Market institutions, prices and distribution of surplus: a theoretical and experimental investigation

Nick Feltovich*
Department of Economics
Monash University
Clayton VIC 3800, Australia
nicholas.feltovich@monash.edu

Nejat Anbarci
Durham University Business School
Durham University
Durham DH1 3LB, United Kingdom
nejat.anbarci@durham.ac.uk

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Abstract

We examine three market institutions using theory and experiment. Under "posting", sellers post non–negotiable prices, seen by buyers who then choose whom to visit. Under "haggling", prices are not posted, but emerge via bilateral negotiation or bidding. Under "flexible pricing", prices are posted but are flexible upwards or downwards (as under haggling). Theoretical predictions for sellers' posted prices and buyers' visit choices – and outcome variables like efficiency and profits – will therefore depend on how agents bargain and bid. Observed market performance deviates from standard–theory predictions in systematic ways. A modified theory that accounts for more realistic bargaining and bidding behaviour has some success at improving characterisation of observed behaviour.

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1 Introduction

Determination of the prices of goods and services has been one of the most fundamental, widespread, and long–lasting questions in economics.[1] Historically, much of the study of how prices are formed in markets has placed little emphasis on the markets themselves. The classical analysis of perfectly competitive markets either ignores market features as irrelevant or relies on mechanisms (Cournot tâtonnement, Walrasian auctioneer) that no–one believes to exist. The theory of industrial organisation has had marked success in understanding the connection between prices and many aspects of the market, such as the numbers of buyers and sellers, the presence of search costs, or the degree of substitutability between firms' products. However, other aspects have received much less attention, such as whether prices are fixed or negotiable, whether and by whom they are posted (buyers, sellers, or neither), and whether buyers visit sellers, the reverse, or neither. Many combinations of these factors exist in real markets. Indeed, heterogeneity in these market institutions exists not only economy–wide, but also for particular goods. A prime example is housing: in the same region, houses can be sold by auction, by bilateral negotiation between the seller and individual buyers, and by a fixed posted price. Items on internet shopping websites can often be found both for auction and at a fixed posted price, and in most big cities, the same souvenir t–shirt can be bought at a posted price in souvenir shops and by negotiation at market stalls.

In this paper, we use theory and a lab experiment to investigate the effects of the market institution itself on outcomes such as prices, efficiency and profits. We focus on a fairly simple setting in which identical sellers produce a homogeneous good to sell to identical buyers, with seller costs and buyer valuations both common knowledge. We exogenously vary the market institution under which the good is traded, and we compare the outcomes. Using the lab allows us to minimise issues of selection and endogeneity; to have more precise control over product characteristics, seller costs, buyer values, and agents' information; and to record aspects of outcomes that may not be observable in the field, such as those involving units that are not traded.

While there have been previous studies with experimental comparisons of market institutions, these have tended to assume all buyers and sellers can meet in a central location, with an explicit or implicit financial–market context, and focussing on comparisons involving double auctions (Smith, 1964; Williams, 1973; Plott and Smith, 1978; Smith et al., 1982; Ketcham et al., 1984; Mestelman and Welland, 1988; McCabe et al., 1990; Friedman, 1993; Cason and Friedman, 2008; Mestelman, 2008; Van Boening and Wilcox, 2008). By contrast, we direct our attention to goods markets, with two implications. First, instead of centralised trading, we assume a more decentralised market, by adapting the directed–search settings of Montgomery (1991), Shimer (1996), Moen (1997), and Burdett et al. (2001). In these settings, sellers may compete for buyers by posting (fixed or negotiable) prices, and buyers direct their search based on the information they receive. This means that *frictions* are possible and indeed likely, due to the combination of capacity constraints and the coordination problem amongst buyers: even though all potential exchanges are mutually profitable, some buyers will be unable to buy and some sellers will be unable to sell. Also, even though we will concentrate on markets with equal numbers of buyers and sellers overall – either 2 (seller) x 2 (buyer) or 3x3 – the realisations of buyers' visit choices will mean that some sellers will face *local* excess demand and others will not. We thus add to a small but growing literature on experiments involving directed–search markets (Cason and Noussair, 2007; Anbarci and Feltovich, 2013, 2018; Anbarci et al., 2015; Kloosterman, 2016; Helland et al., 2017; Kloosterman and Paul, 2018). None of this earlier work compared different market institutions, though

[1] For example, the "diamonds–water paradox" mentioned in introductory economics textbooks dates back at least to Adam Smith (1776).

some examined price posting on its own.

Second, rather than double auctions, we consider three pricing institutions more typical of goods markets. Under *non–negotiable price posting* (which we will often simply call "posting"), sellers post prices which are observed by buyers prior to the visit choice, and any trade is at the posted price. Under *negotiated prices* ("haggling"), no prices are posted; instead, the price is determined after the buyers have made their visit choices, either by bilateral bargaining if the seller faces only one buyer, or by an auction if the seller faces multiple buyers (see Section 2 for details). Under *price posting with negotiation* ("flexible prices"), sellers post prices that are observed by buyers, but these prices are non–binding: they can be revised downward (by bilateral bargaining) or upward (by auction), depending on how many buyers visit the seller.[2] This is obviously an incomplete sampling of the institutions in existence, but it arguably covers the most prevalent ones over the last century or so.[3] There has been some comparative theoretical analysis of these institutions and related ones (Lu and McAfee, 1996; Kultti, 1999; Julien et al., 2000, 2001, 2002; Albrecht et al., 2006; Camera and Selcuk, 2009), but we are unaware of any previous controlled experimental studies.

We formulate predictions for the experiment with a theoretical analysis in Section 2. While our posting treatment is a straightforward application of Burdett et al.'s (2001) model, our flexible–pricing treatment represents, to our knowledge, the first study of flexible prices in an experimental directed–search environment. (Our haggling treatment is also novel, though it is arguably not a directed–search setting.) Our analysis uses backward induction: predictions for earlier decisions like sellers' posted prices depend on how price–sensitive buyers will be, which in turn depends on what the outcomes of bargaining and auctions will be. Our predictions for the bargaining and auction stages are based on standard bargaining and auction theory, but whether these predictions are reasonable – in the sense of describing actual behaviour – is of course an empirical question.

Market outcomes in our experiment, described in Section 3, are only partly in line with the theory. There are substantial deviations from point predictions, such as efficiency being lower under haggling and flexible pricing, and sellers' profits being lower under haggling and flexible pricing but higher under posting. These deviations also affect treatment effects, with observed seller profit in the 2x2 market higher under posting than under flexible pricing, the opposite sign of the theoretically–predicted effect.

Part of the explanation for these deviations from predicted market outcomes may be deviations in the bargaining and auction subgames. Bargaining in our haggling treatment favours the seller, who receives roughly 55 percent of the cake in agreements despite this being a symmetric bargaining setting. Bargaining in the flexible–pricing treatment is even more skewed towards sellers, with little tendency for even high posted prices to be negotiated downwards. Auction results also favour the seller, though not to the extent implied by theory. Disagreements, which happen about 10 percent of the time in bargaining and under 5 percent in auctions, are also inconsistent with the theoretical model, though common in experiments.

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[2]Both upward and downward flexibility are possible. For example, Han and Strange (2014) showed that during the US housing boom between 2003 and 2006, 13.5 percent of houses sold above the asking price and 57.1 percent sold below the asking price. Even during the 2007–2010 housing bust, there were non–trivial fractions of both increases and decreases: 8.2 percent sold above the asking price and 74.3 percent sold below the asking price. See also Case and Shiller's (2003) Table 13.

[3]Bargaining can be traced back to 6000 B.C. (see `http://www.barternewyork.net/history-of-bartering.html`). Auctions are very old as well: Milgrom and Weber (1982), relying on the Greek historian Herodotus, report that they date back to around the fifth century B.C.. In contrast, the use of posted prices by sellers is a relatively recent phenomenon, to our knowledge having begun in 1823 when Alexander Stewart introduced posted prices in his "Marble Dry Goods Palace" in New York (see Scull and Fuller, 1967).

In Section 4 we modify our theoretical model to account for some of the regularities we observed in bargaining and auction behaviour. With these new assumptions, but continuing to make standard assumptions elsewhere (sellers' price posting and buyers' visit decisions), we formulate new theoretical predictions for buyer and seller profits. Prediction error for seller profits is lower for our behavioural theory than for the standard theory, while prediction error for buyer profits is unchanged on average.

2 Theory and experiment

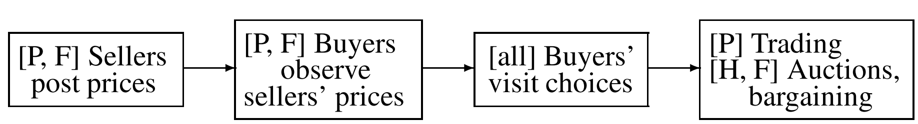
We consider mxn markets, with $m \geq 2$ sellers and $n \geq 2$ buyers. Sellers produce a single unit of a homogeneous, indivisible, perishable good. Identical buyers each have valuation 20 for a single unit.[4] Trading takes place under one of three exogenously imposed market institutions. Under *posting*, sellers simultaneously post prices in $[0, 20]$. Buyers observe these prices and each simultaneously chooses a seller to visit. A seller visited by at least one buyer sells at the posted price; in the case of multiple buyers, one is chosen randomly to buy, while the other buyers are unable to buy.

Under *haggling*, sellers do not post prices, so buyers simultaneously choose a seller to visit based on no information at all. If exactly one buyer visits a seller, they bargain over the price. Bargaining is modelled by a variant of the Nash (1953) demand game, in which the buyer and seller simultaneously make a single price choice in $[0, 20]$. (This is strategically equivalent to the standard formulation where each bargainer claims a share of the available surplus.) If the buyer's "bid price" is at least as high as the seller's "offer price", they trade at a price halfway between these; otherwise they do not trade. A seller visited by two or more buyers conducts a second–price auction, with buyers' bids and the seller's reserve price chosen simultaneously in $[0, 20]$. If one or more bids is at least as high as the reserve price, the seller sells to the highest bidder, and the price is the larger of the reserve price and the second–highest bid. If all bids are less than the reserve price, they do not trade.

Our third institution, *flexible pricing*, combines aspects of the other two. Sellers post prices in $[0, 20]$, after which buyers are informed of these and choose whom to visit. However, these prices are negotiable. If a seller posting price p^p is visited by exactly one buyer, they play a Nash demand game as under haggling, but with the bid and offer prices restricted to $[0, p^p]$. If the seller is visited by multiple buyers, there is an auction with bids and reserve price restricted to $[p^p, 20]$. The initial posted price is therefore not cheap talk, but neither is it completely binding; it can be negotiated downwards in case of a single visiting buyer, or upwards if there are multiple buyers.

Figure 1 shows the sequence of decisions in the three institutions.

Figure 1: Sequence of decisions in the experiment (P=posting, H=haggling, F=flexible pricing)



[4] The buyer valuation of 20 is merely a scaling parameter, with no non–trivial effect on the theory.

2.1 Theoretical predictions

Our experiment uses 2x2 and 3x3 markets, so there are six cases to analyse: each possible combination of institution (posting, haggling, flexible pricing) and market (2x2 and 3x3).[5] We will often abbreviate our cells as Post2, Hagg2 and Flex2 for the three 2x2 institutions, and with similar notation for the 3x3 institutions. The two posting cases (Post2 and Post3) are analysed in detail by Burdett et al. (2001); the rest are analysed below.

