the buyer and seller are:

Buyer’s Payoff: $\pi_B = v(q) - (1 - \rho)p - r\rho p$

Seller’s Payoff: $\pi_S = (1 - \rho)p + r\rho p - c(q)$

The outside option for non-trading parties is zero. A bid can be chosen from the discrete price grid $B = \{c(q^L), c(q^L) + \Delta, \ldots, v(q^H) - \Delta, v(q^H)\}$, where $\Delta$ is assumed to be small. Bids must be greater than or equal to the seller’s cost of low quality plus the outside option, up to and including the buyer’s maximum valuation for the product. We impose two restrictions in the model. First, to simulate buyer trust under zero retainage, we set $c(q^H) > v(q^L)$. To incentivize high quality in the absence of retainage, buyers must leave themselves vulnerable to loss. Second, we set $\frac{c(q^L)}{(1-\rho)} \geq c(q^H)$. This will enable a bid mark-up at auction to permit an efficient outcome in non-zero retainage contracts.

2.1 Standard Theory

The assumption that individuals are self-interested and take purely profit-maximizing actions is sufficient to model the interaction as an extensive-form game of complete information.

Proposition 1.

a. For $\rho \in \left[0, 1 - \frac{c(q^L)}{v(q^H)}\right]$, in each subgame perfect equilibrium the price is equal to $\frac{c(q^L)}{(1-\rho)}$ or $\frac{c(q^L)}{(1-\rho)} + \Delta$ the buyer accepts the transaction, low quality is delivered, and the retainage payment rate is zero.

b. For $\rho \in \left(1 - \frac{c(q^L)}{v(q^H)}, 1\right)$, there exists a unique subgame perfect equilibrium in which the market unravels with no bids submitted at auction.

Proof.

To identify the subgame perfect Nash equilibria for all values of $\rho$, we apply backward induction. For ease of exposition, we denote the buyer as female and the seller as male.

a. There are two cases to consider.
Case (i): $\rho = 0$. Retainage is zero and so the final Payment Stage is obsolete.

At the Delivery Stage, the guaranteed payment is determined and set equal to the auction price. The winning supplier chooses product quality to solve:

$$\max_{q \in \{q_L, q_H\}} u_S = \pi_S = p - c(q)$$  \hspace{1cm} (1)

High quality costs the seller more than low quality and so he will always provide $q_L$. At the Procurement Stage, the buyer anticipates this behavior and will not accept to purchase the product at a price greater than her valuation of low quality. At the Bidding Stage, suppliers will either bid their cost of low quality or an arbitrarily small unit $\Delta$ above. To see this, recall that the rules of the auction state that the buyer can only trade with the supplier who submits the lowest bid at auction. For all bids above $c(q_L) + \Delta$, a seller always has an incentive to undercut: by doing so, he can increase his probability of trade to one. If all suppliers bid $c(q_L) + \Delta$, each makes a (small) positive expected profit. Any deviation would yield zero profit. Similarly, if at least two suppliers bid $c(q_L)$, they earn a profit of zero but deviation to a higher price or to exiting the auction would not improve their position.

Case (ii): $0 < \rho \leq 1 - \frac{c(q_L)}{v(q_H)}$. Retainage is positive and so all stages are relevant.

At the Payment Stage, the trade quality and auction price are known, and the buyer selects a proportion of the retainage money $r$ to solve:

$$\max_{r \in [0, 1]} u_B = \pi_B = v(q) - (1 - \rho)p - r\rho p$$  \hspace{1cm} (2)

Since buyer profit is decreasing in $r$, the buyer will seize all the retainage money and make no payment to the seller over and above the guaranteed component. At the Delivery Stage, the winning supplier anticipates this and so has no incentive to deliver a high-quality product. The buyer is insured against loss in any transaction at $p \leq \frac{v(q_L)}{(1 - \rho)}$. As in case (i), suppliers have an incentive to undercut the bids of their competitors at auction, but now only up to a certain point: the minimum cost threshold is marked up in proportion to the retainage money vulnerable to loss, $\frac{c(q_L)}{(1 - \rho)} + \Delta$. The entire trade surplus accrues to the buyer and the market collapses to an inefficient outcome. ■
b. For $1 - \frac{c(q^L)}{v(q^H)} < \rho < 1$, all stages are relevant. The seller bears the full trust burden conditional on trade, since $b_i^{\text{Max}} = v(q^H) < \frac{c(q^L)}{(1-\rho)}$. There is no available bid in the discrete grid $B$ at which a supplier can avoid making a loss in anticipation of zero payment of the retainage money. Any bid would enable a buyer not only to appropriate full trade surplus, but also to appropriate a part of the seller’s relation-specific cost outlay. Thus, all suppliers exit at the Bidding Stage and receive the outside option of zero. No trade surplus is realized since a market fails to form. ■

2.2 Model of Social Preferences

For retainage to be successful (i.e. yield high product quality) a certain amount of trust must exist between the buyer and the seller. We provide alternative predictions for the retainage contract using a model of outcome-based fairness. For its simplicity, we use the Fehr and Schmidt (1999) specification of inequity-averse preferences. Let the reference group for comparison consist of solely the buyer and seller. This is intuitive when supplier’s compete anonymously and a buyer’s agreement to purchase initiates a fundamental transformation (Williamson 1985). We adopt an incomplete information approach, based around thresholds for the emergence of trust behaviors. Our analysis is related to the distributional approach of Bolton and Ockenfels (2000). Incomplete information is a more realistic assumption due to the private information component of fairness trade-offs.

The utility of a direct trade party $i$ can be represented by the following function:

$$u_i = \pi_i - \alpha_i \cdot \max\{\pi_j - \pi_i, 0\} - \beta_i \cdot \max\{\pi_i - \pi_j, 0\}$$

(3)

Where $\pi_i$ is the monetary payoff of party $i$, and $\pi_j$ is the monetary payoff of the other party $j$. The parameter $\alpha_i$ is a privately observed measure of an economic agent’s aversion to disadvantageous payoff inequality and $\beta_i$ is their aversion to advantageous inequality, with $0 \leq \beta_i \leq \alpha_i$. The larger the values of the fairness parameters, the greater the utility loss experienced by $i$ for a given payoff difference. Seller delivery costs are included in comparisons, based on prior evidence from hold-up experiments that buyers consider sunk costs when making decisions on final surplus divisions (Ellingsen and Johannesson 2004, Hackett 1994). If a transaction takes place, it follows from (3) that the buyer’s utility is:

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8 Given our assumption of a bilateral reference group for comparison, the predictions of the model are invariant to which specification of outcome-based preferences is employed. Our behavioral analysis complements Fugger et al. (2018), who formulate similar predictions for the case of $\rho = 0$ and multiple quality levels, using a model of homogeneous Fehr-Schmidt social preferences with and without decision errors.
\[ u_B(y, q) = v(q) - y - \alpha_B \cdot \max\{2y - v(q) - c(q), 0\} - \beta_B \cdot \max\{v(q) + c(q) - 2y, 0\} \] (4)

And that the seller's utility is:

\[ u_S(y, q) = y - c(q) - \alpha_S \cdot \max\{v(q) + c(q) - 2y, 0\} - \beta_S \cdot \max\{2y - v(q) - c(q), 0\} \] (5)

Where \( y = (1 - \rho)p + rpp \) is total payment from the buyer to the seller.

To incorporate heterogeneity in our model, we assume a simplification of Fehr and Schmidt's (1999) inequity aversion distribution. There are two population types: \( z \cdot 100\% \) of agents are "fair" with \( \alpha = 2 \) and \( \beta = 0.6 \). The remaining \( (1 - z) \cdot 100\% \) of agents are "selfish" with \( \alpha = \beta = 0.9 \) Thus, a firm's prior belief as to the likelihood of encountering a fair type can be described by a single number \( z \in [0,1] \), which is correct on average. We interpret \( z \) as the commonly held industry belief as to whether a buyer or seller will act in good faith. Types are assumed to be independent of beliefs. The type that nature has assigned to one agent does not change their expectation of encountering one or other type in a one-shot procurement interaction. The standard theory is captured by \( z = 0 \), with no uncertainty about individual types. For comparability, in appendix A.1 we analyze the model for \( z = 1 \). Interestingly, because of the binding auction selection rule, an inefficient outcome with low product quality still exists in a world in which everyone knows \textit{ad infinitum} that everyone is fair.

When \( z \in (0,1) \), the model can be analyzed as an extensive-form game of incomplete information. We apply a perfect Bayesian equilibrium solution concept, which requires that beliefs correspond to the objective probabilities for all equilibrium actions. Our approach is to derive the minimum proportion of fair agents in the population for which a truster would be willing to take a trusting action in a procurement interaction, given a consistent set of beliefs. We denote this minimum proportion as the \textit{threshold trust requirement}.

To proceed, we divide our discrete price grid into two regions: a low-price region \( B = \{c(q^L), c(q^L) + \Delta, \ldots, v(q^L) - \Delta, v(q^L)\} \), and a high-price region \( B = \{v(q^L) + \Delta, v(q^H) + 2\Delta, \ldots, v(q^H) - \Delta, v(q^H)\} \). Let the composite function \( s(q) = \frac{v(q) + c(q)}{2} \) define the equal surplus-sharing point at a product quality level. For \( \rho = 0 \), the truster is the buyer as penultimate-mover and a trusting action would be to accept an auction price in the high-price region. For \( \rho \in (0,1) \), the

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9 A similar simplification is used elsewhere in the literature for tractability (Fehr et al. 2007, Fehr et al. 2008, Fehr and Schmidt 2004). In the original formulation, Fehr and Schmidt (1999) assumed that 30% of individuals have \( \alpha_i = \beta_i = 0 \), 30% have \( \alpha_i = 0.5 \) and \( \beta_i = 0.3 \), 30% have \( \alpha_i = 1 \) and \( \beta_i = 0.6 \), and 10% have \( \alpha_i = 4 \) and \( \beta_i = 0.6 \). In our model, the key threshold parameter is \( \beta = 0.5 \) to enable the possibility of positive retainage payments. Thus, the predictions are qualitatively unchanged by reducing the distribution to two types.
trustor is the seller as penultimate-mover \( \forall p \leq \frac{s(q^L)}{(1-\rho)} \) and a trusting action would be to deliver high product quality. For brevity, in the main text we derive threshold trust requirements for cases in which the trustor is selfish and the last-mover can be either fair or selfish. In appendix A.2, we outline analogous requirements for a fair trustor, which are everywhere higher.

**Proposition 2.** For \( \rho = 0 \), if a perfect Bayesian equilibrium exists in the high-price region with a feasible and consistent set of beliefs it is unique. All suppliers submit the same bid equal to \( p^H \), the buyer accepts, a fair seller delivers high quality and a selfish seller delivers low quality.