Bargaining/auction stage

When multiple buyers visit a seller in the haggling and flexible–pricing treatments, the good is allocated by a second–price sealed–bid auction. Since there is perfect information about the good's valuation of 20 for all buyers, it is weakly dominant for each buyer to bid this valuation. Thus the unit is traded with certainty, and all bids, the transaction price, and the seller's profit will be equal to 20, and each buyer earns zero.

When one buyer visits a seller in these treatments, the buyer and seller choose prices of p_b and p_s respectively (constrained to be at most the posted price in the flexible–pricing treatment). Payoffs are $20 - (p_b + p_s)/2$ for the buyer and $(p_b + p_s)/2$ for the seller if $p_b \geq p_s$, and zero otherwise. Any pair of equal, feasible bid and offer prices is consistent with Nash equilibrium. To overcome this multiplicity of equilibria, we impose risk dominance (Harsanyi and Selten, 1988), which selects a unique Nash equilibrium, shown in Figure 2. Under flexible pricing with a posted price of p^p, risk dominance implies a transaction price of $\min\{p^p, 10\}$, while under haggling (which in the bargaining stage can be thought of as a special case of flexible pricing with $p^p = 20$), the transaction price is 10. This is also known as the "deal me out" outcome (Sutton, 1986; Binmore et al., 1989; Binmore et al., 1998), and is identical to both the Nash (1950) bargaining solution applied to the corresponding unstructured bargaining problem, and Carlsson's (1991) limiting solution when bargainers' errors become arbitrarily small. Given the confluence of predictions from different selection techniques, this outcome can arguably called "the" prediction of bargaining theory for our bargaining stage, despite the multiplicity of Nash equilibria.[6] As in the auction case, the unit is traded with certainty.

Visit–choice stage

Suppose Seller i in the flexible–pricing treatment posts price p_i^p. From the bargaining and auction outcomes discussed above, a buyer earns zero when more than one chooses the same seller, while a buyer who is the only one to visit Seller i earns $v_i = \max\{20 - p_i^p, 10\}$. Hence buyers in the 2x2 market play a symmetric two–player game between themselves (see Figure 3), that has a unique symmetric Nash equilibrium where each buyer visits Seller 1 with probability $q = v_1/(v_1 + v_2)$. Similarly, the buyers in the 3x3 market under flexible pricing play a three–player game amongst themselves, also with a unique symmetric equilibrium that is completely mixed (see the appendix for details).[7]

[5] We choose the 2x2 market because it is the simplest non–trivial directed–search setting, and the 3x3 market because it is the next–simplest version with no structural excess demand or excess supply. Using markets with no structural excess demand or supply has the advantage that in the experiment, we would expect to observe with substantial frequency all three possibilities: local excess demand, local excess supply, and local market clearing. Using both 2x2 and 3x3 markets made it possible to conduct sessions with 12, 16, 18 or 20 subjects, reducing wasted participation fees spent on subjects who show up but are sent away.

[6] Note however that Kalai and Smorodinsky's (1975) bargaining solution, applied to the corresponding unstructured bargaining problem, implies a different transaction price of $p = 20p^p/(20 + p^p)$, and thus different payoffs.

[7] In the 2x2 case, q is bounded by one–third and two–thirds, while for each seller i in the 3x3 case, q_i (the probability of a given buyer visiting i) is bounded by approximately 0.17 and 0.48. This illustrates a difference between the equilibria in buyer visits under flexible pricing

Figure 2: Bargaining set (hatched area) and bargaining solution, haggling and flexible–pricing treatments

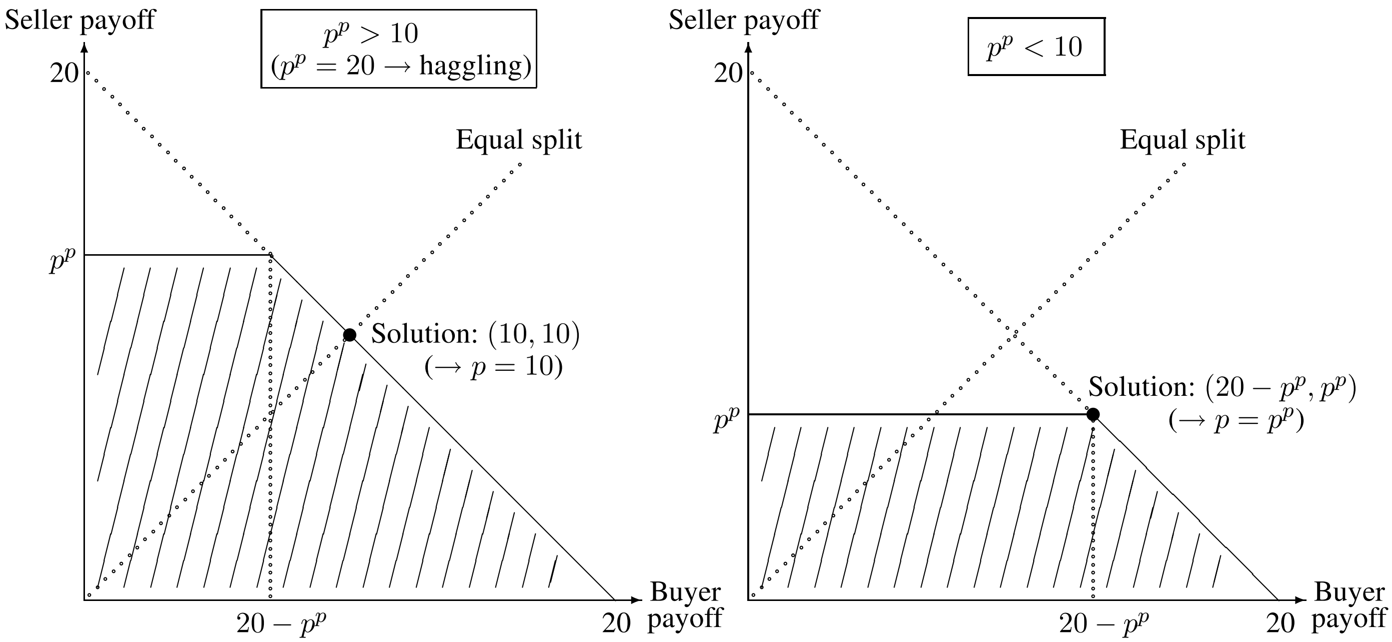


Figure 3: Normal form of the 2x2 market with flexible pricing ($v_i = \max\{20 - p_i^p, 10\}$, with posted prices p_1^p, p_2^p)

		Buyer 2	
		Visit Seller 1	Visit Seller 2
Buyer	Visit Seller 1	0, 0	v_1, v_2
1	Visit Seller 2	v_2, v_1	0, 0

Since we have assumed bargaining and auctions always to lead to the good being traded (i.e., there is no disagreement in bargaining or passing in at an auction), the only predicted source of inefficiency is frictions: the possibility a seller is not matched due to the realisations of buyers' (independent) visit choices. In the 2x2 market, both units are traded if and only if the buyers visit different sellers; otherwise only one unit is traded. So, if both buyers visit Seller i with probability q_i, the expected number of units traded is $1 + 2q_1q_2$, so efficiency (normalising to a scale from zero to one) is $(1 + 2q_1q_2)/2$. The corresponding calculation for the 3x3 market is more complicated, since it can happen that 1, 2, or all 3 sellers are visited. Efficiency in that market is given by $[2 + 6q_1q_2q_3 - (q_1^3 + q_2^3 + q_3^3)]/3$, given visit probabilities q_1, q_2 and q_3. When all sellers post the same price, and in the special case of haggling, buyers visit

compared with posted pricing: the former is always completely mixed while the latter need not be. Under posted pricing, visiting one seller may be a dominant strategy in the buyer–visit game when the rivals' prices are so high that buying from a rival for sure is less profitable than having a one–in–n chance of buying from the low–price seller. This does not happen under flexible pricing, since being the sole visitor to a high–price seller means bargaining for a lower price than the one posted, while being one of multiple visitors to a low–price seller means a zero profit from the auction. Intuitively, there is an equilibrium degree of price–responsiveness by buyers under both flexible pricing and posted pricing: lower–price sellers are (weakly) more likely to be visited by a given buyer, but the seller's capacity constraint provides an incentive to visit even higher–price sellers with positive probability. However, flexible pricing places less emphasis on the advertised price and more on local market tightness (i.e., whether or not there is excess demand for that particular seller's item) than posted pricing.

each seller with equal probability, so efficiency is 3/4 in the 2x2 market and 19/27 in the 3x3 market.

Price–posting stage

The above discussion completes the analysis of haggling. Under flexible pricing, Seller i posting price p_i^p earns zero if no–one visits her, $\min\{p_i^p, 10\}$ if exactly one buyer visits, and 20 if two or more visit. Let Φ_1 and Φ_2 be the probabilities of Seller i being visited by exactly one and at least two buyers (respectively), computed from the buyers' equilibrium visit probabilities. Then her profit is given by

$$\Pi_i = \Phi_1 \cdot \min\{p_i^p, 10\} + \Phi_2 \cdot 20. \tag{1}$$

(Note that Π_i is continuous but not necessarily differentiable at $p_i^p = 10$.) To find a symmetric equilibrium in prices, we first compute the first–order condition given that all rival sellers post price p^p, then we impose symmetry ($p_i^p = p^p$ and each buyer mixes uniformly over sellers). In the 2x2 market, this procedure yields a continuum of equilibria; sellers can post any price in $[10, 20]$. In the 3x3 market, there is a unique equilibrium in seller prices: each chooses $p^p = 20/3$. Given these prices, each buyer visits each seller with the same probability.

2.2 Experimental design and hypotheses

Table 1 summarises the theoretical predictions for our six experimental cells, which give rise to our hypotheses. First, since the only source of inefficiency is frictions due to buyers' visit choices, which in equilibrium are uniform

Table 1: Theoretical predictions

Cell	Market		Efficiency	Posted	Transaction price			Profit	
	institution	size		price	All	1 visit	2+ visits	sellers	buyers
Post2	posting	2x2	0.750	10.00	10.00	10.00	10.00	7.50	7.50
Post3		3x3	0.704	9.33	9.33	9.33	9.33	6.57	7.51
Hagg2	haggling	2x2	0.750		13.33	10.00	20.00	10.00	5.00
Hagg3		3x3	0.704		13.68	10.00	20.00	9.63	4.44
Flex2	flexible	2x2	0.750	10.00*	13.33	10.00	20.00	10.00	5.00
Flex3	pricing	3x3	0.704	6.67	11.58	6.67	20.00	8.15	5.93

**: or any higher value up to 20.00*

in all three institutions, predicted efficiency depends only the numbers of buyers and sellers, not on the institution itself.

Hypothesis 1 *Efficiency in the 2x2 market is the same across all three market institutions.*

Hypothesis 2 *Efficiency in the 3x3 market is the same across all three market institutions.*

Second, the table nearly always shows unambiguous order relationships for the *transaction price* – the price at which the good is traded (which may differ from the posted price) – in both 2x2 and 3x3 markets, implying a hypothesis for each market.