**Proof.**

We restrict attention to the high-price region. At the Delivery Stage, the seller chooses product quality to solve:

\[
q^*[p, (\alpha_s, \beta_s)] = \arg \max_{q \in \{q_L, q_H\}} u_s
\]  

(6)

A selfish seller will always deliver low quality at minimum cost. For a fair seller, the quality choice depends on the agreed price. Let \( p^H \) denote the lowest price in \( \bar{B} \) at which high quality is implementable with zero retainage and so a fair seller prefers to deliver high quality over low quality or exiting at the Bidding Stage. From (5), with our inequity aversion parameters a fair seller weakly prefers high quality when:

\[
p^H \geq 2v(q^H) + 3c(q^H) + 0.6v(q^L) - 0.4c(q^L) \]

(7)

We can now partition \( \bar{B} \) into a non-implementable sub-region \( \bar{B}_- = \{v(q^L) + \Delta, v(q^L) + 2\Delta, ..., p^H - 2\Delta, p^H - \Delta\} \); and an implementable high-price region \( \bar{B}_+ = \{p^H, p^H + \Delta, ..., v(q^H) - \Delta, v(q^H)\} \). At the Procurement Stage, the buyer anticipates these possible outcomes in the final stage and will only agree to purchase from the winning supplier if her expected utility is non-negative:

\[
EU_B = E(q^L|p) \cdot u_B(p, q^L) + E(q^H|p) \cdot u_B(p, q^H) \geq 0
\]

(8)

Where \( E(q|a, p) \) is a buyer’s expectation of product quality if she accepts a transaction at the winning auction price and is driven by her posterior belief \( \hat{z} \) after the Bidding Stage about the probability that the winning supplier is fair. The buyer expects a negative profit from exchange \( \forall p \in \bar{B}_- \), since both fair and selfish sellers will deliver low quality. No buyer will accept the transaction in this sub-region.
A selfish buyer will accept the transaction at a price in the implementable high-price region if $\tilde{z}$ satisfies her individual rationality (IR) constraint:

$$IR_{B, Self}^{\rho=0}: \tilde{z} \geq \frac{p - v(q^L)}{v(q^H) - v(q^L)}$$

Thus, there exists a feasible $\tilde{z} \forall p \in \bar{B}_+$ for a transaction to occur, which corresponds to the threshold trust requirement for a selfish buyer with zero retainage.

There is a perfect Bayesian equilibrium at $p^H$ associated with high quality if, during the Bidding Stage, neither a fair nor selfish supplier has an incentive to deviate to a lower price or submit no bid at auction. The benchmark for comparison is a no-transaction scenario, in which the buyer and all suppliers earn zero profit. For any price $p \in \bar{B}_+$, a supplier earns non-negative expected utility from trade and there is no incentive to exit the auction. There is no incentive for a fair or selfish supplier to submit a bid above $p^H$, since he can always increase his selection probability to 1 by undercutting his competitors whilst only decreasing his expected profit by an arbitrarily small amount. There is also no incentive for either type to deviate to a price $p' \in \bar{B}_-$, because the buyer would reject the transaction at this price, knowing that low quality would be delivered by both supplier types and so both parties would earn zero profit. The unique equilibrium in the high-price region is thus at $p^H$. Since both types submit the same bid, on the high-price equilibrium path a buyer's posterior beliefs at the Procurement Stage are not updated from the prior belief $z$ and suppliers cannot use bids to signal private information about their type. □

Proposition 2 characterizes necessary conditions for an equilibrium associated with high quality to emerge in the high-price region with $\rho = 0$. It does not rule out the possibility that there exists an incentive for a supplier to deviate to a substantially lower price $p'' \in \bar{B}_-$. Thus, it lacks predictive power versus the standard theory. Fugger et al. (2018) show that with inequity-averse preferences there always exists a low-price equilibrium in a binding price-based auction. Since the selection probability is decreasing in the number of competing suppliers, this incentive to deviate will be higher in setups with a larger number of bidders.

**Proposition 3.** For $\rho \in (0,1)$, there can exist a perfect Bayesian equilibrium in the high-price region with a feasible and consistent set of beliefs and characterized by certain conditions, in which a selfish supplier submits a bid, a fair supplier submits no bid, the buyer accepts, and the selfish seller delivers high quality.

**Proof.**
We again restrict attention to the high-price region. At the Payment Stage, the buyer selects a proportion of the retainage money to solve:

\[
    r^*[q, p, (\alpha_B, \beta_B)] = \arg \max_{r \in [0, 1]} u_B
\]

A selfish buyer will always choose \( r^*_{\text{Self}} = 0 \), independent of the price and quality. If a fair buyer's profit at the onset of the Payment Stage is above the seller's profit, it follows directly from (4) that she will pay the minimum retainage rate necessary to achieve the social norm of payoff equality (by assumption, \( \beta_B > 0.5 \) and so she prefers to give up one unit to the seller to reduce advantageous payoff inequity by two units). If that is not the case, she will always make zero retainage payment. The discontinuous retainage payment rate function is then defined as:

\[
    r^*_{\text{fair}}(q) = \begin{cases} 
        1, & \text{if } p \leq s(q) \\
        \max\{\frac{s(q)}{pp} - \frac{(1 - \rho)}{\rho}, 0\}, & \text{if } p > s(q)
    \end{cases}
\]

**Corollary 1:** The retainage payment rate is weakly increasing in product quality for any price.

At the Delivery Stage, the seller anticipates this and chooses a product quality to maximize his expected utility. For a selfish seller, this equates to maximizing his expected monetary payoff:

\[
    E\pi_S(r, q, p) = (1 - \rho)p + E(r|q, p)pp - c(q)
\]

Where \( E(r|q, a, p) \) is a supplier's expectation of the retainage payment rate given a quality level and winning bid, which is driven by his posterior belief \( \tilde{z} \) as to the probability that the buyer is fair. He is no longer certain to deliver low quality. The required \( \tilde{z} \) to satisfy a selfish seller's IR constraint is weakly decreasing in price:

\[
    IR_{S, \text{Self}}, \quad \tilde{z} \geq \frac{c(q) - (1 - \rho)p}{r^*_{\text{fair}}(q)pp}, \quad r^*_{\text{fair}}(q) \neq 0
\]

Which is defined \( \forall p < \frac{s(q^H)}{(1-\rho)} \) and weakly decreasing in \( p \). Above this price, the model collapses to the case of \( \rho = 0 \) with a high guaranteed payment component. We examine prices below this. The IR constraint is increasing in the retainage proportion, which leads to our second corollary:

**Corollary 2:** Contracts with higher retainage are less likely to induce suppliers to participate at auction.
If a seller’s rationality constraint is satisfied, he will prefer to deliver high over low quality when the expected payment differential more than compensates a seller for the increase in cost. This incentive compatibility (IC) constraint is satisfied when:

\[ IC_{\rho>0}^{\rho>0}: \frac{c(q^H) - c(q^L)}{r_{fair}^*(q^H) - r_{fair}^*(q^L)} \geq \frac{1}{\rho}, \quad r_{fair}^*(q^H) \neq 0 \]  \hspace{1cm} (14)

To understand the comparative statics in (14), we examine separate intervals of its price domain:

**Interval (a):** \( p \leq s(q^L) \). We can rule out this possibility since \( c(q^H) > v(q^L) > c(q^L) \) and so \( s(q^L) < c(q^H) \), the lower bound of \( \bar{B} \).

**Interval (b):** \( s(q^L) < p \leq s(q^H) \). From (11), \( r_{fair}^*(q^H) = 1 \) and \( r_{fair}^*(q^L) = \max\{\frac{s(q^L)}{\rho \rho} - \frac{(1-\rho)}{\rho}, 0\} \). \( IC_{\rho>0}^{\rho>0} \) is weakly decreasing in \( p \) as the difference between a fair buyer’s retainage payment rate in exchange for high quality and for low quality widens. If \( \frac{s(q^L)}{(1-\rho)} \leq s(q^H) \), \( IC_{\rho>0}^{\rho>0} \) reaches a minimum at a price equal to \( \frac{s(q^L)}{(1-\rho)} \). Such a price is guaranteed to lie in the high-price region, by our earlier restriction that \( \frac{c(q^L)}{(1-\rho)} \geq c(q^H) \). If \( \frac{s(q^L)}{(1-\rho)} > s(q^H) \), \( IC_{\rho>0}^{\rho>0} \) is strictly decreasing in \( p \).

**Interval (c):** \( p > s(q^H) \). From (11), \( r_{fair}^*(q^H) = \max\{\frac{s(q^H)}{\rho \rho} - \frac{(1-\rho)}{\rho}, 0\} \) and \( r_{fair}^*(q^L) = \max\{\frac{s(q^L)}{\rho \rho} - \frac{(1-\rho)}{\rho}, 0\} \). \( IC_{\rho>0}^{\rho>0} \) is weakly increasing in \( p \) as the difference between a fair buyer’s retainage payment in exchange for high quality and for low quality narrows. If \( \frac{s(q^L)}{(1-\rho)} \geq s(q^H) \), \( IC_{\rho>0}^{\rho>0} \) remains at a minimum until \( p = \frac{s(q^L)}{(1-\rho)} \). If \( \frac{s(q^L)}{(1-\rho)} < s(q^H) \), \( IC_{\rho>0}^{\rho>0} \) is strictly increasing in \( p \).

Thus, (14) is concave upward in the high-price region: it is weakly decreasing at prices to the left of \( \frac{s(q^L)}{(1-\rho)} \) and weakly increasing to the right. This implies that at some price the compatibility constraint must become the binding constraint for selfish sellers, since it crosses and then remains above the rationality constraint for high quality. In other words, it becomes the threshold trust requirement.

We now show by construction that there can exist a high-price perfect Bayesian equilibrium associated with high quality for \( \rho \in (0,1) \). To do this, we examine the first two stages of the interaction for prices in the concave up, decreasing region of a selfish seller’s IC constraint, \( \Delta \in [v(q^L) + \Delta, \frac{s(q^L)}{(1-\rho)}] \). During the Procurement Stage, a selfish buyer will always accept a transaction in this price region, since acceptance guarantees a positive profit. A fair buyer will also never reject a transaction at a price.
in $D$, since acceptance would either guarantee her an equal split of the surplus in the event of low quality or the ability to distribute profits evenly in the event of high quality. Thus, acceptance does not signal information to the winning supplier about the buyer’s type and so there is no updating by the trustor of his prior belief $z$. Moreover, any information about a supplier’s type that the buyer infers from the Bidding Stage will not influence her decision because she has a dominant strategy.

Now let there be a feasible $z’$ such that $IC_{ρ>0}^{S,Self}$ is just satisfied with equality at the highest price in $D$, $p’ = \frac{s(q^H)}{1-ρ}$. During the Bidding Stage, a fair supplier will not submit a bid less than or equal to $p’$, since his threshold trust requirement is strictly higher than for a fair seller (see appendix A.2). There is no incentive for a supplier to deviate to a higher bid, because it would yield zero probability of selection in case of being matched with at least one other selfish supplier at the Bidding Stage. To ensure that there is no incentive to deviate to a lower bid, we require that two further conditions hold. First, $z$ must satisfy a selfish supplier’s rationality constraint for high quality, such that he prefers to submit a bid than to exit the auction and receive the outside option of zero. This holds when $IC_{ρ>0}^{S,Self}$ is the binding constraint, which is always true at $p’$.10

Second, there must be no incentive for a selfish supplier to undercut the price at auction and subsequently deliver high or low quality. For high quality, this holds when $z’$ is at a weakly decreasing point on $IC_{ρ>0}^{S,Self}$, which is true $∀p ∈ D$. For low quality, $IR_{ρ>0}^{S,Self}$ begins at $z = 1$ and is decreasing in price. Thus, the condition holds for all prices at which the rationality constraint for low quality remains weakly above the compatibility constraint. The decreasing property of the rationality constraint also implies that with belief $z’$ there is no incentive for a supplier to deviate to a bid in the low-price region and deliver low quality. The conditions are thus sufficient for a high-price equilibrium to emerge associated with high quality. This contrasts with Proposition 2. ■

**Proposition 4.** For a large enough $ρ$, there exists a non-empty price subset of the high-price region in which the threshold trust requirement is strictly lower for non-zero retainage contracts than for zero retainage contracts.