Hypothesis 3 *Transaction prices in the 2x2 market are the same under either haggling or flexible pricing, and higher under either than under posting.*

Hypothesis 4 *Transaction prices in the 3x3 market are highest under haggling and lowest under posting.*

Since expected profits for buyers and sellers depend only on profit per trade (determined by the transaction price) and the probability of trading (determined by efficiency, which does not vary across market institutions), the hypotheses for buyers' and sellers' profits follow immediately from Hypotheses 3 and 4.

Hypothesis 5 *Sellers' profits in the 2x2 market are the same under either haggling or flexible pricing, and higher under either than under posting.*

Hypothesis 6 *Sellers' profits in the 3x3 market are highest under haggling and lowest under posting.*

Hypothesis 7 *Buyers' profits in the 2x2 market are the same under either haggling or flexible pricing, and lower under either than under posting.*

Hypothesis 8 *Buyers' profits in the 3x3 market are lowest under posting and highest under haggling.*

2.3 Experimental procedures

The experiment was conducted in MonLEE at Monash University; subjects were mainly undergraduates and were recruited using ORSEE (Greiner, 2015). A total of 376 subjects participated, with at least ten markets in each of the six cells (see Table 8 in the appendix for details). Some sessions with large numbers of subjects were partitioned into two "matching groups", each at least twice the size of an individual market, and closed with respect to interaction, allowing two independent observations from the same session. Subjects played 40 market rounds with the cell (Post2, etc.) and role (buyer or seller) fixed in all rounds, but were randomly re–assigned to markets each round.

The experiment was computerised, and programmed using z–Tree (Fischbacher, 2007). All interaction took place anonymously via the computer program; subjects were visually isolated and received no identifying information about other subjects.[8] Written instructions were given to subjects before the first round. (See the appendix for sample instructions and screen–shots.) These were read aloud in an attempt to make the rules common knowledge. There was no "instructions quiz", but subjects could ask questions privately before the first round started or at any later point. All price choices (posted prices, bids, etc.) were restricted to multiples of AUD 0.10 (during the experiment, the Australian dollar varied from roughly 0.70 to 0.80 USD), to ensure that earnings were multiples of $0.05, the smallest circulating coin. End–of–round feedback included all posted prices (when applicable), the number of visits (if a seller) or buyers visiting the same seller (if a buyer), quantity traded, and profit for the round, as well as bargaining and auction results when applicable. No information about other markets' results was provided.

After the 40th round, subjects were given a new set of instructions detailing two additional tasks: an incentivised Eckel–Grossman (2008) lottery–choice task, and a survey of demographic and attitudinal questions, including an

[8] In particular, sellers were labelled on buyers' computer screens as "Seller 1", "Seller 2" and "Seller 3", but these ID numbers were randomly re–assigned in each round, and were not made known to the sellers. This anonymity reduces the scope for repeated–game behaviour such as tacit collusion by sellers (by making it impossible to recognise and punish a deviator in future rounds) or dynamic coordination by buyers (such as alternating who visits the low–priced seller).

elicitation of what price is "fair" given one, or more than one, buyers visit a seller.[9] After completing these tasks, subjects were paid. Subjects received (exactly) the sum of their profits from four randomly–chosen rounds, plus the earnings from the lottery–choice task, plus a show–up fee of $10. Total earnings averaged $42.07, including $26.94 from the market rounds ($31.99 for sellers and $21.89 for buyers), for a session that typically lasted about 90 minutes.

3 Results

Table 2 shows aggregate results from the experiment, including several sharp differences from theoretical point predictions (see Table 1). First, efficiency under haggling and flexible pricing is often lower than predicted, varying from 3.4 to 6.5 percentage points below the theoretical prediction. By contrast, efficiency under posting is exactly at the predicted level in the 2x2 market and only 2.5 percentage points below it in the 3x3 market.

Table 2: Aggregate observed behaviour (all sessions and rounds)

Cell	Market		Efficiency	Posted	Transaction	Profit	
	institution	size		price	price	sellers	buyers
Post2	posting	2x2	0.750	11.28	11.03	8.27	6.73
Post3		3x3	0.679	10.64	10.40	7.06	6.52
Hagg2	haggling	2x2	0.716		12.54	8.98	5.34
Hagg3		3x3	0.643		13.37	8.59	4.27
Flex2	flexible	2x2	0.685	9.66	11.47	7.86	5.84
Flex3	pricing	3x3	0.657	10.24	11.97	7.86	5.27

Second, sellers' profits are higher than predicted under posting, and lower than predicted under haggling and flexible pricing. The latter result partly reflects the lower–than–predicted efficiency levels in those treatments. It also reflects transaction prices that in three of those four cells are below their predicted levels, by amounts ranging from 31 cents to $1.86. (In the Flex3 cell, transaction prices are 41 cents above the predicted level, though this is not enough to offset the below–predicted efficiency.) By contrast, transaction prices are above their predicted levels under posting, due in part to higher–than–predicted posted prices.

Third, buyers' profits often, but not always, deviate from theory in the opposite direction to sellers' profits; the exceptions are the Hagg3 and Flex3 cells, where the below–predicted efficiency (which reduces profits for both buyers and sellers) outweighs the deviation in transaction prices (which affects buyers and sellers in opposite ways), so that both buyers and sellers earn lower profits than predicted. In the Hagg2 and Flex2 cells, buyers' profits are higher than predicted, while in the two posting cells, they are lower than predicted.

These deviations between predicted and observed profits can be substantial (eight out of twelve represent increases or decreases of more than 10 percent from the theoretical point prediction), and lead to observed treatment

[9]Subjects' original instructions stated that there would be a Part 2 to the session, but nothing about what would take place. See the appendix for sample instructions and screen–shots, including those for the post–market tasks. Additional materials including the raw data are available from the corresponding author upon request.

effects that can differ qualitatively from the predicted treatment effects. Seller profits in the 2x2 market are actually higher under posting than under flexible pricing, while the theory entails the opposite ordering. Even when the ordering across treatments is not changed, the size of treatment effects can be substantially different. For sellers, profits under haggling are predicted to be higher than under posting by \$2.50 in the 2x2 market and by \$3.06 in the 3x3 market (see Table 1), but the actual differences are much smaller: only \$0.71 and \$0.73 respectively.

We further examine treatment effects with regressions using disaggregated data: probits for efficiency (which is binary for an individual subject) and Tobits for transaction price, seller profit, and buyer profit. The main explanatory variables are indicators for the Hagg and Post treatments (so Flex is the baseline). We additionally include the round number and its interactions with the treatment indicators, the number of markets in the matching group (as a proxy for incentives for seller collusion), and a constant term.

All models were estimated by Stata, separately for the 2x2 and 3x3 markets, and with standard errors clustered by matching group. Table 3 displays some of the results, with a focus on treatment effects. Differences between

Table 3: Tobit results (average marginal effects, with standard errors in parentheses)

	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]
	Efficiency		Transaction price		Seller profit		Buyer profit	
	2x2	3x3	2x2	3x3	2x2	3x3	2x2	3x3
Post treatment (vs. Flex)	0.073***	0.027*	–0.415	−1.702***	0.594	−0.630**	1.142*	1.302***
	(0.020)	(0.016)	(0.847)	(0.523)	(0.454)	(0.307)	(0.616)	(0.369)
Hagg treatment (vs. Flex)	0.033**	–0.012	1.049*	1.340***	0.996***	0.449*	–0.209	−0.736***
	(0.017)	(0.014)	(0.634)	(0.479)	(0.330)	(0.340)	(0.479)	(0.282)
p–value, Post vs. Hagg	$p \approx 0.020$	$p \approx 0.012$	$p \approx 0.017$	$p < 0.001$	$p \approx 0.35$	$p < 0.001$	$p < 0.001$	$p < 0.001$
Round	0.0030***	0.002***	0.042***	0.041***	0.064***	0.045***	0.002	–0.009
	(0.0004)	(0.001)	(0.009)	(0.005)	(0.007)	(0.006)	(0.008)	(0.006)
Matching group size	−0.015***	−0.025**	–0.134	0.384	−0.287***	–0.082	–0.057	−0.500**
(num. of markets)	(0.006)	(0.012)	(0.213)	(0.376)	(0.108)	(0.256)	(0.162)	(0.250)
Sample	Sellers	Sellers	Sellers	Sellers	Sellers	Sellers	Buyers	Buyers
N	3200	4320	2287	2844	3200	4320	3200	4320
$\|ln(L)\|$	1892.70	2766.74	6009.97	7351.04	8790.49	11471.62	8218.98	10506.17

* (**,***): *Marginal effect significantly different from zero at the 10% (5%, 1%) level.*

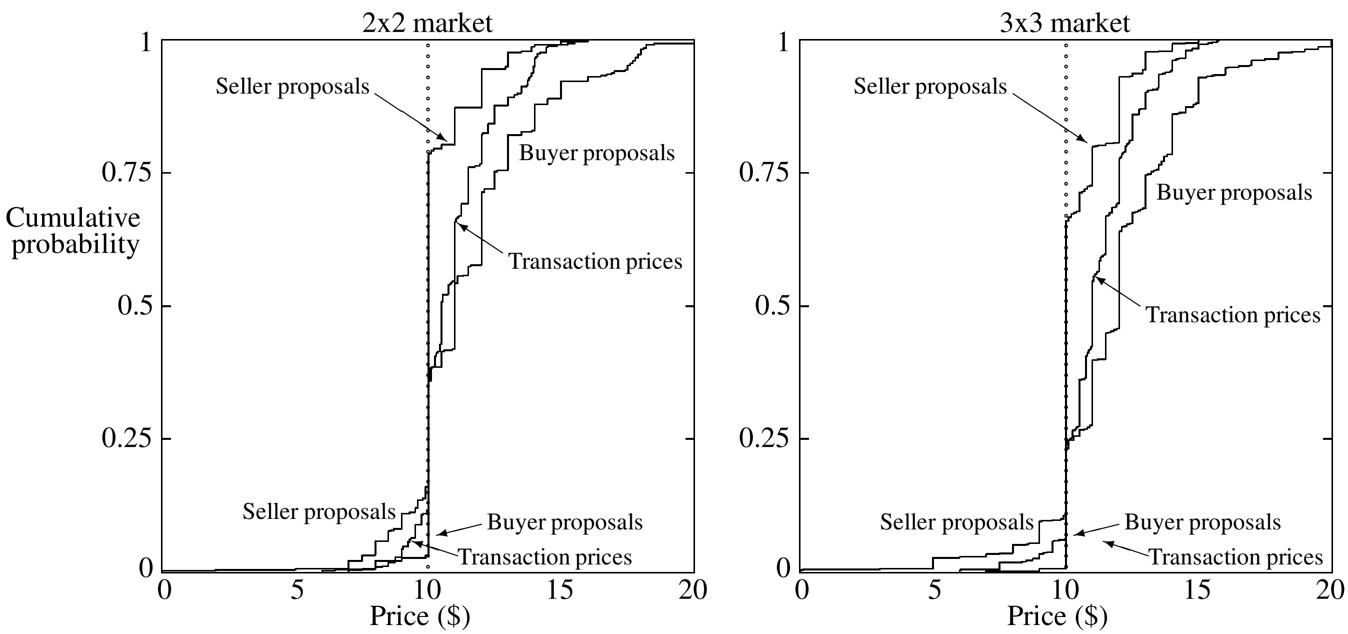
either the Post or Hagg treatments and the Flex treatment are given by the average marginal effects (MEs) of the Post and Hagg indicators in the table, while differences between the Post and Hagg treatments are given by the p–value for the Post–versus–Hagg comparison immediately below the Hagg treatment indicator. (Corresponding point estimates are approximately given by the difference between the Post– and Hagg–treatment indicators.)

The results reinforce what was seen in the summary statistics. Despite the theoretical prediction of equal efficiency across market institutions, efficiency is actually significantly higher in the Post treatment than in the other treatments (though the difference between Post2 and Flex2 is only significant at the 10–percent level). While the other three variables are ordered across treatments in the same way as the theoretical predictions in the 3x3 market, the 2x2 market shows qualitative deviations from the theory, similar to those in the descriptive statistics. Seller profit is significantly higher in the Hagg treatment than Flex, as is transaction price, whereas the theory predicted both of these to be equal between those cells. Also, seller profits were predicted to be lower in the Post2 cell than in the Hagg2 and Flex2 cells, but Table 3 shows no significant differences there, and in the case of Flex2, the effect is actually in the opposite direction.

3.1 Observed bargaining behaviour

Bargaining and auction behaviour provide a possible explanation for the deviations from predictions in the market outcomes. In the Hagg treatment, all bargaining situations are identical: no price is posted, so the feasible bargaining set comprises all non–negative payoff pairs summing to $20, and disagreement payoffs are zero for both buyer and seller. Normally, such symmetric bargaining settings show a strong tendency toward equal splits, corresponding here to agreement on a price of $10. However, Figure 4 shows that our setting actually favours the seller.

Figure 4: Bargaining results in Hagg treatment – cumulative distribution functions



While transaction prices of $10 appear to be focal, the distributions are not centred there: prices are more likely to be above $10 than below it. Mean transaction prices are $10.97 in 2x2 markets and $11.24 in 3x3 markets, significantly higher than $10 (two–tailed Wilcoxon signed–ranks test, pooled Hagg2 and Hagg3 matching–group–level data, $p \approx 0.008$).[10] While seller price proposals, averaging $10.16 and $10.33 in 2x2 and 3x3 markets respectively, do not significantly differ from equal splits ($p \approx 0.16$), buyers' proposals at $11.74 and $12.18 in 2x2 and 3x3 markets respectively are significantly higher ($p \approx 0.004$). Our bargaining environment differs from standard bargaining settings in two ways: (i) framing as a buyer–seller interaction rather than symmetric roles, and (ii) the presence of other components of the market (price posting, auctions, etc.) rather than exclusively bargaining. Either of these could have disrupted the usual pull toward equal splits.[11] Another departure from standard experiments involving the Nash demand game is the relatively low but non–negligible frequency of disagreements: 8.9 percent

[10] See Siegel and Castellan (1988) for descriptions of the non–parametric tests used here.

[11] Holm and Runnemark (2014) report a similar effect.

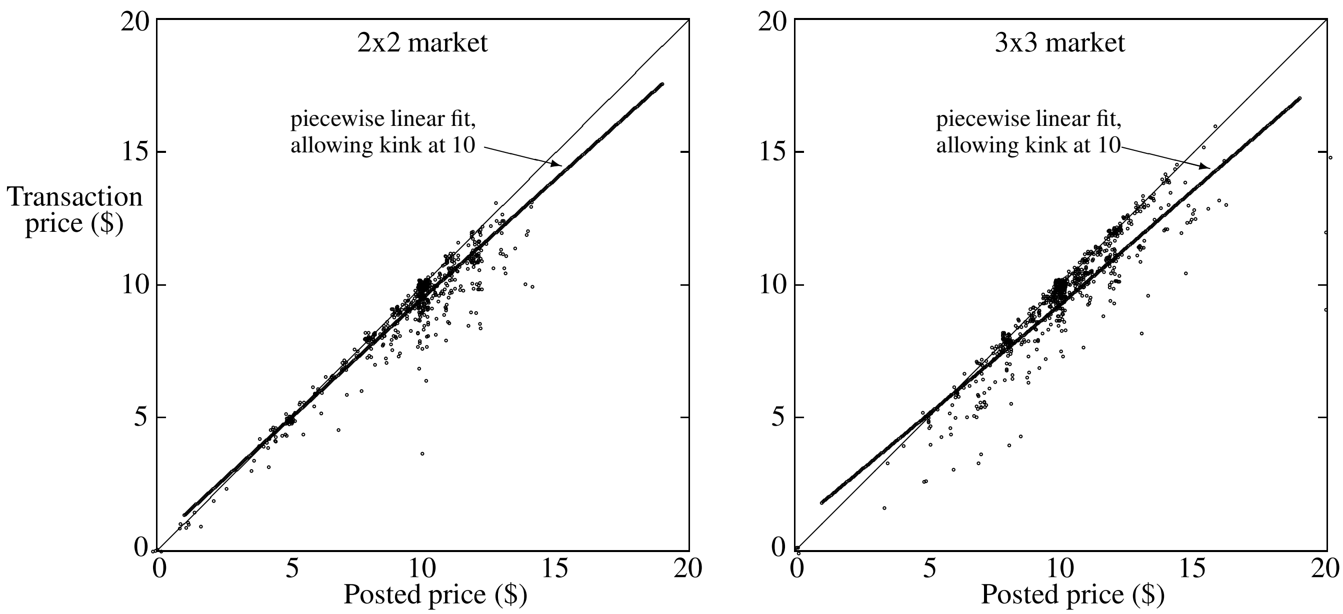
in the 2x2 market and 11.7 percent in the 3x3 market.

In the Flex treatment, the bargaining set depends on the posted price, which provides an upper bound on proposed prices for both buyer and seller. There is little tendency for prices to be negotiated downward however. Transaction prices determined by bargaining average $8.83 in the Flex2 cell and $9.57 in the Flex3 cell, compared to the maximum possible transaction prices of $9.36 and $10.09 respectively (i.e., if all transactions were at the posted price).[12]

Figure 5 shows scatterplots of the posted and transaction price for all bargaining agreements in the Flex treatment, separately for 2x2 and 3x3 markets. The horizontal and vertical coordinates of the points are both perturbed with uniform$[-0.2, 0.2]$ noise, to minimise observations obscuring one another. Also shown are the 45–degree line and a least–square line that is piecewise linear, with a kink at $10 (as implied by the deal–me–out solution used to formulate the theoretical predictions).

Figure 5: Bargaining results in Flex treatment – scatterplots of posted and transaction price

(both perturbed with uniform$[-0.2, +0.2]$ *noise)*



The most striking result in the figure is the lack of any tendency to settle on equal splits, but nor is the typical result similar to that seen in the Hagg treatment. Instead, sellers in the Flex treatment capture nearly the maximum surplus possible, with transaction prices tending to remain close to the original posted price. This outcome is consistent with deal–me–out when the posted price is below $10, but not when it is above $10 (where deal–me–out implies a transaction price of $10). As in the Hagg treatment, disagreement frequencies are fairly low but well above zero: 12.4 percent in the 2x2 market and 9.4 percent in the 3x3 market.

Table 4 shows results from panel linear regressions with (buyer or seller) price proposal as the dependent variable. (Tobits, not reported here, yielded similar qualitative and significance results.) Eight models are estimated, corresponding to the possible combinations of Hagg or Flex treatment, buyer or seller price proposals, and 2x2 or 3x3 markets, so the samples we use are the subsets of Hagg2, Hagg3, Flex2 or Flex3 market rounds where the seller

[12]Even when the posted price is above $10, meaning that the equal–split norm ought to nudge prices downward, average transaction prices are $10.59 and $11.32 in the Flex2 and Flex3 cells respectively, compared to maximum prices of $11.50 and $12.01.

is visited by exactly one buyer.[13] Explanatory variables include the posted price, on its own and multiplied by a "low price" indicator equal to one if the posted price is less than 10 (again, allowing for the deal–me–out bargaining solution), the low–price indicator on its own, all three of these multiplied by the round number, and the round number on its own, as well as a constant term and subject random effects. As additional controls, we include an indicator for female, the degree of risk tolerance from the lottery–choice task, and the elicited fair price.[14] As before, standard errors are clustered at the matching–group level.

Table 4: Factors affecting bargaining proposals (average MEs unless noted, clustered standard errors in parentheses)

Dep. var.: proposed price	[9]	[10]	[11]	[12]	[13]	[14]	[15]	[16]
Role:	Seller		Buyer		Seller		Buyer	
Cell:	Hagg2	Hagg3	Hagg2	Hagg3	Flex2	Flex3	Flex2	Flex3
Posted price...								
...if > 10					0.758^{***}	0.323^{**}	0.644^{***}	0.712^{***}
					(0.135)	(0.156)	(0.114)	(0.111)
...if < 10					0.932^{***}	1.045^{***}	0.990^{***}	0.996^{***}
					(0.024)	(0.053)	(0.006)	(0.043)
signif. diff. from each other?					$p \approx 0.20$	$p < 0.001$	$p \approx 0.004$	$p \approx 0.004$
Low price ($p^p < 10$)					0.009	0.073	–0.165	–0.024
					(0.185)	(0.140)	(0.145)	(0.114)
Round	–0.006	0.005	–0.018	–0.023	0.013	0.024^{**}	0.018^{***}	0.019^{***}
	(0.015)	(0.007)	(0.016)	(0.022)	(0.008)	(0.011)	(0.005)	(0.005)
Female	–0.282	0.314	0.170	0.166	–0.112	–0.031	0.086	–0.059
	(0.381)	(0.283)	(0.320)	(0.718)	(0.209)	(0.416)	(0.135)	(0.262)
Risk tolerance	–0.051	0.182	-0.755^{***}	–0.106	-0.120^{**}	0.119^{***}	–0.050	–0.079
	(0.085)	(0.177)	(0.112)	(0.309)	(0.053)	(0.036)	(0.042)	(0.051)
Fair price	0.456	0.213	0.627^{***}	0.206	–0.067	0.120	0.020	0.047^{*}
	(0.331)	(0.179)	(0.211)	(0.173)	(0.058)	(0.120)	(0.026)	(0.028)
N	482	471	482	470	644	764	642	762
R^2	0.082	0.052	0.464	0.072	0.799	0.656	0.810	0.801

* (**,***): *Marginal effect significantly different from zero at the 10% (5%, 1%) level.*

Models 9–12 add little to what we could see in Figure 4 about bargaining in the Hagg treatment, and we do not elaborate further on the results. The results for the Flex treatment are more noteworthy. As before, we find evidence that deal–me–out does not characterise bargaining well. While it does correctly predict that transaction prices are less responsive to the posted price when the latter is above \$10 than when it is below \$10, observed responsiveness when the posted price is above \$10 is significantly greater than the predicted value of zero in all four models, and in

[13] In this and the next set of regressions, we drop those observations where either (a) the posted price is 0 and one buyer visits, or it is 20 and multiple buyers visit, in either of which case the subsequent choices by buyer and seller are forced (0 in the former case and 20 in the latter), or (b) the decision maker does not choose a price before time expires in the bargaining or auction stage (and a default choice is imposed, of the minimum allowable choice for sellers or the maximum for buyers). Combined, these cases make up less than 0.5 percent of observations in the Hagg and Flex treatments.