**Proof.**

It remains to show that $∃p ∈ D$ at which the threshold trust requirement for a selfish trustor in contracts with non-zero retainage is below the threshold in contracts with zero retainage. We

---

10 Proof: For $p = \frac{s(q^H)}{1-ρ}$, if $s(q^H) ≤ s(q^H)$, $IC_{S,Self}^{ρ>0}$: $z = \frac{2(1-ρ)[c(q^H)−c(q^L)]}{ρ[q^H−q^L]} > IR_{S,Self}^{ρ>0}$: $z = \frac{2(1-ρ)[c(q^H)−s(q^L)]}{ρ[q^H−s(q^L)]}$; if $s(q^H) > s(q^H)$, $IC_{S,Self}^{ρ>0}$: $z = \frac{c(q^H)−c(q^L)}{s(q^H)−s(q^L)} > IR_{S,Self}^{ρ>0}$: $z = \frac{c(q^H)−s(q^L)}{s(q^H)−s(q^L)}$ ■
showed in Proposition 2 that $IR_{B,Self}^{\rho=0}$ is strictly increasing in the high-price region. We also showed in Proposition 3 that $IR_{S,Self}^{\rho>0}$ and $IC_{S,Self}^{\rho>0}$ are weakly decreasing in price $\forall p \in D$. Thus, we restrict attention to the highest price in $D$ permitted by our model. This is $p = \frac{s(q^L)}{1-\rho}$ if $\rho \leq 1 - \frac{s(q^L)}{v(q^H)}$, or $p = v(q^H)$ otherwise. If the proposition is not satisfied here, it cannot be satisfied at any lower price either.

Case (i): $\rho \in (0,1 - \frac{s(q^L)}{v(q^H)})$. $IC_{S,Self}^{\rho>0}$ is always binding at $p = \frac{s(q^L)}{1-\rho}$ (see footnote 10). Thus, we must show that $IC_{S,Self}^{\rho>0} < IR_{B,Self}^{\rho=0}$. For analytical tractability, we assume that $\frac{s(q^L)}{1-\rho} > s(q^H)$. Using (11), this is satisfied for large enough values of $\rho$:

$$\rho > \frac{[v(q^L) - c(q^L)][v(q^H) + c(q^H) - v(q^L) - c(q^L)] + 4[c(q^H) - c(q^L)][v(q^H) - v(q^L)]}{2(v(q^L)[v(q^H) + c(q^H) - v(q^L) - c(q^L)] + 2[c(q^H) - c(q^L)][v(q^H) - v(q^L)])}$$

(15)

Case (ii): $\rho \in (1 - \frac{s(q^L)}{v(q^H)}, 1)$. Since $IR_{B,Self}^{\rho=0}$ reaches a value of one at $p = v(q^H)$, we check that both the compatibility constraint and rationality constraint for high quality are always less than one (the rationality constraint will bind if $\rho$ is very large). First, substituting $p = v(q^H)$ into (14) yields:

$$IC_{S,Self}: \tilde{z} = \frac{2[c(q^H) - c(q^L)]}{v(q^H) + c(q^H) - c(q^L) - v(q^L)}$$

(16)

Which is strictly less than one because $v(q^H) - c(q^H) > v(q^L) - c(q^L) > 0$.

Second, substituting $p = v(q^H)$ into (13) yields:

$$IR_{S,Self}: \tilde{z} = \frac{c(q^H) - (1-\rho)v(q^H)}{s(q^H) - (1-\rho)v(q^H)}$$

(17)

Which must also be less than one because $s(q^H) > c(q^H)$. ■

---

11 Our experiment parameters will satisfy this assumption.
3. Experiment and Hypotheses

3.1 Experimental Design and Procedures

Since we are interested in the strategic behaviors underlying procurement interactions, we test our theoretical predictions using a laboratory experiment involving human subjects. In our experiment, $n = 2$ suppliers compete to sell a product to a single buyer. A between-subjects design is employed with three treatments that vary the retainage parameter $\rho$ (Table 1). Subjects are randomly allocated to one of the treatments and no subject participated in more than one session. This approach circumvents the behavioral implications of subjects experiencing different conditions in sequence. The first treatment corresponds to a Fixed-Price Contract arrangement with $\rho = 0$ (FPC0), in which the seller receives a guaranteed payment equal to the winning auction price. This scenario benchmarks the previous experimental literature.

In the second treatment, the buyer can withhold a decision over payment of 50% of the auction price until after she observes the product quality. This arrangement is termed an Appropriable Retainage Contract (ARC50). The buyer keeps any retainage money not paid to the seller. The decision to permit the buyer to shade on payment along the unit interval is deliberate and simulates the real-world risk of partial as well as non-payment of retainage monies. We choose 50% for the intermediate scenario because it falls within the retainage interval considered in Proposition 1a for out cost and valuation parameters and is most salient for capturing a mutual trust element in our experiment environment. Whilst recognizing that contemporary clauses rarely exceed ten percent, this scenario parsimoniously captures two main retainage features of interest in our experiment: (i) retainage amounts are economically significant, and (ii) suppliers can fully offset the risk of partial or non-receipt of retainage payment by adjusting their bids at auction.

In our third treatment, the contractual trust burden is switched entirely to the seller at a retainage proportion of 75%. This falls within the retainage interval considered in Proposition 1b. Since a seller is restricted to bid a price from their own cost of low quality up to the buyer’s valuation for a high-quality product, there is no available bid at which a seller would not be vulnerable to loss if the buyer makes zero retainage payment. Accordingly, we term this scenario an Informal Price Contract arrangement (IPC75). This treatment is closer in design to an agreement that proceeds on intent, rather than a formal contractual retainage provision. We do not permit sellers to dispute the retainage payment decision in any treatment and all subjects are aware of this.

12 We framed the guaranteed payment component as an “Initial Payment” and the retainage payment as a “Deferred Payment” in the experiment, but it is contractibility rather than timing that is central to the model.
13 The median value of retentions withheld on current construction contracts in England is £35,000 (BEIS 2017).
Table 1 – Experiment treatments.

<table>
<thead>
<tr>
<th>Contract Type</th>
<th>Retainage Level</th>
<th>Treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fixed-Price Contract</td>
<td>( \rho = 0.00 )</td>
<td>FPC0</td>
</tr>
<tr>
<td>Appropriable Retainage Contract</td>
<td>( \rho = 0.50 )</td>
<td>ARC50</td>
</tr>
<tr>
<td>Informal Price Contract</td>
<td>( \rho = 0.75 )</td>
<td>IPC75</td>
</tr>
</tbody>
</table>

There are 27 participants in every session of our experiment, split into three cohorts of 9 participants. Each cohort consists of three buyers and six suppliers. Buyer and supplier roles remain fixed throughout. At the beginning of each period, players are randomly matched into groups of three within a cohort (1 buyer: 2 suppliers). Interaction groups are randomly reconstituted every period, for a total of 30 periods. A bespoke algorithm guaranteed that no participant in a cohort plays with the same two individuals in any consecutive periods. We did not inform subjects of the actual cohort size, to mitigate the possibility of tacit collusion in what might be considered a relatively small cohort (see Katok 2011 for a discussion). Profits are calculated and displayed on the participants' screens at the end of each period. Own-group feedback is provided only. This information remains available in an on-screen history table during all subsequent periods of the experiment, to reinforce the game-theoretic assumption of "perfect recall". Table 2 summarizes the cost and value parameters used in the experiment. The cost of high quality is greater than the cost of low quality and so the seller has a monetary incentive to deliver a low-quality product. Both seller cost and buyer valuation schedules are common knowledge. Non-trading parties earn zero profit. We restrict the bid increment to \( \Delta = 1 \).

The experiment sessions were conducted at the laboratory of a large public university in the United States. Each session lasted 60 to 75 minutes. Participants were students recruited using web-based recruitment software. A total of 162 human subjects participated. All sessions followed the same protocol. Upon arrival at the lab, participants are seated at computer terminals and handed a written copy of the instructions to read in private. All terminals have physical dividers to prevent subjects from seeing the screens of other participants. The instructions are played from an audio recording at the front, to ensure the description of the game is common knowledge and delivery consistent.\(^{14}\) Participants complete a computerized test of understanding before being randomly assigned into the first interaction group. The experiment is programmed using oTree (Chen et al. 2016). In the ARC50 and IPC75 treatments, a slider with random initial value is used at the Payment Stage to avoid anchoring bias and a calculator displays buyer and seller profits for the different

\(^{14}\) The instructions are framed using neutral language and the examples avoid uniform reciprocity to minimise experimenter demand effects (Zizzo 2010). A compendium of the instructions is contained in appendix B.
available payments. At the end of the experiment, participants answered a non-incentivized questionnaire to elicit demographic information, trust and risk attitudes. Communication was prohibited throughout, and all interactions remained anonymous.

Subjects received monetary incentives for their participation. Each subject was paid his or her summed experiment earnings privately and in cash at the end of a session, in addition to a $5 show-up fee. We employed a symmetric exchange rate of 20 experiment currency units (ECU) to $1. Average subject earnings were $17.70 in the FPC0 treatment, $22.70 in the ARC50 treatment and $25.00 in the IPC75 treatment. In our experiment, the possibility of losses is necessary to simulate vulnerability to uncertain behavior. To address this, each subject received a non-refundable endowment of 7 ECU per period. Below this amount, limited liability was imposed. Limited liability was never a problem in the FPC0 or ARC50 treatments. In the IPC75 treatment, it was imposed for two out of 54 subjects.\(^{15}\)

<table>
<thead>
<tr>
<th>Quality Level</th>
<th>Low ((q = q^L))</th>
<th>High ((q = q^H))</th>
</tr>
</thead>
<tbody>
<tr>
<td>Buyer Valuations: (v(q))</td>
<td>35</td>
<td>80</td>
</tr>
<tr>
<td>Seller Costs: (c(q))</td>
<td>30</td>
<td>40</td>
</tr>
</tbody>
</table>

3.2 Hypotheses

Our theoretical predictions afford several testable experiment hypotheses, which are summarized in Table 3. The standard theory predicts that suppliers will always bid and deliver low quality under a binding price-based auction with zero retainage, competing away their profits in the process. This is encapsulated in components (a) and (c) of Hypothesis 1. With our experiment parameters, self-interest implies Nash transaction efficiency of 12.5%, measured as the percentage of surplus realized out of the total made available. The introduction of a 50% retainage mechanism serves only to increase prices in proportion to the retainage level, as sellers compensate for anticipated loss of money withheld. As indicated by Hypothesis 2, when the retainage level is set high enough, it imposes too great a trust burden on suppliers for an auction price to form, due to the high

\(^{15}\) From an analysis of subject-level data in the IPC75, we are satisfied that the onset of limited liability did not induce an increase in subjects’ risk-seeking behavior. The two subjects differed markedly in the degree to which limited liability became a problem. For the first, liability totaled $2 and after period 20 this subject learnt to either submit the highest possible bid of 80 or exit at the auction stage. The second subject maintained an unsuccessful but nevertheless consistent strategy throughout: bid between 30-40 and deliver predominantly low quality. This strategy incurred large period losses and a total liability of $16.
### Table 3 – Experiment hypotheses.

<table>
<thead>
<tr>
<th>Hypothesis</th>
<th>Support</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Standard Theory</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Hypothesis 1.</strong></td>
<td></td>
</tr>
<tr>
<td>For the treatments FPC0 and ARC50 with ( \rho \in [0, 0.625] ),</td>
<td>Proposition 1a.</td>
</tr>
<tr>
<td>(a) Prices will not exceed ( 30/(1 - \rho) + \Delta ), which equals 31 in the FPC0 and 61 in the ARC50;</td>
<td></td>
</tr>
<tr>
<td>(b) Transactions will fail due to buyer rejection at prices greater than ( v(q^t)/(1 - \rho) ), which equals 35 in the FPC0 and 70 in the ARC50;</td>
<td></td>
</tr>
<tr>
<td>(c) Sellers will deliver low product quality at minimum cost independent of their bid and, in the ARC50, buyers will make zero retainage payment;</td>
<td></td>
</tr>
<tr>
<td>(d) Buyer profit will equal four or five and seller profit equal zero or one.</td>
<td></td>
</tr>
<tr>
<td><strong>Hypothesis 2.</strong></td>
<td></td>
</tr>
<tr>
<td>For the treatment IPC75 with ( \rho \in (0.625, 1) ), auctions will uniformly fail and all suppliers will exit at the Bidding Stage.</td>
<td>Proposition 1b.</td>
</tr>
<tr>
<td><strong>Model of Social Preferences</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Hypothesis 3.</strong></td>
<td></td>
</tr>
<tr>
<td>In the ARC50 and IPC75, retainage payment rates will be positively related to the product quality level.</td>
<td>Proposition 3 (Corollary 1).</td>
</tr>
<tr>
<td><strong>Hypothesis 4.</strong></td>
<td></td>
</tr>
<tr>
<td>Auctions are more likely to fail in the IPC75 than in the ARC50 or FPC0.</td>
<td>Proposition 3 (Corollary 2).</td>
</tr>
<tr>
<td><strong>Hypothesis 5.</strong></td>
<td></td>
</tr>
<tr>
<td>Transactions in the high-price region are more likely to be associated with high product quality in the ARC50 and IPC75 than in the FPC0.</td>
<td>Proposition 4.</td>
</tr>
</tbody>
</table>
sunk cost involved in delivering a relation-specific product. Any transactions that do take place will be associated with low quality and no buyer reciprocity in the form of retainage payment.