[14] Recall from section 2.3 that two fair prices were elicited at the end of the experimental session: one for when only one buyer visited a seller, and one for when multiple buyers visited. Here, we use the former; the latter is used in the auction regressions below.

model 11, responsiveness is significantly less than the predicted value of unity when posted prices are below $10.[15]

3.2 Observed auction behaviour

In our auctions, the theoretical prediction is for all of the available surplus going to the seller: prices of $20 irrespective of the market and whether there are two buyers or three. Table 5 shows some features of observed auction behaviour in the Hagg treatment: buyers' and sellers' proposed prices (bids and reservation prices, respectively), and in the case of agreement, transaction prices. Bids at the predicted level of $20 occur only between one–fourth and one–third of the time when there are two bidders, and even with three bidders, they are seen less than half of the time. Average bids are roughly $17, and despite the different frequencies of equilibrium bids, do not vary much across the three cases. Transaction prices are higher when there are three bidders than two, while not apparently

Table 5: Auction results, haggling treatment

	2x2	3x3, 2 buyers	3x3, 3 buyers
Mean bid (buyers)	16.56	17.03	17.06
Fraction of $20 bids (buyers)	0.261	0.280	0.392
Mean reservation price (sellers)	12.13	12.48	13.41
Mean transaction price (agreements only)	16.14	16.35	18.27

affected by the market (2x2 versus 3x3). In all cases, they are well below $20, though sellers still receive the lion's share of the surplus.[16]

Overall, auction results in the Flex treatment are comparable to those in the Hagg treatment, with average transaction prices of $16.04 in the Flex2 cell, and $15.80 and $17.46 in the Flex3 cell (when there are two and three bidders respectively). Figure 6 shows more dis–sggregated results, as scatterplots with 45–degree and linear–trend lines. When there are two bidders, average transaction prices lie roughly midway between the posted price and the theoretically–predicted price of $20, with the latter seen in only about 20 percent of the observations. The theoretical prediction is more common (occurring 45 percent of the time) when there are three bidders, but average transaction prices are still well below this level.[17] We also see positive associations between posted and transaction prices in all three panels, in contrast to the theoretical prediction of no systematic relationship between the two.

Table 6 shows results from additional panel linear regressions, with buyer proposed prices (bids) as the dependent variable.[18] Explanatory variables include the round number, the posted price and its product with the round number (for the Flex–treatment models), as well as the female indicator, the level of risk tolerance, the relevant fair price, a

[15]There is also no apparent tendency toward deal–me–out over time, as the coefficient of the interaction term between posted price and the round number is positive in all four regressions (though insignificant in three of these), in contrast to the negative sign that would be needed to suggest convergence toward the deal–me–out prediction of a $10 transaction price whenever the posted price is above $10.

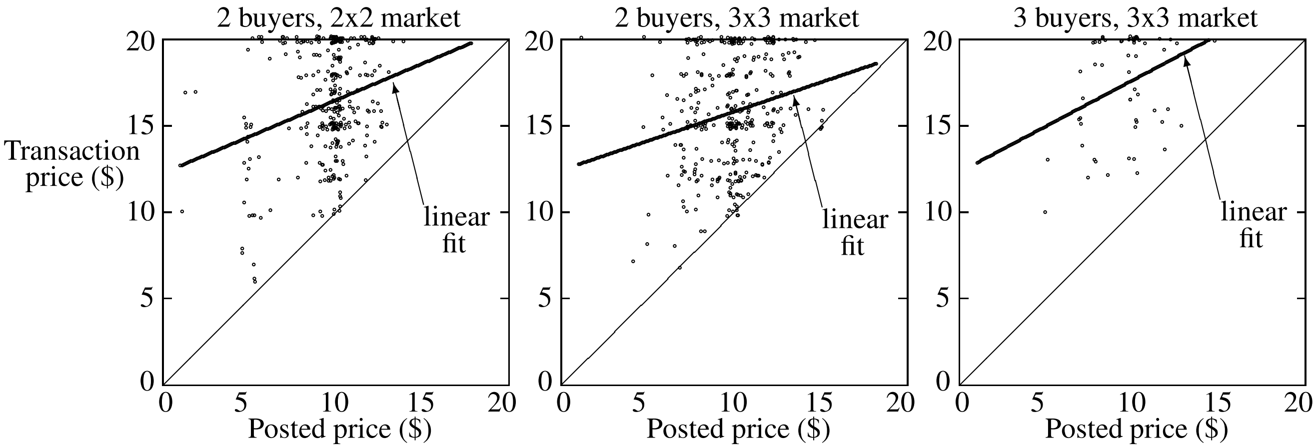
[16]While we saw in the previous section that disagreements in bargaining occur about ten percent of the time, unsold units (due to the seller's reserve price exceeding all of the bids) are rare in our auctions. In each of Hagg2, Hagg3, Flex2 and Flex3 treatments, and whether two or three bidders are present, the unit goes unsold less than 5 percent of the time, and the average clearance rate in all auctions is 96.7 percent.

[17]For comparison, transaction prices of exactly $20 are seen in the Hagg treatment about 12 percent of the time when there are two bidders and 42 percent when there are three bidders.

[18]We leave out seller reserve–price choices, which are of secondary importance here, as trade took place at the reserve price less than 14 percent of the time in auctions.

Figure 6: Auction results in Flex treatment – scatterplots of posted and transaction price

(both perturbed with uniform$[-0.2, +0.2]$ *noise)*



constant term, and subject random effects.

Table 6: Factors affecting auction bids (average MEs, clustered standard errors in parentheses)

Dep. var.: buyer proposed price	[17]	[18]	[19]	[20]	[21]	[22]
Cell:	Hagg2	Hagg3 (2 visit)	Hagg3 (3 visit)	Flex2	Flex3 (2 visit)	Flex3 (3 visit)
Posted price				0.199	0.180***	0.405***
				(0.161)	(0.065)	(0.132)
Round	0.099*	0.107***	0.008	0.129***	0.089***	0.106***
	(0.056)	(0.025)	(0.080)	(0.023)	(0.017)	(0.037)
Female	0.274	−1.236**	−1.520***	–0.388	0.657	0.572
	(0.788)	(0.571)	(0.213)	(0.757)	(0.840)	(0.753)
Risk tolerance	–0.234	−0.485***	−1.204***	–0.152	0.097	−0.171***
	(0.392)	(0.184)	(0.313)	(0.287)	(0.202)	(0.273)
Fair price	0.208***	0.275	0.021	0.013	–0.092	–0.128
	(0.065)	(0.177)	(0.316)	(0.088)	(0.107)	(0.105)
N	398	491	117	631	632	156
R^2	0.080	0.220	0.149	0.290	0.145	0.255

* (**,***): *Marginal effect significantly different from zero at the 10% (5%, 1%) level.*

In the Flex treatment, bids increase in the posted price, in contrast to the theoretical prediction of $20 irrespective of the posted price. The positive (and often significant) marginal effect of the round number suggests that subjects learn to increase their bids as the session progresses, and we see mixed but suggestive evidence that bids are lower for more risk–seeking subjects.

4 Using observed bargaining and auction behaviour to update the theory

In this section, we adapt the theory from Section 2 to account for how subjects actually behave in our bargaining and auction stages.[19] We will refer to the new theoretical results in this section as our *behavioural theory* results, to distinguish them from our previous *standard theory* results.

In order to avoid over–fitting to the detailed results of this particular experiment, we concentrate on the broadest characterisation of bargaining and auction behaviour. We begin with a small number of stylised facts:

1. In the Hagg treatment when exactly one buyer visits a seller, the transaction price will be \$11 conditional on agreement, which occurs 90 percent of the time.
2. In the Hagg treatment when more than one buyer visits a seller, the transaction price will be \$17.
3. In the Flex treatment with a posted price of p^p when exactly one buyer visits a seller, the transaction price will be p^p conditional on agreement, which occurs 90 percent of the time.
4. In the Flex treatment with a posted price of p^p when more than one buyer visits a seller, the transaction price will be $12 + (2/5)p^p$.

The transaction prices in the first two items come from the descriptions of Hagg results in Sections 3.1 and 3.2. The third reflects the closeness of the trend line in Figure 5 to the 45–degree line, while the last crudely characterises the trend lines in Figure 6, with an intercept near 12 and a posted price of 20 leading to a transaction price of 20. The probability of disagreement in bargaining is based on the experimental results, and since the frequency of disagreement in the auction is much lower (less than 5 percent), we round this to zero for simplicity.

These stylised facts are obviously a gross simplification of the experimental results, ignoring variation across matching groups within treatments, across subjects within matching groups, and across rounds. However, they are approximately correct on average, and using them avoids the risk of over–fitting the data. Also, it is not too much of a stretch to suppose that subjects internalise these stylised facts when forming expectations, while assuming beliefs precisely fitted to more disaggregated subject behaviour seems implausible.

These new assumptions only change behaviour in our Flex treatment. The Post treatment has no bargaining or auctions, so the behavioural theory is identical to the standard theory in that treatment. In the Hagg treatment, these assumptions do not affect decision making, since buyers continue to visit sellers with equal probability, and there is no price–posting stage, though they will affect market outcomes like efficiency and profits. In the Flex treatment, the changes affect the visit–choice game played between the buyers. Details are in the appendix, but intuitively, there are two modifications to the bargaining and auction stages that have implications for the buyer's trade–off between (i) visiting a higher–priced buyer and being relatively likely to be the only buyer visiting (hence receiving the payoff from bargaining), and (ii) visiting a lower–priced buyer and being relatively likely to be one of multiple buyers visiting (hence receiving either zero or the payoff from the auction). The change to the bargaining stage is unfavourable to the buyer – agreements are weakly more favourable to the seller and disagreements sometimes occur – and thus lowers the buyer's payoff to visiting a higher–price seller (compared to under standard theory).

[19] Clearly, there are other potential explanations for the differences we have observed between predicted and observed market outcomes, such as over– or under–pricing by sellers in the posting and flexible–pricing treatments, and failure by buyers to choose equilibrium mixed strategies in their visit choices. Equally clearly, these potential explanations are not mutually exclusive.

The change to the auction stage is in the buyer's favour, and thus raises the payoff to visiting a lower–price seller. Since both changes make the lower–priced seller more attractive, buyers will become more price–responsive under the behavioural theory than under the standard theory.

The changes also affect the sellers' pricing decision in the Flex treatment, both directly via the profit conditional on being visited by one buyer and by two (or more) buyers, and indirectly from the changes to buyers' visit probabilities (via the probabilities Φ_1 and Φ_2). The incentive to be the lower–price seller is strengthened by the increased price–responsiveness of buyers and by disagreements in bargaining, but weakened by the decrease in the seller auction payoff and the increase in the seller bargaining payoff, making the overall effect on prices ambiguous. The behavioural–theory predictions are shown in Table 7 (see Table **??** for comparison).