With population-level heterogeneity in social preferences, we obtain alternative predictions. To confirm that the propositions derived from our model extend to the laboratory environment, we plot the minimum proportion \( z \) of fair agents in the population necessary to satisfy a selfish trustor's incentive compatibility and/or individual rationality constraints, using our experiment parameter values. The resulting thresholds are displayed in Figure 2 (the requirements for a “fair” trustor are displayed in Figure 7 of appendix A.3). Our objective here is not to show how threshold trust requirements would look for all parameterizations, but to demonstrate the differences predicted by the social preferences model between treatments in our experiment.

For \( \rho = 0 \) the rationality constraint corresponds to equation (9). In the FPC0, there exists a feasible \( z \) for which high quality can become a preferred strategy for fair sellers at any \( p \geq 56 \), the lower bound of the implementable high-price region. For \( \rho \in \{0.5, 0.75\} \), the rationality and compatibility constraints correspond to equations (13) and (14) respectively. Hypothesis 3 states that high quality will be rewarded reciprocally with higher retainage payment rates than low quality, while Hypothesis 4 formalizes the prediction that auctions are most likely to fail in the IPC75. We confirm that \( \rho \) is large enough for Proposition 4 to be valid in both the ARC50 and IPC75. This yields Hypothesis 5: Conditional on auction success, transactions in the high-price region associated with high product quality are more likely in the ARC50 and IPC75 than in the FPC0. Figure 2 corroborates this. At prices in the implementable high-price region, the threshold trust requirement is always lower in the ARC50 than in the FPC0. In the IPC75, this is true at prices greater than or equal to 60.

\[ \frac{16}{16} \]

\[ \text{With our parameters, equation (15) is satisfied for all } \rho > 0.367. \]
Figure 2. Threshold beliefs $z$ for a “selfish” trustor to trust in our experiment, by retainage level.

Notes: Plots display the minimum proportion $z$ of commonly known “fair” agents in the population required to satisfy the relevant constraint for a “selfish” trustor, using our experiment parameters and assuming inequity aversion parameters for fair agents in the population of $\alpha_i = 2$ and $\beta_i = 0.6$. The vertical dotted line signifies the beginning of the implementable high-price region. Compatible Trust is the threshold belief required for a trusting action to be strictly preferred to a non-trusting action by the trustor. Rational Trust is the belief required for a trusting action to yield the trustor non-negative expected utility. A trusting action is defined as a buyer acceptance decision when retainage equals 0 or a high quality seller choice when retainage equals 0.5 or 0.75. The shaded area corresponds to the region in which the trusting action is both rational and incentive-compatible.
4. Experimental Results

4.1 Aggregate Findings

In Table 4, we present average values for the key outcome measures of our experiment. Since there is no interaction between subjects playing in different cohorts, each cohort is considered as a statistically independent observation.\(^{17}\) As predicted by Hypothesis 1a, average trade prices are significantly higher in the ARC50 than in the FPC0 \((p = 0.001)\). Whilst we statistically reject the point price prediction that trade prices do not exceed 31 in the FPC0 \((p = 0.031)\), we fail to reject an average price of 61 in the ARC50 \((p = 0.219)\). In contrast to Hypothesis 1b, there is a 31.5\% conditional buyer acceptance probability of a winning price above 35 in the FPC0, which is observed at 184 out of 540 auctions. Although in the ARC50 a price above 70 was accepted in 57.1\% of cases, it was only observed at 14 auctions.

The experiment data clearly falsify Hypothesis 2: during 78\% of auctions in the IPC75, at least one supplier submitted a bid for the buyer to accept or reject. Yet whilst the supplier exit probability is only 1-2\% in the FPC0 and ARC50, it is 36\% in the IPC75. Auctions were consequently more likely to fail here than in either of the other two treatments, which each attained full auction efficiency. This result confirms our social preferences Hypothesis 4. There is no difference in the average trade price between the non-zero retainage treatments. Unsurprisingly, buyer acceptance rates are significantly higher in the ARC50 than in the FPC0 \((p = 0.013)\) and in the IPC75 than in the ARC50 \((p = 0.045)\), reflecting the reduced buyer vulnerability to loss at greater contractual retainage levels. In the IPC75, nearly all prices are accepted.

Conditional on trade, Hypothesis 1c is largely supported in the FPC0. Low quality was delivered in 93.9\% of transactions. There is a notable increase in market trust as represented by an improvement in average product quality in the ARC50 and IPC75. This cannot be explained by the standard theory. Instead, there is support in favor of our social preferences Hypothesis 5, which implies that the burden of trust required to realize high quality conditional on price is lower with buyer retainage. The proportion of transactions associated with high quality is 30.2\% in the ARC50 and 50.4\% in the IPC75, although the difference between the two treatments is not significant at the 5\% statistical threshold \((p = 0.093)\). In Figure 3, we present the relative frequencies of trade by price and quality level, conditional on auction success and buyer acceptance. Quality is near-uniformly low

\(^{17}\) Unless explicitly stated, in the analysis that follows we employ a two-tailed Wilcoxon Signed-Rank test for one-sample comparisons and two-tailed Wilcoxon-Mann-Whitney test for two-sample comparisons. When making multiple comparisons, we use Holm’s (1979) p-value adjustment method. We acknowledge the potential caveat of arbitrary static correlations within sessions (Fréchette, 2012). In our experiment, cohorts were recruited across two sessions per treatment and power considerations preclude use of session averages.
Table 4 – Cohort means and standard deviations.

<table>
<thead>
<tr>
<th></th>
<th>FPC0</th>
<th>ARC50</th>
<th>IPC75</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Price</strong></td>
<td>35.08</td>
<td>57.79</td>
<td>57.21</td>
</tr>
<tr>
<td>(1.72)</td>
<td>(5.42)</td>
<td>(8.08)</td>
<td></td>
</tr>
<tr>
<td><strong>Buyer Acceptance Rate</strong></td>
<td>0.60</td>
<td>0.91</td>
<td>0.98</td>
</tr>
<tr>
<td>(0.20)</td>
<td>(0.08)</td>
<td>(0.01)</td>
<td></td>
</tr>
<tr>
<td><strong>High Quality Rate</strong></td>
<td>0.06</td>
<td>0.30</td>
<td>0.50</td>
</tr>
<tr>
<td>(0.02)</td>
<td>(0.20)</td>
<td>(0.19)</td>
<td></td>
</tr>
<tr>
<td><strong>Retainage Payment Rate</strong></td>
<td>N/A</td>
<td>0.15</td>
<td>0.29</td>
</tr>
<tr>
<td></td>
<td>(0.11)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>For Low Quality</td>
<td>0.06</td>
<td>0.16</td>
<td></td>
</tr>
<tr>
<td>(0.07)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>For High Quality</td>
<td>0.32</td>
<td>0.40</td>
<td></td>
</tr>
<tr>
<td>(0.16)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Supplier Exit Rate</strong></td>
<td>0.01</td>
<td>0.02</td>
<td>0.36</td>
</tr>
<tr>
<td>(0.01)</td>
<td>(0.03)</td>
<td>(0.26)</td>
<td></td>
</tr>
<tr>
<td><strong>Auction Success Rate</strong></td>
<td>1.00</td>
<td>1.00</td>
<td>0.78</td>
</tr>
<tr>
<td>(0.00)</td>
<td>(0.00)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Buyer Profit</strong></td>
<td>2.83</td>
<td>15.83</td>
<td>31.40</td>
</tr>
<tr>
<td>(1.07)</td>
<td>(7.65)</td>
<td>(2.49)</td>
<td></td>
</tr>
<tr>
<td><strong>Winning Supplier Profit</strong></td>
<td>4.43</td>
<td>-0.25</td>
<td>-8.75</td>
</tr>
<tr>
<td></td>
<td>(1.54)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Notes: Displayed are mean (SD) values for the key experiment parameters based on 6 independent cohort observations per treatment. **Auction Success Rate** measures the proportion of auction at which ≥ 1 supplier bid. **Price, High Quality Rate and Retainage Payment Rate** are conditional on auction success and buyer acceptance. Profit is expressed in ECU per period conditional on trade and excludes the endowment.

in the FPC0 independent of price. In the ARC50, high quality transactions are concentrated over a narrow range of prices, which reflect those at which the trust requirement is lowest in Figure 2. High quality in the IPC75 extends over a wider range of winning auction bids in the high-price region. This is also consistent with the social preferences model. By substituting our parameters into equation (13), we can verify that given entry a supplier’s rationality constraint for a trusting action is less stringent than for a non-trusting action at 75% retainage.

Overall, we cannot reject the null hypothesis that transaction efficiency attained its Nash equilibrium level of 12.5% in the FPC0 (p = 0.31). There was, however, a substantial improvement relative to the FPC0 in the ARC50 (36% transaction efficiency, p = 0.007) and the IPC75 (56% transaction efficiency, p = 0.009). In Figure 4, we plot time-series of the realized auction and transaction efficiency separately across the 30 periods in each experiment treatment. Whilst auctions
always succeed when retainage is zero or 50%, at 75% retainage the experimental markets begin to unravel after period five and the collapse in auction efficiency continues until the final period at which point half of auctions fail. Trend differences in transaction efficiency are also pronounced. In the FPC0, transaction efficiency remains in the 0 – 25% interval, whereas in the ARC50 it is in the 25 – 50% interval. For both, transaction efficiency becomes less volatile over time. In the IPC75, transaction efficiency begins in the 25 – 50% interval and then trends upwards over time, but with fewer trades in the market. Consequently, there is no significant difference in global efficiency between the ARC50 and IPC75 ($p = 0.39$).^18

^18 Global efficiency is realized surplus out of the total possible, rather than the total made available by suppliers.
Figure 4. Decomposition of auction versus transaction efficiency over time.

![Graph showing auction efficiency and transaction efficiency over time.]

Notes: Based on 18 market interaction groups per treatment in a period. Auction efficiency is a measure of the total surplus made available at auction. Transaction efficiency is a measure of the surplus captured in the period divided by the surplus that suppliers had made available.

From the information in Table 4, we reject the part of Hypothesis 1c that states buyers make zero retainage payments and instead deduce some evidence to support our reciprocal Hypothesis 3. A supplier's probability of receiving a non-zero retainage payment in the ARC50 is 31% after delivering low quality and 61% after delivering high quality. Buyers paid suppliers 31.8% of retainage monies withheld in exchange for high quality and just 6.1% in exchange for low quality. In the IPC75, for which the retainage amount constitutes a larger share of the agreed price, the respective probabilities of non-zero payments are 54% and 74% and payment rates are 15.6% and 40.4%. The premium paid for high quality is significant ($p < 0.001$). In Figure 8 of appendix A.4, we provide visual evidence of this positive reciprocity over time in our experiment.

Since reciprocity is imperfect, total payments are lower on average in the ARC50 (mean of 32.77) versus the FPC0. Mean payments are also lower in the IPC75 at 26.29, although these aggregate
The differences are not statistically significant and mask heterogeneity at the cohort level. The standard theory does not provide a satisfactory explanation of the profit distributions that emerge. In qualitative terms, the distribution postulated in Hypothesis 1d is reversed in the FPC0: sellers earn 1.60 more per period than buyers, a significant difference ($p = 0.047$), even though buyers enjoy market power. We reject the hypothesis that sellers receive a profit equal to 1 ($p = 0.031$) and at a lower statistical level that buyers earn 4 ($p = 0.063$). When the buyer withholds 50% retainage, outcomes change substantially. Whilst sellers now earn a per period profit no different from zero on average ($p = 0.844$), buyers earn 18.53, an economically large and significant increase relative to the theoretical prediction ($p = 0.031$). Sellers fare even worse under 75% retainage, incurring a period loss of 8.75, as opportunistic buyers appropriate surplus to double their average profit to 31.40.

Figure 5 illustrates average buyer and seller profits by quality level as a function of price in the three treatments. Prices at which trade occurred more frequently are represented by a larger circle in the figure. Delivering low quality is an unprofitable strategy for sellers unless the price is high or retainage low enough. Buyer profit increases monotonically in the retainage level, at the expense of sellers who fail to adjust their bidding behavior when confronted with an untrustworthy buyer.

### 4.2 Learning and Cohort Dynamics

The exposure of sellers to losses in our experiment suggests scope for learning. We therefore conduct a statistical analysis of the differences in decision-making over time (see Table 8 in appendix A.5). There are some significant differences between periods 1-10 and 11-20. Sellers quickly learn not to deliver high quality in the FPC0. As buyers lower their retainage payments in exchange for low quality in the ARC50 and IPC75, suppliers learn to raise their bids or alternatively exit the auction in the IPC75. No learning is evident after the first 11-20 periods in any treatment.

In Table 5 we display the results of a random-effects panel regression of supplier bidding behavior over time. There is a significant negative time trend with zero retainage contracts, which changes to a significant positive time trend in treatments with non-zero retainage. The size of the bid adjustment is largest in the IPC75, and the smaller sample size reflects the elevated supplier exit rate. Controlling for these adjustments, the supplier bid determinants are stable across treatments: bids rise in response to the bid submitted by a subject’s most recently matched competitor and fall when a transaction occurred last period.

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19 FPC0 versus ARC50 ($p = 0.19$), FPC0 versus IPC75 ($p = 0.12$), ARC50 versus IPC75 ($p = 0.19$).

20 Since there are multiple observations per subject, we allow for random-effects at the subject level.

21 In Table 9 of appendix A.6 we report a similar regression for determinants of the supplier exit rate in the IPC75. Only the positive time trend is significant.
Figure 5. Average buyer and seller profits as a function of trade price.

Notes: Based on 174 price-profit pairs observed for buyers and sellers, split by quality level. The size of a circle corresponds to the number of observations of a price-profit pair. The dashed line is at the breakeven profit level.

To obtain detailed insight into the heterogeneity between cohorts, we visualize buyer and winning supplier decisions for the six cohorts in a treatment separately and classify them according to the dynamics observed. Figure 6 displays the outcomes from two representative cohorts per treatment. These cohorts suffice to capture the main behavioral differences that emerge over time within each retainage arrangement. In this figure, the x-axis is the period-group and the y-axis corresponds to the winning auction price (conditional on auction success) and the sum of guaranteed and retainage payment if price does not equal total payment. An open triangle in the figure is an auction failure and a cross is a transaction failure. A solid circle is an accepted auction price at which the seller delivered low quality, and an open circle is the corresponding payment. A solid square is an

---

22 The remaining four experiment cohorts per treatment are contained in Figure 9 of appendix A.7 and exhibit a mixture of the respective representative cohort dynamics identified in Figure 6.
Table 5 – Random effects panel regression of supplier bidding behavior.

<table>
<thead>
<tr>
<th></th>
<th>FPC0</th>
<th>ARC50</th>
<th>IPC75</th>
</tr>
</thead>
<tbody>
<tr>
<td>Competitor's Bid t-1</td>
<td>0.25***</td>
<td>0.35***</td>
<td>0.37***</td>
</tr>
<tr>
<td></td>
<td>(0.03)</td>
<td>(0.03)</td>
<td>(0.04)</td>
</tr>
<tr>
<td>Trade t-1</td>
<td>-3.49***</td>
<td>-3.64***</td>
<td>-4.10***</td>
</tr>
<tr>
<td></td>
<td>(0.54)</td>
<td>(0.50)</td>
<td>(1.10)</td>
</tr>
<tr>
<td>Period</td>
<td>-0.12***</td>
<td>0.20***</td>
<td>0.44***</td>
</tr>
<tr>
<td></td>
<td>(0.03)</td>
<td>(0.03)</td>
<td>(0.06)</td>
</tr>
<tr>
<td>Constant</td>
<td>32.98***</td>
<td>39.06***</td>
<td>35.50***</td>
</tr>
<tr>
<td></td>
<td>(1.43)</td>
<td>(1.65)</td>
<td>(2.19)</td>
</tr>
<tr>
<td>R²</td>
<td>0.13</td>
<td>0.23</td>
<td>0.40</td>
</tr>
<tr>
<td>Observations (Subjects)</td>
<td>1014 (36)</td>
<td>999 (36)</td>
<td>523 (35)</td>
</tr>
</tbody>
</table>

Notes: Standard errors in parentheses. *** p < 0.001, ** p < 0.01, * p < 0.05.
Regressions reported estimate the effect of the most recent competitor’s bid, last period trade participation and the current period on the supplier’s bid at auction.

accepted price at which the seller delivered high quality; an open square the corresponding payment. Arrows represent the price-payment differential. The approach yields 90 observations per cohort.

Panel (a) in Figure 6 exemplifies the disciplining power of competition in the FPC0 as implied by the standard theory. Winning suppliers bid in the 30 – 35 range and deliver low quality, after some learning, which in cohort 2 is almost immediate. Panel (b) reveals a different dynamic: suppliers attempt to elicit buyer trust and trade in the high-price region. If buyers adhere perfectly to the standard theory, they will reject all prices above the dashed line. Since this is largely the case here, we label this cohort as low buyer trust. Panels (c) and (d) demonstrate the reversal in the price time-series in the ARC50 and the convergence of winning auction bids towards the Nash equilibrium price of 60 from below. Although in cohort 5, suppliers consistently followed the non-trusting strategy of low quality delivery, receiving little if any retainage payment, in some cohorts suppliers did attempt to sustain reciprocal and high quality procurement. In cohort 3, this was often rewarded by buyers, who paid a total amount above the cost of high quality - the dotted line in panel (d) - and supports Hypothesis 3. Yet vulnerability to loss, as realized in interactions with a price-payment differential that left the compensation arrowhead below 40, undermined market trust.

Outcomes in the IPC75 were more variable still. Panels (e) and (f) present two opposing cohort dynamics. Suppliers in cohort 6 maintained a strategy close to the equilibrium as anticipated in Hypothesis 2 and exited at the Bidding Stage. Two-thirds of auctions failed in this cohort. In cohort 1, suppliers were more willing to trust that the buyer would reward product delivery and profited as a result. However, in interactions where a buyer failed to reciprocate, the supplier downside is substantially larger (longer arrows in the figure), resulting in the large average seller losses. This lack of buyer trustworthiness manifested itself to different degrees across cohorts in the IPC75.
Figure 6. Representative cohort outcomes over time.

(a) FPC0: cohort 2. *Nash supplier bidding.*

(b) FPC0: cohort 6. *Low buyer trust.*
(c) ARC50: cohort 5. *Nash supplier bidding with mark up.*

(d) ARC50: cohort 3. *Supplier trust, imperfect buyer reciprocity.*
Notes: Panels (a) to (f) display price, payment and product quality outcomes over time in the specified treatment – cohort, between-subjects design. Each observation corresponds to the outcome of a randomly matched interaction group in the period, with 1 buyer and 2 suppliers. An open triangle is an auction failure (neither supplier submitted a bid). A cross is a transaction failure (buyer rejection of the winning auction price). A solid circle is an accepted auction price at which the seller delivered low quality, and an open circle is the corresponding payment. A solid square is an accepted auction price at which the seller delivered high quality and an open square is the corresponding payment. The arrows represent the price-payment differential. In panels (a) and (b), the dashed line corresponds to the buyer valuation for low quality. In panels (c) to (f), the dashed (dotted) line corresponds to the seller delivery cost of low (high) quality.
4.3 Individual Trust and Trustworthiness

To examine the individual-level determinants of trust in our experiment, in Table 6 we conduct random effects logit regressions with the dependent variable as the penultimate mover’s action. For the FPC0, the dependent variable is the buyer acceptance decision and for the ARC50 and IPC75 it is the seller quality decision. We estimate two specifications per treatment. The first specification estimates the effect of price and the current period on a buyer or seller’s propensity to trust. We specify price as a quadratic relationship in non-zero retainage treatments based on the analytical result from equation (14) that the threshold trust requirement is concave up on the price domain. The second specification adds the trustworthy action experienced by an individual in the previous interaction as an independent variable, to capture any indirect reciprocity between periods. For the FPC0, this is the lagged quality decision and for the ARC50 and IPC75 it is the lagged retainage payment rate.

In columns 1 and 2 of Table 6, we observe that the buyer acceptance probability is decreasing in price with zero retainage, but that there is no robust temporal effect. Prior receipt of high product quality makes no significant difference, due presumably to its rare occurrence. The determinants of supplier quality in columns 3 to 6 are qualitatively similar between the ARC50 and IPC75, but only significant in the latter. That is, price is able to serve as a meaningful (non-linear) function of quality only when the supplier is confronted with greatest uncertainty and cannot rely on the guaranteed payment component as insurance. The lagged retainage payment rate has a strong and positive effect on trust in all specifications, but in the ARC50 is statistically weak ($p = 0.068$). Supplier quality is increasing over time in the IPC75, which captures the market withdrawal of less trusting suppliers.

Turning our attention to the factors influencing individual trustworthiness, in Table 7 we employ random effects Logit and Tobit with the dependent variable as the last mover’s action. For the FPC0, the dependent variable is the seller quality decision and for the ARC50 and IPC75 it is the buyer retainage payment rate, which requires two-sided censoring at zero and one. From column 1, the probability of high quality delivery is significantly increasing in the price and decreasing over the course of the experiment when contracts impose zero retainage. The determinants of buyer trustworthiness in payment of retainage monies are stable and highly significant. Payment rates are decreasing in price and over time, but the effect sizes are small. The most important factor is the transaction quality, providing strong evidence once again in support of our reciprocal Hypothesis 3.
Table 6 – Random effects Logit regressions of trust in procurement interactions.