Table 7: Predictions from behavioural theory

Cell	Market		Efficiency	Posted	Transaction price			Profit	
	institution	size		price	All	1 visit	2+ visits	sellers	buyers
Post2	posting	2x2	0.700	10.00	10.00	10.00	10.00	7.50	7.50
Post3		3x3	0.659	9.33	9.33	9.33	9.33	6.57	7.51
Hagg2	haggling	2x2	0.700		13.14	11.00	17.00	9.20	4.80
Hagg3		3x3	0.659		13.36	11.00	17.00	8.81	4.38
Flex2	flexible	2x2	0.700	10.27	12.35	10.27	16.11	8.65	5.35
Flex3	pricing	3x3	0.659	6.67	9.81	6.67	14.67	6.47	6.72

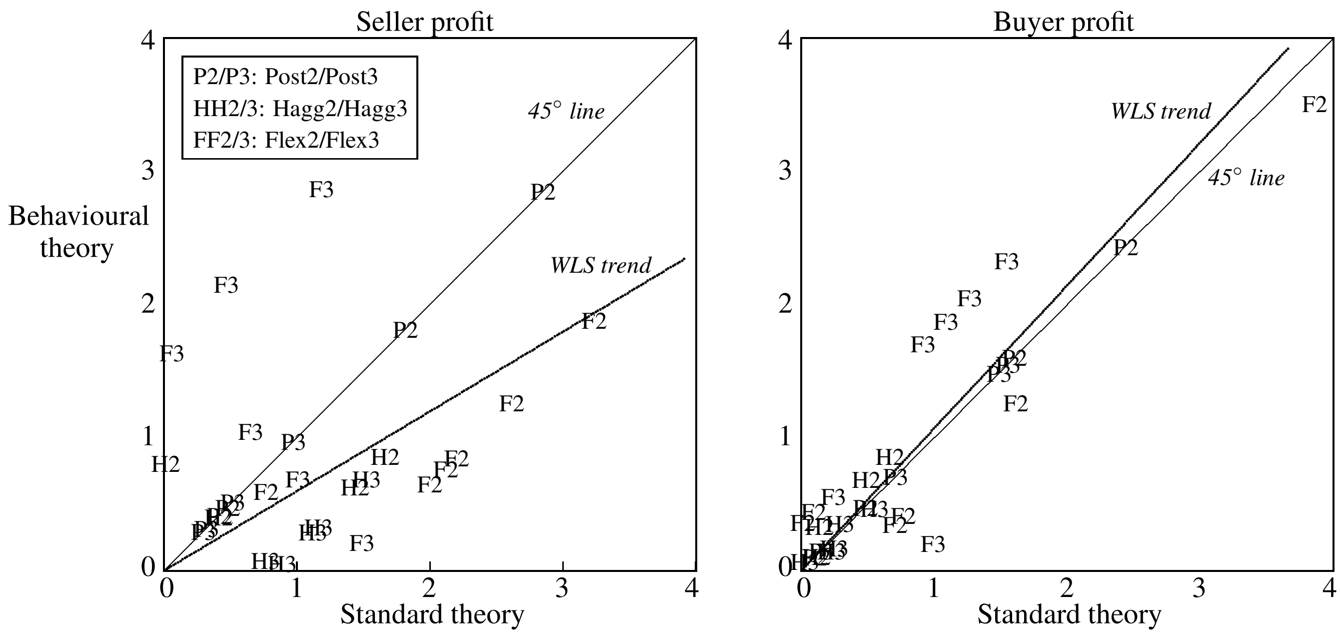
In order to test the behavioural theory against the standard theory, we start by disaggregating the data by matching group. For each matching group, we compute the absolute error (the absolute value of the difference between predicted and observed value) for both buyer profit and seller profit, using the standard– and behavioural–theory predictions. Finally, we plot each pair of standard–theory error and behavioural–theory error in Figure 7. The reason we focus on buyer and seller profits because these incorporate both factors affecting efficiency and factors affecting transaction price. This allows all of the stylised facts underlying our behaviour theory to have an impact, but also allows a role for alternative explanations (such as sellers choosing out–of–equilibrium prices, or buyers choosing out–of–equilibrium visit probabilities).

In addition to the plotted points, the figure shows weighted–least–squares trend lines (where the weights are the number of observations in each matching group, and the intercept is constrained to be zero). As the figure shows, replacing the standard theory with the behavioural theory has little effect on buyer–profit predictions. The estimated slope coefficient is 1.07, and not significantly different from the value of one implied by equally good predictions by both theories. By contrast, there is a substantial improvement in seller–profit predictions, as the slope coefficient of 0.60 (significantly less than one at the 0.1–percent level) implies a forty–percent decrease in prediction error.

5 Discussion

Understanding the performance of pricing mechanisms such as price posting, haggling, and flexible pricing is an important step towards understanding why these institutions have survived for so long, how they can co–exist in

Figure 7: Predictive ability of standard and behavioural theories for seller and buyer profit (absolute error between predictions and observed data, disaggregated by matching group)



some markets, and when buyers, sellers, or social planners may prefer one to another. Our investigation of these mechanisms has comprised theory and experiment. We find that standard theory has mixed success in characterising actual market outcomes, both in point predictions and in directional predictions of treatment effects. But a behavioural theory, differing from the standard theory only in a more realistic set of assumptions concerning bargaining and auctions (which occur in our haggling and flexible–pricing treatments), generates predictions that better fit the experimental data.

The particular assumptions made in our behavioural model are based on a broad characterisation of subject behaviour in the bargaining and auction subgames, rather than a detailed data–fitting exercise. We incorporate a small frequency of disagreements in bargaining, and a tendency for trade to take place on terms that favour the seller to a higher degree than predicted by standard bargaining theory, but less than predicted by auction theory. The bargaining and auction subgames are only some of the places where deviations from standard theory can impact market outcomes: buyers may choose out–of–equilibrium visit probabilities (either too much or too little price–responsiveness), or sellers may choose above– or below–equilibrium posted prices. A behavioural theory that incorporates all of the regularities in the experimental data may well perform even better than our minor adjustment, and is a worthwhile topic for future research, though beyond the scope of the current paper.[20] Even the current behavioural theory improves the model, however, with lower prediction error for sellers' profits, and a negligible effect on prediction error for buyers' profits.

Our work is in the spirit of other recent work that adapts theoretical models to account for stylised facts observed

[20]The main outlier in our results is the Flex3 cell, where the behavioural model performs worse than the standard model on both buyer and seller profit (see Figure 7). The standard theory seems to perform well in that cell due to out–of–equilibrium behaviour in other areas (e.g., price posting by sellers) countervailing that in bargaining and auctions.

in the lab. A well–known example is the ultimatum game (UG), a bargaining setting where one side (the proposer) is predicted to earn all of the available surplus, but where agreements in the lab tend toward giving that side only 60–70 percent of the surplus (Roth, 1995). Both Bolton and Karagözoğlu (2016) and Kloosterman and Paul (2018) develop (quite different) models that include UGs as subgames, and use the empirical regularities in formulating their theoretical predictions, rather than relying exclusively on the standard–theory UG solution. However, such practice is still fairly rare. We encourage theorists and applied theorists to make more use of insights from the experimental–economics literature when constructing and analysing theoretical models.

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A Derivations of standard equilibrium predictions

Posting in 2x2 and 3x3 markets was covered by Burdett et al. (2001); we encourage the interested reader to refer there (see especially their Equation 5 on p. 1068). Our analysis of the haggling and flexible–pricing cases proceeds by backward induction.

Final stage (auction)

When multiple buyers visit a seller in the haggling and flexible–pricing treatments, the good is allocated by a second–price sealed–bid auction. Since there is perfect information about the good's valuation, which is 20 and common to all buyers, it is weakly dominant for each buyer to bid this valuation. Thus irrespective of the number of buyers (as long as there are at least two), each buyer will bid $p_b = 20$. The seller's reserve price p_s is irrelevant, as is the posted price p^p. The good is traded with certainty, and the transaction price and seller's profit will be $p = 20$. Each buyer is equally likely to trade, but profit is zero whether or not they are able to trade at $p = 20$.

Final stage (bargaining)

When exactly one buyer visits a seller in the haggling and flexible–pricing treatments, the good is allocated by a variant of Nash bargaining where instead of making demands directly, both bargainers choose prices that are equivalent to proposals for shares of the cake (worth 20 in total). Let p_b and p_s be the buyer's bid price and the seller's offer price respectively; then payoffs are $20 - (p_b + p_s)/2$ for the buyer and $(p_b + p_s)/2$ for the seller if $p_b \geq p_s$, and zero for both bargainers otherwise. That is, if the buyer's and seller's "demands" for shares of the surplus are compatible, each gets their demand plus half the remainder, while both get zero in case of disagreement.

Any feasible pair (p, p) of bid and offer prices is a Nash equilibrium, but Harsanyi and Selten's (1988) risk dominance selects a unique Nash equilibrium (see Figure 2 in the main text). Under flexible pricing when the posted price p^p is more than 10, or under haggling, risk dominance implies a transaction price of $p = 10$, while when $p^p < 10$, the transaction price is given by $p = p^p$; when $p^p = 10$, the two outcomes coincide. The unit is traded with certainty, and the transaction price is $p = \min\{p^p, 10\}$, so that buyer and seller profits are $20 - p$ and p respectively.

Penultimate stage (visit choices)

Suppose sellers in the Flex2 cell post prices p_1^p and p_2^p. A buyer visiting Seller i earns zero if the other buyer visited the same seller, and $v_i = \max\{20 - p_i^p, 10\}$ if the other buyer visited the other seller. Hence buyers play a symmetric 2x2 game between themselves, shown in Figure 3 in the main text. The game has a symmetric Nash equilibrium in which each buyer visits Seller 1 with probability $q = v_1/(v_1 + v_2)$. Note that q is bounded by one–third and two–thirds (so that the equilibrium is always completely mixed), and that it is equal to one–half whenever both posted prices are equal or both are at least 10, as well as in the Hagg2 cell where prices are not posted.

In the 3x3 market, with posted prices p_1^p, p_2^p and p_3^p, the three buyers play a 3x3x3 game amongst themselves, shown in Figure 8. In the symmetric Nash equilibrium, each buyer visits Seller i with probability q_i, where

$$q_i = \frac{\left(\frac{v_i}{v_j}\right)^{1/2} + \left(\frac{v_i}{v_k}\right)^{1/2} - 1}{\left(\frac{v_i}{v_j}\right)^{1/2} + \left(\frac{v_i}{v_k}\right)^{1/2} + 1} \tag{2}$$

with $i, j, k \in \{1, 2, 3\}$ and all distinct. For each seller i, q_i is bounded by approximately 0.17 and 0.48 (as in Flex2, the equilibrium is always completely mixed), and is equal to one–third whenever all three posted prices are equal or

Figure 8: The symmetric game played by buyers in the 3x3 market under flexible pricing, given posted prices p_1^p, p_2^p, p_3^p and with $v_i = \max\{20 - p_i^p, 10\}$ *(only Buyer–1 payoffs shown)*

		Buyer 2			Buyer 2			Buyer 2		
		Seller 1	Seller 2	Seller 3	Seller 1	Seller 2	Seller 3	Seller 1	Seller 2	Seller 3
Buyer 1	Seller 1	0	0	0	0	v_1	v_1	0	v_1	v_1
	Seller 2	v_2	0	v_2	0	0	0	v_2	0	v_2
	Seller 3	v_3	v_3	0	v_3	v_3	0	0	0	0
		Buyer 3: Visit Seller 1			Visit Seller 2			Visit Seller 3		

all three are at least 10, as well as in the Hagg3 cell.