<table>
<thead>
<tr>
<th>Predictor</th>
<th>FPC0</th>
<th>ARC50</th>
<th>IPC75</th>
</tr>
</thead>
<tbody>
<tr>
<td>Price</td>
<td>-0.12***</td>
<td>0.19</td>
<td>0.37***</td>
</tr>
<tr>
<td></td>
<td>(0.02)</td>
<td>(0.12)</td>
<td>(0.07)</td>
</tr>
<tr>
<td>Price^2</td>
<td>-0.002</td>
<td>-0.003</td>
<td>-0.003**</td>
</tr>
<tr>
<td></td>
<td>(0.001)</td>
<td>(0.002)</td>
<td>(0.0006)</td>
</tr>
<tr>
<td>Period</td>
<td>0.02*</td>
<td>-0.01</td>
<td>0.07***</td>
</tr>
<tr>
<td></td>
<td>(0.01)</td>
<td>(0.02)</td>
<td>(0.02)</td>
</tr>
<tr>
<td>Quality_{t-1}</td>
<td>0.27</td>
<td>0.01</td>
<td>0.13***</td>
</tr>
<tr>
<td>Retainage Payment Rate_{t-1}</td>
<td>1.13</td>
<td>1.40*</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.59)</td>
<td>(0.02)</td>
<td>(0.03)</td>
</tr>
<tr>
<td>Constant</td>
<td>4.57***</td>
<td>-5.44</td>
<td>-11.14**</td>
</tr>
<tr>
<td></td>
<td>(0.85)</td>
<td>(3.26)</td>
<td>(1.92)</td>
</tr>
<tr>
<td>Log Likelihood</td>
<td>-308.87</td>
<td>-254.71</td>
<td>-231.51</td>
</tr>
<tr>
<td>Observations (Subjects)</td>
<td>540 (18)</td>
<td>492 (36)</td>
<td>415 (35)</td>
</tr>
</tbody>
</table>

Notes: Standard errors in parentheses. *** p < 0.001, ** p < 0.01, * p < 0.05. Columns 1, 3 and 5 estimate the effect of the winning auction bid and current period on the probability of a trusting action by the penultimate-mover. A trusting action constitutes buyer acceptance in the FPC0, and high quality seller delivery in the ARC50 and IPC75. Column 2 accounts for the quality received by the buyer in the previous period. Columns 4 and 6 account for the retainage payment received by the seller in the previous period. The number of observations is lower in columns 2, 4 and 6 since they are restricted to cases in which the buyer or seller traded in the prior period.

Table 7 – Random effects Logit and Tobit regressions of trustworthiness in procurement interactions.

<table>
<thead>
<tr>
<th>Predictor</th>
<th>FPC0</th>
<th>ARC50</th>
<th>IPC75</th>
</tr>
</thead>
<tbody>
<tr>
<td>Price</td>
<td>0.08**</td>
<td>-0.01***</td>
<td>-0.005**</td>
</tr>
<tr>
<td></td>
<td>(0.03)</td>
<td>(0.001)</td>
<td>(0.002)</td>
</tr>
<tr>
<td>Period</td>
<td>-0.09**</td>
<td>-0.01***</td>
<td>-0.01**</td>
</tr>
<tr>
<td></td>
<td>(0.03)</td>
<td>(0.001)</td>
<td>(0.002)</td>
</tr>
<tr>
<td>Quality</td>
<td>0.57**</td>
<td>0.41***</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.02)</td>
<td>(0.02)</td>
<td></td>
</tr>
<tr>
<td>Constant</td>
<td>-4.41***</td>
<td>0.57**</td>
<td>0.37***</td>
</tr>
<tr>
<td></td>
<td>(1.28)</td>
<td>(0.06)</td>
<td>(0.10)</td>
</tr>
<tr>
<td>Log Likelihood</td>
<td>-64.53</td>
<td>-123.80</td>
<td>-187.56</td>
</tr>
<tr>
<td>Observations (Subjects)</td>
<td>326 (36)</td>
<td>492 (18)</td>
<td>415 (18)</td>
</tr>
</tbody>
</table>

Notes: Standard errors in parentheses. *** p < 0.001, ** p < 0.01, * p < 0.05. Column 1 reports a random effects panel Logit regression that estimates the effect of the price and current period on the probability of a trustworthy action by the final-mover in the FPC0, namely high quality seller delivery. Columns 2 and 3 report random effects two-sided Tobit regression models that estimate the effect of the price, current period and product quality on the level of a trustworthy action by the final-mover in the ARC50 and IPC75, namely the buyer retainage payment rate. The Tobit specification censors the dependent variable at 0 and 1. In the ARC50, 294 observations are left-censored, and 11 observations are right-censored. In the IPC75, 146 observations are left-censored, and 16 observations are right-censored.
5. Discussion

Our experimental results reinforce the earlier finding of Fugger et al. (2018) that reverse auctions with zero-retainage contracts perform poorly from an efficiency perspective in complex procurement projects. When performance cannot be tied to outcomes, trust can be improved if the buyer withholds retainage monies up-front. But trusting actions, in the form of high product quality delivery, are not profitable on average for individual suppliers due to the difficulty in sustaining trustworthy buyer payment behavior. Some suppliers are too ready to trust in our experiment, particularly in the IPC75. Thus, whilst the pecuniary benefit to buyers is substantial, appropriable retainage mechanisms are unable to yield a Pareto improvement in the market.

We developed our behavioral hypotheses ex-ante using the Fehr and Schmidt (1999) specification of outcome-based social preferences, whilst assuming private information about individual agent types. By focusing on the distribution of payoffs, we could tractably characterize expected outcomes, \textit{ceteris paribus}, for different sub-populations. The finding that, conditional on auction success and buyer acceptance of a transaction, the relative frequency of high quality is higher in the IPC75 than in the ARC50 is not at odds with our model. The rationality constraint for low quality in the IPC75 is strictly above the rationality constraint for high quality in the implementable high-price region for our experiment parameters. Thus, there is a lower threshold trust requirement for suppliers to enter and deliver high quality in the IPC75 than there is to enter and deliver low quality. The reverse is true in the ARC50.

Whilst learning can account for some of the bidding behavior observed early on, our analysis does not explain why a large fraction of sellers persisted in entering the market in the IPC75. Loss aversion would also predict the opposite. To check whether heterogeneous risk preferences played a part, we regress the cumulative profits of subjects who played the role of the penultimate-mover in each treatment on their individual risk and trust attitudes as elicited in the post-experiment questionnaire, controlling for subject gender and age (see Table 10 in appendix A.8 for details).\footnote{These measures are non-incentivized and so the results are only suggestive.} There is no evidence to suggest that more risk-seeking subjects earned significantly lower profits in the IPC75. There is some evidence that buyers who are willing to take greater risks earned less in the FPC0 and that suppliers with a greater propensity to trust others in general earn more in the ARC50.

Our model relies on the interaction between “fair” and “selfish” types in the population for its ability to make predictions as to the impact of different retainage levels. A somewhat counterintuitive prediction of the model that we are unable to test is the insight in Proposition 3 that it is \textit{selfish} rather than fair seller types who are more likely to deliver high quality with non-zero retainage contracts.
This is not without precedent in the social preferences literature. Fehr et al. (2007) show that only selfish agents reciprocate optimal wage offers with high effort in bonus contracts; fair agents are unwilling to risk the inequity that would result from a principal’s failure to honor a bonus payment. Bohnet and Zeckhauser (2004) provide experimental evidence that fairness concerns inhibit trusting behavior. Whilst it would be possible to test this insight directly by eliciting social preferences using a separate incentivized task in the experiment, we choose not to do so based on a methodological concern about the consistency of preferences across auction games and elicitation tasks.

Models that nest inequity aversion in a broader reciprocity framework, such as Charness and Rabin (2002), are unlikely to explain a lack of reciprocity by buyers in exchange for high quality. There is also ambiguity surrounding the reference point against which “kind” behavior should be compared: whilst we avoided connotations of property rights in our experiment instructions, both buyers and sellers might have felt entitled to some or all of the retainage money following contracting. Alternative intentions-based theories of reciprocity (Dufwenberg and Kirchsteiger 2004, Falk and Fischbacher 2006) do not generate clear predictions when a player makes multiple decisions in extensive-form games. Since intentions are largely unambiguous in our non-stochastic setting, there seems little to gain from modelling them here.

A plausible explanation for the lack of positive buyer reciprocity in non-zero retainage arrangements versus the gift-exchange literature has to do with its relative cost. Like in the Trust Game (Berg et al. 1995), in the post-auction phase of our experiment the buyer must spend a dollar to give a dollar of retainage money to the seller. By contrast, effort provision in typical gift exchange games or in the Buyer-Determined Reverse Auction treatment of Fugger et al. (2018) raises the buyer’s value by a factor substantially above one.24 Trusting via the delivery of high quality is then a break-even strategy at best.

6. Concluding Remarks

The managerial literature has devoted substantial attention to how auction institutions might be designed to improve market efficiency. In binding reverse auctions, when sellers compete over a fixed price, principal-agent models cannot sustain high quality equilibria under moral hazard. The identification of alternative mechanisms that can both reap the benefits of price competition and sustain cooperation in principal-agent relationships is thus of considerable economic significance. In a complex one-shot tender process, the alignment of incentives is crucial. A contractual imbalance

such that one side bears a greater burden of trust in the relationship than the other can shape the outcome of the procurement transaction.

In this paper, we conduct a controlled laboratory test of a real-world contractual retainage mechanism prevalent in the global construction industry. We compare contracts at a price-based reverse auction in which there is (1) zero retainage, (2) partial retainage set such that a supplier can fully adjust their bid to compensate for the increased vulnerability, and (3) a high retainage structure analogous to intent in which the supplier can only guarantee to avoid a loss by withdrawing from the market. Whilst the standard theory predicts that efficiency will be low in the first two contract types and zero in the third contract type, our data reveals significant differences between treatments. The probability of high product quality is greater in non-zero retainage arrangements, due to the incentive effect of deferred payment. But if supplier’s are engaged informally with no ability to enforce a minimum payment, we also observe unravelling in auction efficiency over time.

There is a marked trade-off between transaction efficiency and profit equality in the experiment. Sellers earn a greater share of a smaller pie in the absence of retainage. Buyers are able to appropriate nearly all the surplus from an enlarged pie when retainage is permitted and payment cannot be enforced. Our behavioral model based on social preferences with incomplete information can explain many of the contractual differences observed. An open question in the managerial literature is the extent to which models of social preferences, originally conceived of to explain individual behavior, can usefully explain firms’ decisions. We propose that our approach to derive common threshold beliefs as to the likelihood of a buyer or supplier in the market acting in good faith is a useful compromise at the sector level.

The results of this research suggest that policymakers’ concerns about retainage payment malpractices in the supply chain may be justified when contractual obligations are difficult for third-parties to verify. They also provide a cautionary tale for suppliers as to the dangers of engaging in work based on intent and with no guarantee over payment to cover production costs. In our setting, suppliers are unable to dispute the buyer’s retainage payment decision. In practice, whilst formal litigation is costly, alternative dispute opportunities are sometimes available. Future research might investigate the effect of introducing such a mechanism into the setup. One example is third-party arbitration, observed empirically in the rental housing market for the administration of tenants’ security deposits. In addition, consideration could be given to the impact of a buyer’s payment record in an effective procurement process. Reputation has previously been observed to improve supplier trustworthiness under conditions of moral hazard (Brosig-Koch and Heinrich 2014).
Appendix A.1: Model of homogenous social preferences.

Below we derive model predictions for the complete information case of homogenous social preferences. All individuals are assumed to be fair with the same inequity aversion parameters and it is common knowledge that \( z = 1 \). Since in our model \( \alpha \geq \beta > 0.5 \) for fair types, the fairness motive dominates the profit-maximizing motive for both a buyer and supplier. The utility function of each has its global maximiser at a price equal to \( s(q^H) + \Delta \), which implements an equal profit split at the highest quality level.

**Proposition 5.** For all \( \rho \in [0, 1) \), there exist up to two subgame-perfect equilibria: one in the low-price region at \( p_L \), in which the buyer accepts, and the seller delivers low quality; and another in the high-price region at \( p_H \) in which the buyer accepts, and the seller delivers high quality.

**Proof.**

There are two cases to consider.

Case (i): \( \rho = 0 \). Retainage is zero and so the final Payment Stage is obsolete. Denote the lowest acceptable bid for a supplier associated with non-negative utility as \( p_L \leq s(q^L) \). We know that a seller (weakly) prefers high quality \( \forall p \geq p_H \) and low quality \( \forall p_L \leq p < p_H \). At the Procurement Stage, the buyer anticipates these possible outcomes in the final sub-game and will accept to purchase from the winning supplier if her utility \( u_B(q^*(p), p) \geq 0 \), or refuse to purchase if not.