First stage (price posting)

From the analysis of the final stage, Seller i posting price p_i^p under flexible pricing earns zero if no–one visits her, $\min\{p_i^p, 10\}$ if exactly one buyer visits, and 20 if two or more visit. Let Φ_1 and Φ_2 be the probabilities of Seller i being visited by exactly one and at least two buyers (respectively), computed from the buyers' visit probabilities. Then that seller's profit is given by

$$\Pi_i = \Phi_1 \cdot \min\{p_i^p, 20\} + \Phi_2 \cdot 20.$$

We look for a symmetric equilibrium in prices, so suppose all rival sellers post price p^p. Note that when $p_i^p \geq 10$, Π_i does not depend on p_i^p.[21]

In the 2x2 market, if $p_i^p \leq 10$ then we have

$$\frac{\partial \Pi_i}{\partial p_i^p} = \Phi_1 + p_i^p \cdot \frac{\partial \Phi_1}{\partial p_i^p} + 20 \cdot \frac{\partial \Phi_2}{\partial p_i^p}, \tag{3}$$

with $\Phi_1 = 2q(1-q)$ and $\Phi_2 = q^2$, where q is given by the solution to the buyer–visit stage discussed above. From here, it is straightforward but tedious to show that this derivative is strictly positive for all $p_i^p < 10$. Since it is zero for $p_i^p \geq 10$ as noted above, all prices greater than or equal to 10 yield equal profit, and each dominates any price less than 10. Hence there is a continuum of equilibria in this case; any seller can post any price in $[10, 20]$.

In the 3x3 market, if $p_i^p \leq 10$ then again (3) holds, with $\Phi_1 = 3q_1(1-q_1)^2$ and $\Phi_2 = q_1^2(3-2q_1)$ and q_1 given by (2). Setting $p_i^p = p^p$ and $q = 1/3$, so that $\Phi_1 = 12/27$ and $\Phi_2 = 7/27$, and noting that (2) implies $\frac{\partial q}{\partial p_i^p} = -\frac{2}{9(20-p_i^p)}$ when $p_1^p = p_2^p = p_3^p$, yields the solution $p^p = 20/3$. Unlike the 2x2 case, this maximum is strict, so no p_i^p equal to 10 or anything higher is a best response. Also, it is again easily verified that $\frac{\partial \Pi_i}{\partial p_i^p} < 0$ when all sellers post 10, which means that posting this price (or anything higher) cannot be an equilibrium strategy.

Other market variables

Once the equilibrium posted prices are derived, it is straightforward to compute the other aspects of the equilibrium of the Flex treatment; the same process also works for the other treatments. The equilibrium transaction price conditional on one buyer visiting is found by substituting the posted price into the bargaining solution, and thus

[21] Profit is also unaffected by changes to opponent posted prices over the interval $[10, 20]$. Both results are due to our solution to the final stage, where any posted price in $[10, 20]$ leads to a transaction price of 10 if one buyer visits or 20 if multiple buyers visit, which means that equilibrium visit probabilities are the same for any posted prices in this interval.

equal to $20/3 \approx 6.67$ in the Flex treatment's 3x3 market, and 10 in its 2x2 market and both markets of the Hagg treatment. The equilibrium transaction price conditional on two or more buyers visiting is 20 in the Flex and Hagg treatments, as already discussed. The equilibrium seller profit is found by weighting these conditional transaction prices by the probabilities of them occurring (Φ_1 and Φ_2, along with the analogous probability Φ_0 of not being visited), our normalised measure of efficiency is simply the probability of a given seller being visited ($\Phi_1 + \Phi_2$), and the unconditional expected transaction price is the seller profit divided by our efficiency measure (i.e., seller profit conditional on being visited). Finally, equilibrium buyer profit is found by subtracting the unconditional transaction price from 20 (i.e., buyer valuation), and multiplying the result by the probability the buyer is able to buy, which is equal to our efficiency measure since there are equal numbers of buyers and sellers. These measures can also be calculated for the Post treatment, remembering that the transaction price is always equal to the posted price whenever a seller is visited by at least one buyer.

B Session information

Table 8: Session and treatment information

Session	Treatment	Market type (number of markets)		Session	Treatment	Market type (number of markets)	
		Matching grp. 1	Matching grp. 2			Matching grp. 1	Matching grp. 2
1	Flex	3x3 (2)		13	Post	3x3 (3)	
2	Hagg	3x3 (3)		14	Hagg	3x3 (2)	2x2 (2)
4	Flex	3x3 (3)		15	Flex	2x2 (5)	
5	Hagg	3x3 (2)	2x2 (2)	16	Flex	3x3 (3)	
6	Flex	3x3 (2)	2x2 (2)	17	Post	2x2 (5)	
8	Post	3x3 (2)	2x2 (2)	18	Hagg	2x2 (5)	
9	Post	3x3 (3)		19	Flex	2x2 (3)	2x2 (2)
10	Hagg	3x3 (2)	2x2 (2)	20	Post	2x2 (4)	
11	Post	3x3 (2)	2x2 (2)	21	Flex	3x3 (2)	2x2 (2)
12	Flex	3x3 (2)	2x2 (2)	22	Hagg	3x3 (3)	

Treatment	2x2 markets	3x3 markets	Subjects
Post	13	10	112
Hagg	11	12	116
Flex	16	14	148

Notes: Sessions 103 and 107 dropped due to programming error in main program. Sessions 101 and 102 had programming error in post–experiment questionnaire, but kept in sample except when those questions are used.

C Details of behavioural theory

As noted in the main text, we develop the behavioural theory by replacing the equilibrium predictions for the bargaining and auction stages with the following:

1. In the Hagg treatment when exactly one buyer visits a seller, the transaction price will be \$11 conditional on agreement, which occurs 90 percent of the time.

2. In the Hagg treatment when more than one buyer visits a seller, the transaction price will be \$17.

3. In the Flex treatment with a posted price of p^p when exactly one buyer visits a seller, the transaction price will be p^p conditional on agreement, which occurs 90 percent of the time.

4. In the Flex treatment with a posted price of p^p when more than one buyer visits a seller, the transaction price will be $12 + (2/5)p^p$.

These changes do not affect the posting treatment, where bargaining and auctions do not occur, or the haggling treatment (though they will affect market outcomes there). So we concentrate on the flexible–pricing treatment.

In the Flex2 cell, the visit–choice stage consists of the following game played between the buyers:

Figure 9: Updated Flex2 market visit–choice game (symmetric, only Buyer 1 payoffs shown)

		Buyer 2	
		Visit Seller 1	Visit Seller 2
Buyer	Visit Seller 1	$(20 - p_1^p)/5$	$9(20 - p_1^p)/10$
1	Visit Seller 2	$9(20 - p_2^p)/10$	$(20 - p_2^p)/5$

The off–diagonal and diagonal entries come from (3) and (4) respectively. The symmetric mixed–strategy equilibrium has each buyer choosing Seller 1 with probability

$$q_1^{behavioural} = \frac{140 - 9p_1^p + p_2^p}{280 - 7p_1^p - 7p_2^p} \tag{4}$$

as long as this value is strictly between 0 and 1. Unlike the standard–theory case, this condition is not guaranteed (i.e., for some price pairs, both buyers will visit the lower–price seller with certainty), but it will hold in a region containing the equilibrium in prices (this is also true for the Flex3 case we consider below). Price responsiveness at the symmetric price $p_1^p = p_2^p$ is given by

$$\left.\frac{\partial q_1^{behavioural}}{\partial p_1^p}\right|_{p_1^p = p_2^p} = -\frac{11}{28(20 - p_1^p)}.$$

The visit–choice game in the Flex3 market is more complicated (with 3 players and 3 pure strategies for each), but is constructed and solved similarly. The expected payoff for a buyer visiting Seller i is $\frac{9}{10}(20 - p_i^p)$ if neither of the other buyers visits that seller, $\frac{1}{5}(20 - p_i^p)$ if one of the other buyers does so, and $\frac{2}{15}(20 - p_i^p)$ if both other buyers do so; these are based on the bargaining and auction results, and in the latter case, the chance of being the auction winner. If each of the other buyers visits Seller i with probability q_i, the expected payoff to visiting that seller is

$$
\begin{aligned}
& (1-q_i)^2 \cdot \frac{9}{10}(20-p_i^p) + 2q_i(1-q_i) \cdot \frac{1}{5}(20-p_i^p) + q_i^2 \cdot \frac{2}{15}(20-p_i^p) \\
= \quad & (20-p_i^p)\left[\frac{9}{10} - \frac{7}{5}q_i + \frac{19}{30}q_i^2\right] \qquad (5)
\end{aligned}
$$

The equilibrium visit–choice probabilities q_1, q_2 and q_3 are those that equalise the expected payoff to visiting each of the sellers; this provides an implicit expression for these probabilities. From there, we obtain equilibrium price responsiveness at the symmetric price $p_1^p = p_2^p = p_3^p$:

$$
\left.\frac{\partial q_1^{behavioural}}{\partial p_1^p}\right|_{p_1^p = p_2^p = p_3^p} = -\frac{34}{99(20-p_1^p)}.
$$

We now move to the price–posting decisions under flexible pricing. Seller i posting price p_i^p earns an expected profit of zero if no–one visits her, $\frac{9}{10}p_i^p$ if exactly one buyer visits, and $12 + \frac{2}{5}p_i^p$ if two or more visit. Let Φ_1 and Φ_2 be the probabilities of Seller i being visited by exactly one and at least two buyers respectively, computed from the buyers' visit probabilities. Then Seller i profit is given by

$$
\Pi_i = \Phi_1 \cdot \left(\frac{9}{10}p_i^p\right) + \Phi_2 \cdot \left(12 + \frac{2}{5}p_i^p\right).
$$

In the 2x2 market, we have $\Phi_1 = 2q_i(1-q_i)$ and $\Phi_2 = q_i^2$, where q_i is given by (4). In a symmetric equilibrium in prices, Π_i is maximised for both sellers when $p_1^p = p_2^p$ (so $q_1 = q_2 = 1/2$); this occurs at $p_1^p = p_2^p = \frac{1160}{113} \approx 10.27$.

In the 3x3 market, we have $\Phi_1 = 3q_i(1-q_i)^2$ and $\Phi_2 = 3q_i^2(1-q_i)^2 + q_i^3 = q_i^2(3-2q_i)$, where q_1, q_2 and q_3 are the values that equalise the expected payoffs given by (5). In a symmetric equilibrium in prices, Π_i is maximised for each of the sellers when $p_1^p = p_2^p = p_3^p$ (so $q_1 = q_2 = q_3 = 1/3$); this occurs at $p_1^p = p_2^p = p_3^p = \frac{20}{3} \approx 6.67$.

D Experiment instructions

Below is the text of the instructions used in the experiment. Text that differed across treatments is placed inside square brackets, along with the relevant treatment (this was not in the original instructions). Part 2 was the same in all three treatments.

Instructions (Part 1)

You are about to participate in a decision making experiment. Please read these instructions carefully, as the money you earn may depend on how well you understand them. If you have a question at any time, please feel free to ask the experimenter. We ask that you not talk with the other participants during the experiment, and that you put away your mobile phones and other devices at this time.