First, let all suppliers submit a bid in the low-price region equal to \( p_L \). There is no incentive to undercut this price because any lower price would yield a supplier negative utility. There is no incentive to deviate to a higher price because it is associated with zero selection probability due to the binding price-based rules of the auction. For the same reason, there is always an incentive to undercut a competing supplier at auction at any \( p > p_L \) in the low-price region. There is no incentive to exit the auction because the outside option is a profit of zero. Thus, there is an equilibrium, unique in the high-price region, in which all suppliers submit a bid of \( p_L \) and deliver low quality.

Now, consider the possibility that all suppliers submit a bid in the high-price region equal to \( p_H \). A buyer will always accept a price of \( p_H \) in the implementable high-price region, since \( p_H \leq s(q^H) \) and \( \beta < 1 \). Thus, in the high-price region there is always an incentive for a supplier to undercut a competitor at auction until reaching a bid of \( p_H \), to increase his or her selection probability to one. Like in Proposition 2, there is no incentive for a supplier to submit a bid below this level in the non-implementable high-price region because it has zero acceptance probability. Similarly, deviation to a higher bid would entail zero probability of winning the auction. Thus, there is another equilibrium,
unique in the high-price region, in which all suppliers submit a bid of \( p^H \) and deliver high quality. As in Proposition 2, this condition is necessary but not sufficient: a further requirement is the no-deviation incentive to the low-price region.

*Case (ii):* \( \rho \in (0,1) \). Retainage is non-zero and so all stages are relevant. At the Payment Stage, the product quality and auction price are known, and the buyer selects a proportion of the retainage money \( r \) to achieve the most equal profit distribution possible according to equation (11). At the Delivery Stage, the winning supplier anticipates this and so the model collapses to the case of \( \rho = 0 \) with the exception that the nature of the discontinuity at \( p^H \) changes. Specifically, a buyer will accept any price in the non-implementable region so long as \( u_B(q^L, (1 - \rho)p^H) \geq 0 \), i.e. the retainage proportion is large enough to permit a sufficiently equal distribution of payoff. The discontinuity in seller quality choice at \( p^H \) ensures that his profit incentive from undercutting to the buyer’s highest acceptable price in the non-implementable region is equivalent to his incentive to undercut to the buyer’s highest acceptable price in the low-price region for the case of \( \rho = 0 \). \( \square \)
Appendix A.2: Rationality and compatibility constraints for a “fair” trustor in the model of social preferences.

Complements Proposition 2 for $\rho = 0$.

In the Procurement Stage, a fair buyer will accept the transaction at a price in the implementable high-price region $\bar{B}$ if the proportion of fair agents in the population satisfies the following individual rationality constraint:

$$IR_{B,Fair}^{\rho=0}: \tilde{z} \geq \frac{5p - 3v(q_L) - 2c(q_L)}{v(q^H) - v(q_L) + w}$$

(18)

Where:

$$w = \begin{cases} 2.8p[v(q_L) - c(q_L)] - 0.6[v(q^H) + c(q^H)], & \text{if } p^H \leq p \leq s(q^H) \\ 2[v(q^H) - v(q_L) + c(q^H) - c(q_L)], & \text{if } p > s(q^H) \end{cases}$$

Which is strictly above $IR_{B,Self}^{\rho=0}$ due to the potential payoff inequalities that arise from trade.

Complements Proposition 3 for $\rho \in (0, 1)$.

A fair seller at the Delivery Stage also cares about relative profits. His expected utility is:

$$E\pi_S(q; p) = (1 - \rho)p + z \cdot [r_{fair}^*(q)\rho p] - c(q)$$

$$-2 \cdot \max\{v(q) + c(q) - 2(1 - \rho)p - 2z \cdot [r_{fair}^*(q)\rho p], 0\}$$

$$-0.6 \cdot \max\{2(1 - \rho)p - v(q) - c(q), 0\}$$

To make the problem interesting, we assume that a fair seller remains in the area of disadvantageous inequality after delivering high quality and receiving the guaranteed payment component.\textsuperscript{25}

Like for a selfish seller, the required proportion of fair agents in the population to satisfy a fair seller’s rationality constraint is weakly decreasing in price:

$$IR_{S,Fair}^{\rho>0}: \tilde{z} \geq \frac{3c(q) + 2v(q) - 5(1 - \rho)p}{r_{fair}^*(q)\rho p}, \quad r_{fair}^*(q) \neq 0$$

(20)

\textsuperscript{25} Zero fair agents are required in the population for high quality to be a rational action for a fair seller when the guaranteed payment component is greater than or equal to $s^H$. 
Which is always defined in our area of interest and is strictly above $IR^{\rho>0}_{S,Self}$.

If a fair seller would also remain in the area of disadvantageous inequality after delivering low quality, he prefers to deliver high quality over low quality when:

$$IC^{\rho>0,x}_{S,\text{Fair}}: \bar{z} \geq \frac{3[c(q^H) - c(q^L)] + 2[v(q^H) - v(q^L)]}{5[r_{\text{fair}}^*(q^H) - r_{\text{fair}}^*(q^L)]\rho p}, \quad p \leq \frac{s(q^L)}{(1 - \rho)}$$

(21)

If he would instead find himself in the area of advantageous inequality after delivering low quality, he prefers to deliver high quality over low quality when:

$$IC^{\rho>0,y}_{S,\text{Fair}}: \bar{z} \geq \frac{3c(q^H) - 0.4c(q^L) + 2v(q^H) + 0.6v(q^L) - 5.2(1 - \rho)p}{5r_{\text{fair}}^*(q^H)\rho p},$$

$$p > \frac{s(q^L)}{(1 - \rho)} \text{ and } r_{\text{fair}}^*(q^H) \neq 0$$

(22)

Unlike for a selfish seller, the compatibility constraints in (21) and (22) are strictly decreasing in price because of a fair seller’s additional concern to equalize the payoff distribution. They remain strictly above $IC^{\rho>0}_{S,\text{Self}} \forall p \in \bar{B}$, due to the potential payoff inequalities that arise from trade.
Appendix A.3: Fair trustors and threshold beliefs.

Complements Figure 2 in the main text.

Figure 7. Threshold beliefs $z$ for a “fair” trustor to trust in our experiment, by retainage level.

Notes: Plots display the minimum proportion $z$ of commonly known “fair” agents in the population required to satisfy the relevant constraint for a “fair” trustor, using our experiment parameters and assuming inequity aversion parameters for fair agents in the population of $\alpha = 2$ and $\beta = 0.6$. The vertical dotted line signifies the beginning of the implementable high-price region. Compatible Trust is the threshold belief required for a trusting action to be strictly preferred to a non-trusting action by the trustor. Rational Trust is the belief required for a trusting action to yield the trustor non-negative expected utility. A trusting action is defined as a buyer acceptance decision when retainage equals 0 or a high quality seller choice when retainage equals 0.5 or 0.75. The shaded area corresponds to the region in which the trusting action is both rational and incentive-compatible.
Appendix A.4: Reciprocity in non-zero retainage contracts over time.

Figure 8. High quality and retainage payment rates over time.

Notes: Based on cohort averages, conditional on trade.
Appendix A.5: Learning and repetition effects.

Table 8 – Cohort Means and Standard Deviations of Decision Variables by Period Block.

<table>
<thead>
<tr>
<th></th>
<th>FPC0</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Periods 1-10</td>
<td>Periods 11-20</td>
<td>Periods 21-30</td>
</tr>
<tr>
<td>Bid</td>
<td>42.49</td>
<td>40.69</td>
<td>38.24</td>
</tr>
<tr>
<td></td>
<td>(4.64)</td>
<td>(4.69)</td>
<td>(4.20)</td>
</tr>
<tr>
<td>Supplier Exit Rate</td>
<td>0.02</td>
<td>0.01</td>
<td>0.01</td>
</tr>
<tr>
<td></td>
<td>(0.03)</td>
<td>(0.01)</td>
<td>(0.01)</td>
</tr>
<tr>
<td>Buyer Acceptance Rate</td>
<td>0.56</td>
<td>0.53</td>
<td>0.73</td>
</tr>
<tr>
<td></td>
<td>(0.20)</td>
<td>(0.24)</td>
<td>(0.22)</td>
</tr>
<tr>
<td>High Quality Rate</td>
<td>0.15*</td>
<td>0.03</td>
<td>0.02</td>
</tr>
<tr>
<td></td>
<td>(0.07)</td>
<td>(0.05)</td>
<td>(0.04)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>ARC50</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bid</td>
<td>57.61**</td>
<td>63.46</td>
<td>64.75</td>
</tr>
<tr>
<td></td>
<td>(5.66)</td>
<td>(6.47)</td>
<td>(5.72)</td>
</tr>
<tr>
<td>Supplier Exit Rate</td>
<td>0.01</td>
<td>0.01</td>
<td>0.05</td>
</tr>
<tr>
<td></td>
<td>(0.01)</td>
<td>(0.01)</td>
<td>(0.07)</td>
</tr>
<tr>
<td>Buyer Acceptance Rate</td>
<td>0.94</td>
<td>0.90</td>
<td>0.89</td>
</tr>
<tr>
<td></td>
<td>(0.03)</td>
<td>(0.08)</td>
<td>(0.15)</td>
</tr>
<tr>
<td>High Quality Rate</td>
<td>0.31*</td>
<td>0.35</td>
<td>0.24</td>
</tr>
<tr>
<td></td>
<td>(0.08)</td>
<td>(0.23)</td>
<td>(0.33)</td>
</tr>
<tr>
<td>Retainage Payment Rate for Low Quality</td>
<td>0.10*</td>
<td>0.05</td>
<td>0.03</td>
</tr>
<tr>
<td></td>
<td>(0.10)</td>
<td>(0.08)</td>
<td>(0.05)</td>
</tr>
<tr>
<td>Retainage Payment Rate for High Quality</td>
<td>0.40</td>
<td>0.27</td>
<td>0.33</td>
</tr>
<tr>
<td></td>
<td>(0.25)</td>
<td>(0.17)</td>
<td>(0.09)</td>
</tr>
<tr>
<td></td>
<td>IPC75</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bid</td>
<td>55.22*</td>
<td>64.47</td>
<td>62.35</td>
</tr>
<tr>
<td></td>
<td>(4.43)</td>
<td>(9.51)</td>
<td>(16.21)</td>
</tr>
<tr>
<td>Supplier Exit Rate</td>
<td>0.17*</td>
<td>0.41</td>
<td>0.50</td>
</tr>
<tr>
<td></td>
<td>(0.16)</td>
<td>(0.31)</td>
<td>(0.37)</td>
</tr>
<tr>
<td>Buyer Acceptance Rate</td>
<td>0.96</td>
<td>0.99</td>
<td>1.00</td>
</tr>
<tr>
<td></td>
<td>(0.03)</td>
<td>(0.01)</td>
<td>(0.00)</td>
</tr>
<tr>
<td>High Quality Rate</td>
<td>0.37</td>
<td>0.53</td>
<td>0.55</td>
</tr>
<tr>
<td></td>
<td>(0.15)</td>
<td>(0.25)</td>
<td>(0.37)</td>
</tr>
<tr>
<td>Retainage Payment Rate for Low Quality</td>
<td>0.19</td>
<td>0.12</td>
<td>0.09</td>
</tr>
<tr>
<td></td>
<td>(0.09)</td>
<td>(0.07)</td>
<td>(0.09)</td>
</tr>
<tr>
<td>Retainage Payment Rate for High Quality</td>
<td>0.39</td>
<td>0.36</td>
<td>0.35</td>
</tr>
<tr>
<td></td>
<td>(0.18)</td>
<td>(0.24)</td>
<td>(0.20)</td>
</tr>
</tbody>
</table>

Notes: Displayed are mean (SD) values for the key decision variables based on 6 independent cohort averages per treatment. Matched pairs t-test (two-sided) comparing averages between adjacent blocks, *indicates significant difference between adjacent blocks at the 0.05 level; ** indicates significance at the 0.01 level.
### Appendix A.6: Determinants of supplier exit decisions at auction.

Table 9 – Random effects Logit regression of supplier exit probability.

<table>
<thead>
<tr>
<th></th>
<th>Supplier Exit Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>IPC75</td>
</tr>
<tr>
<td><strong>Competitor’s Bid</strong></td>
<td>0.002 (0.01)</td>
</tr>
<tr>
<td><strong>Trade</strong></td>
<td>0.06 (0.26)</td>
</tr>
<tr>
<td><strong>Period</strong></td>
<td>0.07*** (0.02)</td>
</tr>
<tr>
<td><strong>Constant</strong></td>
<td>-2.66** (0.57)</td>
</tr>
</tbody>
</table>

Log Likelihood: -304.22
Observations (Subjects): 671 (36)

Notes: Standard errors in parentheses. *** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$.
Regressions reported estimate the effect of the most recent competitor’s bid, last period trade participation and the current period on the supplier’s bid at auction.
Appendix A.7: Analysis of the remaining experiment treatment cohorts.

Complements Figure 6 in the main text.

Figure 9. Cohort outcomes over time.

(a) FPC0: cohort 1.

(b) FPC0: cohort 3.
(c) FPC0: cohort 4.

(d) FPC0: cohort 5.
(e) ARC50: cohort 1.

(f) ARC50: cohort 2.
(g) ARC50: cohort 4.

(h) ARC50: cohort 6.
(i) IPC75: cohort 2.

(j) IPC75: cohort 3.
Notes: Panels (a) to (l) display price, payment and product quality outcomes over time in the specified treatment – cohort, between-subjects design. Each observation corresponds to the outcome of a randomly matched interaction group in the period, with 1 buyer and 2 suppliers. An open triangle is an auction failure (neither supplier submitted a bid). A cross is a transaction failure (buyer rejection of the winning auction price). A solid circle is an accepted auction price at which the seller delivered low quality, and an open circle is the corresponding payment. A solid square is an accepted auction price at which the seller delivered high quality and an open square is the corresponding payment. The arrows represent the price-payment differential. In panels (a) to (d), the dashed line corresponds to the buyer valuation for low quality. In panels (e) to (l), the dashed (dotted) line corresponds to the seller delivery cost of low (high) quality.
Appendix A.8: Subject trust and risk attitudes in relation to profits earned in the experiment.

In Table 10 we report the results of an OLS regression of the penultimate-mover’s cumulative profit, excluding endowment, in a treatment on subject measures of willingness to take risks and willingness to trust as elicited in the post-experiment questionnaire. We also include demographic information on subject gender and age. Results for the IPC75 are qualitatively unchanged whether including or excluding the two subjects for whom limited liability was imposed (in Table 10, all subjects are included).

The risk and trust indices were computed as follows.

**Risk Index: Average of six behavioral risk categories, general attitude and specific domains:**

Based on the questions in 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?
2) How would you rate your willingness to take risks while driving a car?
3) How would you rate your willingness to take risks in financial matters?
4) How would you rate your willingness to take risks during sports and leisure?
5) How would you rate your willingness to take risks in job matters?
6) How would you rate your willingness to take risks in health matters?

**Trust Index: Average of three variables:**

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” (1) or “Can’t be too careful” (0).
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” (1) or “Would take advantage of you” (0).
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” (1) or “Just look out for themselves” (0).
### Table 10 – OLS regression of cumulative subject profit.

<table>
<thead>
<tr>
<th></th>
<th>Buyer Profit</th>
<th>Seller Profit</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>FPC0</td>
<td>ARC50</td>
<td>IPC75</td>
</tr>
<tr>
<td>Risk Index</td>
<td>-18.23**</td>
<td>-3.52</td>
<td>-6.49</td>
</tr>
<tr>
<td></td>
<td>(6.08)</td>
<td>(3.99)</td>
<td>(8.13)</td>
</tr>
<tr>
<td>Trust Index</td>
<td>55.96</td>
<td>35.16**</td>
<td>11.23</td>
</tr>
<tr>
<td></td>
<td>(44.55)</td>
<td>(15.86)</td>
<td>(43.46)</td>
</tr>
<tr>
<td>Female</td>
<td>9.66</td>
<td>-36.46***</td>
<td>-46.83*</td>
</tr>
<tr>
<td></td>
<td>(27.56)</td>
<td>(13.04)</td>
<td>(24.90)</td>
</tr>
<tr>
<td>Age</td>
<td>0.04</td>
<td>-0.92</td>
<td>-6.34*</td>
</tr>
<tr>
<td></td>
<td>(4.33)</td>
<td>(0.73)</td>
<td>(3.15)</td>
</tr>
<tr>
<td>Constant</td>
<td>138.27</td>
<td>44.58</td>
<td>124.28</td>
</tr>
<tr>
<td></td>
<td>(117.37)</td>
<td>(29.93)</td>
<td>(88.83)</td>
</tr>
<tr>
<td>( R^2 )</td>
<td>0.44</td>
<td>0.25</td>
<td>0.19</td>
</tr>
<tr>
<td>Observations</td>
<td>18</td>
<td>35</td>
<td>33</td>
</tr>
</tbody>
</table>

Notes: Standard errors in parentheses. *** \( p < 0.01 \), ** \( p < 0.05 \), * \( p < 0.1 \). Regressions reported estimate the effect of individual trust and risk attitudes on cumulative profit earned by the penultimate-mover in each treatment. Controls are included for subject gender (female dummy variable) and age. 1 seller in the ARC50 and 3 sellers in the IPC75 did not provide the relevant data in the post-experiment questionnaire and so are missing from the respective regressions.
Appendix B: Experimental instructions.

This is an experiment in decision making. If you read these instructions carefully and make good decisions, you may earn a considerable amount of money. The amount of money you earn will depend on both your decisions and the decisions of other participants. The currency unit in this experiment is called Experimental Currency Unit, or ECU for short. At the end of the session, you will be asked to complete a short questionnaire. Upon completion, your total earnings from the experiment will be displayed on the screen, including your participation fee of $5, and be paid to you in private and in cash.

How you earn money

For today’s session, one-third of you will be randomly assigned a Buyer role, and two-thirds of you assigned a Seller role. You will see your role at the start of the session and this role will not change for the duration of the session. This experiment will include 30 rounds. In each round a Buyer is matched with two Sellers. The Buyer can purchase a product from one of the two Sellers. The value of the product to the Buyer, and the cost that the Seller incurs to provide the product, depends on the Seller choice to deliver a High or Low Quality product, as follows:

<table>
<thead>
<tr>
<th></th>
<th>Low Quality</th>
<th>High Quality</th>
</tr>
</thead>
<tbody>
<tr>
<td>Buyer Value</td>
<td>35</td>
<td>80</td>
</tr>
<tr>
<td>Seller Cost</td>
<td>30</td>
<td>40</td>
</tr>
</tbody>
</table>

Each player will start each round with 7 ECU. Therefore, when there is a transaction between a Buyer and a Seller,

- The Buyer earns: 7 + Profit, where Profit = Buyer Value – Payment to the Seller
- The Seller earns: 7 + Profit, where Profit = Payment to the Seller – Seller Cost

How a potential Seller is determined

An auction is used to select which of the two Sellers will have the opportunity to transact with the Buyer. At the start of each round, each Seller privately submits a bid for a price at which they would be willing to deliver the product or elects not to participate in the current round’s auction. The Seller submitting the lower bid wins the opportunity to potentially trade with the Buyer. In the event of a tie, the computer will choose the winner at random. Bids can be integers from 30 to 80.
Example:

Seller A bids 35 and Seller B bids 62 = A is winner.

Sellers A and B both bid 40 = A and B each have 50% probability of winning.

A Seller who does not win or elects not to participate in the auction earns 7 ECU for the round (Profit = 0). After the auction, the Buyer is presented the winning bid. The Buyer chooses whether or not to proceed with the transaction. If the Buyer does not proceed the round ends and all three parties earn 7 ECU for the round (Profit = 0).

How the payment to the Seller is determined

Participants in the FPC0 treatment received the following instructions:

If the Buyer chooses to proceed, the Winning Seller receives payment equal to his or her bid amount. Then the Winning Seller must decide to deliver either a Low or High Quality product.

Examples:

• Suppose the winning bid is 50 and the Seller delivers Low Quality. The round profits for the Buyer and Winning Seller are as follows:

  Buyer Profit = 35 – 50 = –15*

  Seller Profit = 50 – 30 = 20

• Now suppose the Seller delivers High Quality. The respective profits are:

  Buyer Profit = 80 – 50 = 30

  Seller Profit = 50 – 40 = 10

*Note that it is possible to lose money in a round. Make your decisions carefully.
Participants in the ARC50 treatment received the following instructions:

If the Buyer chooses to proceed, the Winning Seller receives 50% of his or her bid amount. This is called the **initial payment**. Then the Winning Seller must decide to deliver either a Low or High Quality product. The Buyer learns the quality level of the product and then chooses how much of the remaining 50% of the winning auction bid is paid to the Seller. This amount is called the **deferred payment**. The Buyer keeps any portion of the remaining 50% of the bid not paid to the seller.

**Examples:**

- Suppose the winning bid is 50, the Seller delivers Low Quality, and the Buyer sets the deferred payment at 6. The round profits for the Buyer and Winning Seller are as follows:
  
  Buyer Profit = 35 – 25 – 6 = 4  
  Seller Profit = 25 – 30 + 6 = 1

- Now suppose the Seller delivers High Quality and the Buyer still sets the deferred payment at 6. The respective profits are:
  
  Buyer Profit = 80 – 25 – 6 = 49  
  Seller Profit = 25 – 40 + 6 = –9*

- Now suppose the winning bid is 70, the Seller delivers High Quality and the Buyer sets the deferred payment at 30. The respective profits are:
  
  Buyer Profit = 80 – 35 – 30 = 15  
  Seller Profit = 35 – 40 + 30 = 25

*Note that it is possible to lose money in a round. Make your decisions carefully.*
Participants in the IPC75 treatment received the following instructions:

If the Buyer chooses to proceed, the Winning Seller receives 25% of his or her bid amount. This is called the initial payment. Then the Winning Seller must decide to deliver either a Low or High Quality product. The Buyer learns the quality level of the product and then chooses how much of the remaining 75% of the winning auction bid is paid to the Seller. This amount is called the deferred payment. The Buyer keeps any portion of the remaining 75% of the bid not paid to the seller.

Examples:

- Suppose the winning bid is 60, the Seller delivers Low Quality, and the Buyer sets the deferred payment at 16. The round profits for the Buyer and Winning Seller are as follows:

  Buyer Profit = 35 – 15 – 16 = 4
  Seller Profit = 15 – 30 + 16 = 1

- Now suppose the Seller delivers High Quality and the Buyer still sets the deferred payment at 16. The respective profits are:

  Buyer Profit = 80 – 15 – 16 = 49
  Seller Profit = 15 – 40 + 16 = –9*

- Now suppose the winning bid is 72, the Seller delivers High Quality and the Buyer sets the deferred payment at 44. The respective profits are:

  Buyer Profit = 80 – 18 – 44 = 18
  Seller Profit = 18 – 40 + 44 = 22

*Note that it is possible to lose money in a round. Make your decisions carefully.
How you will be paid

At the end of the session the earnings from all rounds of the session will be converted to US dollars at the rate of 20 ECU for $1. These earnings will be added to your $5 participation fee, displayed on your screen, and paid to you at the end of the session.
References


of Economics, 114(3), 817-868.