This experiment has two parts. These instructions are for Part 1; you will receive new instructions after this part has finished. Part 1 is made up of ***40 rounds***, each consisting of a simple computerised market game. Before the first round, you are assigned a role: buyer or seller. ***You will remain in the same role throughout the experiment.***

In each round, the participants in this session are divided into "markets". A market is either a ***group of 4*** containing a total of ***2 buyers*** and ***2 sellers***, or a group of ***6*** containing ***3 buyers*** and ***3 sellers***. ***The other people in your market will be randomly assigned in each round.*** You will not be told the identity of the people in your market, nor will they be told yours – even after the session ends.

The market game: In each round, a seller can produce ***one*** unit of a hypothetical good, at a cost of ***$0***. A buyer can buy ***up to one*** unit of the good, which is ***resold to the experimenter*** at the end of the round for ***$20***. It is not possible to buy or sell more than one unit in a round.

[Post:
A round begins with sellers choosing their prices, which are entered as ***multiples of 0.10, between 0 and 20*** inclusive (without the dollar sign). After sellers have chosen their prices, the buyers ***are told the prices*** of each of the sellers in their market, and then each buyer chooses ***which seller to visit***. A seller might be visited by zero, one, or more than one buyers. Any seller visited by ***zero*** buyers is ***unable to sell*** in that round. If ***exactly one buyer*** visits a particular seller, then that buyer pays the seller's price for the seller's item. If ***more than one buyer*** visits the ***same*** seller, then since the seller only has one unit, ***one of the buyers is randomly selected*** by the computer to purchase it at that seller's price, and the other buyers are ***unable to buy***.]

[Hagg:
A round begins with buyers choosing ***which seller to visit***. A seller might be visited by zero, one, or more than one buyers. Any seller visited by ***zero*** buyers is ***unable to sell*** in that round.

If ***exactly one buyer*** visits a particular seller, then the buyer and seller ***negotiate*** over the final price. The seller chooses an ***offer price***, and the buyer chooses a ***bid price***. Both of these can be any ***multiple of 0.10, between 0 and 20*** inclusive.
- If the buyer's bid price is ***greater than or equal to*** the seller's offer price, then the buyer and seller trade, and the final price is equal to the ***average of the bid and offer prices*** ([bid price + offer price] / 2).
- If the buyer's bid price is ***less than*** the seller's offer price, then they ***do not trade*** in that round: the buyer doesn't buy and the seller doesn't sell.

If ***more than one buyer*** visits the ***same*** seller, then since the seller only has one unit, ***the unit is auctioned***

off to determine which buyer is able to buy. The seller chooses a ***reserve price***, and each buyer chooses a ***bid price***. These can be any ***multiple of 0.10, between 0 and 20.00*** inclusive.
- If ***one or more*** bids are ***greater than or equal to*** the seller's reserve price, then the seller sells to the buyer with the ***highest*** bid (any ties are broken randomly by the computer), and the final price is equal to either the ***second-highest bid*** or the ***reserve price***, whichever is larger. The other buyers visiting that seller are ***unable to buy*** in that round.
- If ***all*** of the bids are ***less than*** the seller's reserve price, then they ***do not trade*** in that round: the buyers don't buy and the seller doesn't sell.]

[Flex:
A round begins with sellers choosing their prices, which are entered as ***multiples of 0.10, between 0 and 20*** inclusive (without the dollar sign). After sellers have chosen their prices, the buyers ***are told the prices*** of each of the sellers in their market, and then each buyer chooses ***which seller to visit***. A seller might be visited by zero, one, or more than one buyers. Any seller visited by ***zero*** buyers is ***unable to sell*** in that round.

If ***exactly one buyer*** visits a particular seller, then the buyer and seller ***negotiate*** over the final price. The seller chooses an ***offer price***, and the buyer chooses a ***bid price***. These can be any ***multiple of 0.10, between 0 and the seller's original price*** inclusive.
- If the buyer's bid price is ***greater than or equal to*** the seller's offer price, then the buyer and seller trade, and the final price is equal to the ***average of the bid and offer prices*** ([bid price + offer price] / 2).
- If the buyer's bid price is ***less than*** the seller's offer price, then they ***do not trade*** in that round: the buyer doesn't buy and the seller doesn't sell.

If ***more than one buyer*** visits the ***same*** seller, then since the seller only has one unit, ***the unit is auctioned off to determine which buyer is able to buy***. The seller chooses a ***reserve price***, and each buyer chooses a ***bid price***. Both of these can be any ***multiple of 0.10, between the seller's original price and 20.00*** inclusive.
- If ***one or more*** bids are ***greater than or equal to*** the seller's reserve price, then the seller sells to the buyer with the ***highest*** bid (any ties are broken randomly by the computer), and the final price is equal to either the ***second-highest bid*** or the ***reserve price***, whichever is larger. The other buyers visiting that seller are ***unable to buy*** in that round.
- If ***all*** of the bids are ***less than*** the seller's reserve price, then they ***do not trade*** in that round: the buyers don't buy and the seller doesn't sell.]

Profits: Your profit for the round depends on the round's result.
- If you are a ***seller*** and you are ***able to sell***, your profit is the price you chose.
- If you are a ***seller*** and you are ***unable to sell***, your profit is zero.
- If you are a ***buyer*** and you are ***able to buy***, your profit is $20.00 minus the price you paid.
- If you are a ***buyer*** and you are ***unable to buy***, your profit is zero.

Sequence of play in a round:
[Post:
(1) The computer randomly forms markets. You are reminded of how many buyers and sellers are in your market, and whether you are a buyer or seller.
(2) Sellers choose their prices.
(3) Buyers observe the sellers' prices, then each buyer chooses which seller to visit.
(4) The round ends. You are informed of the results of your market, including each seller's price, how many buyers visited you (if you are a seller) or the same seller as you (if you are a buyer), the quantity you bought or sold, and your profit for the round.]

[Hagg:
(1) The computer randomly forms markets. You are reminded of how many buyers and sellers are in your market, and whether you are a buyer or seller.
(2) Each buyer chooses which seller to visit.
(3) If a seller is visited by exactly one buyer, they negotiate: the buyer chooses a bid price and the seller chooses an offer price. If a seller is visited by more than one buyer, there is an auction: the buyers bid and the seller chooses a reserve price.
(4) The round ends. You are informed of the results of your market, including how many buyers visited you (if you are a seller) or the same seller as you (if you are a buyer), the quantity you bought or sold, and your profit for the round.]

[Flex:
(1) The computer randomly forms markets. You are reminded of how many buyers and sellers are in your market, and whether you are a buyer or seller.
(2) Sellers choose their prices.
(3) Buyers observe the sellers' prices, then each buyer chooses which seller to visit.
(4) If a seller is visited by exactly one buyer, they negotiate: the buyer chooses a bid price and the seller chooses an offer price. If a seller is visited by more than one buyer, there is an auction: the buyers bid and the seller chooses a reserve price.
(5) The round ends. You are informed of the results of your market, including each seller's price, how many buyers visited you (if you are a seller) or the same seller as you (if you are a buyer), the quantity you bought or sold, and your profit for the round.]

After this, you go on to the next round.

Payments: Your payment depends on the results of the experiment. At the end of the experiment, ***four*** rounds from Part 1 will be chosen randomly for each participant. ***You will be paid the total of your profits from those selected rounds***, plus whatever you earn in the remainder of the experiment. Payments are made privately and in cash at the end of the session.

Instructions (Part 2)

In this part of the experiment, you will begin by being shown five gambles, and choosing the one you prefer. Each gamble has two possible outcomes, with equal (50%) chance of occurring.

The gambles are as follows:

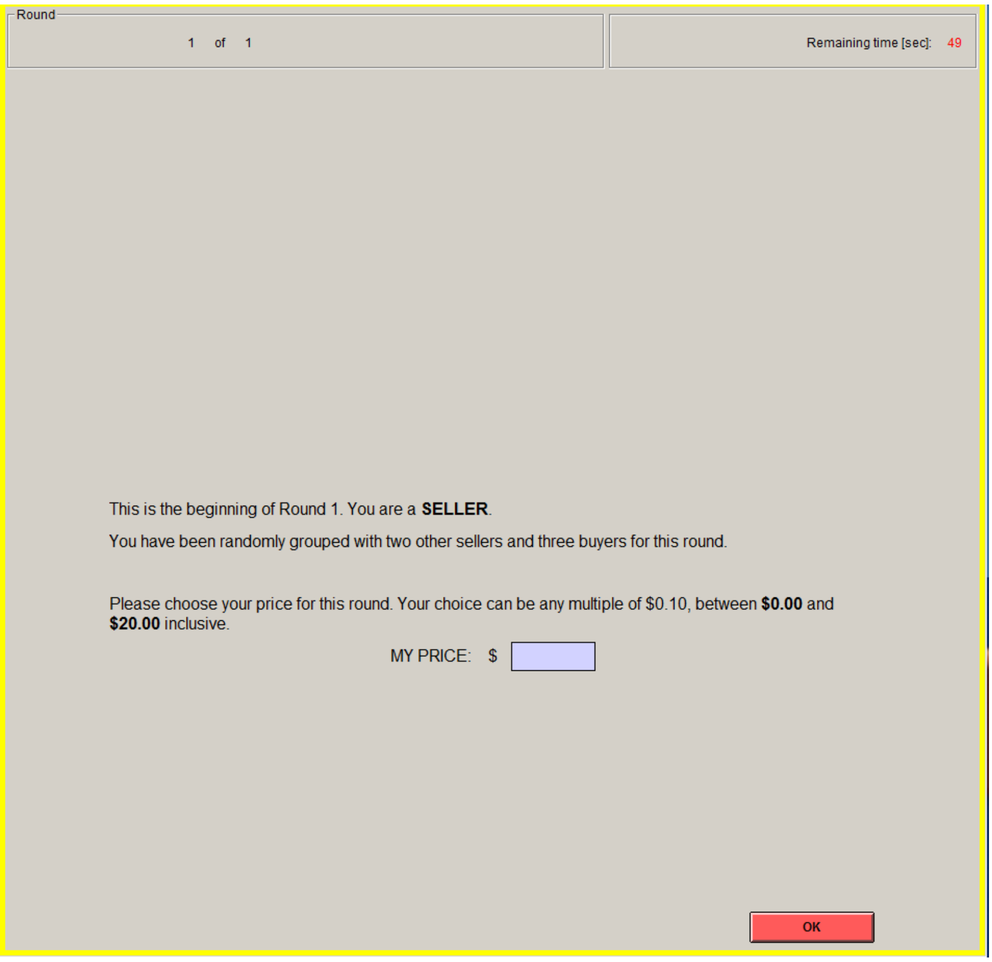
Gamble	Random numbers 1-50 (50% chance)	Random numbers 51-100 (50% chance)
1	You earn $4	You earn $4
2	You earn $6	You earn $3
3	You earn $8	You earn $2
4	You earn $10	You earn $1
5	You earn $12	You earn $0

After you have chosen one of these gambles, the computer will randomly draw a whole number between 1 and 100 (inclusive). If the random number is 50 or less, your earnings from this task are as shown in the middle column of the table. If the random number is 51 or more, your earnings are given by the right column. The random number drawn for you may be different from the ones drawn for other participants.

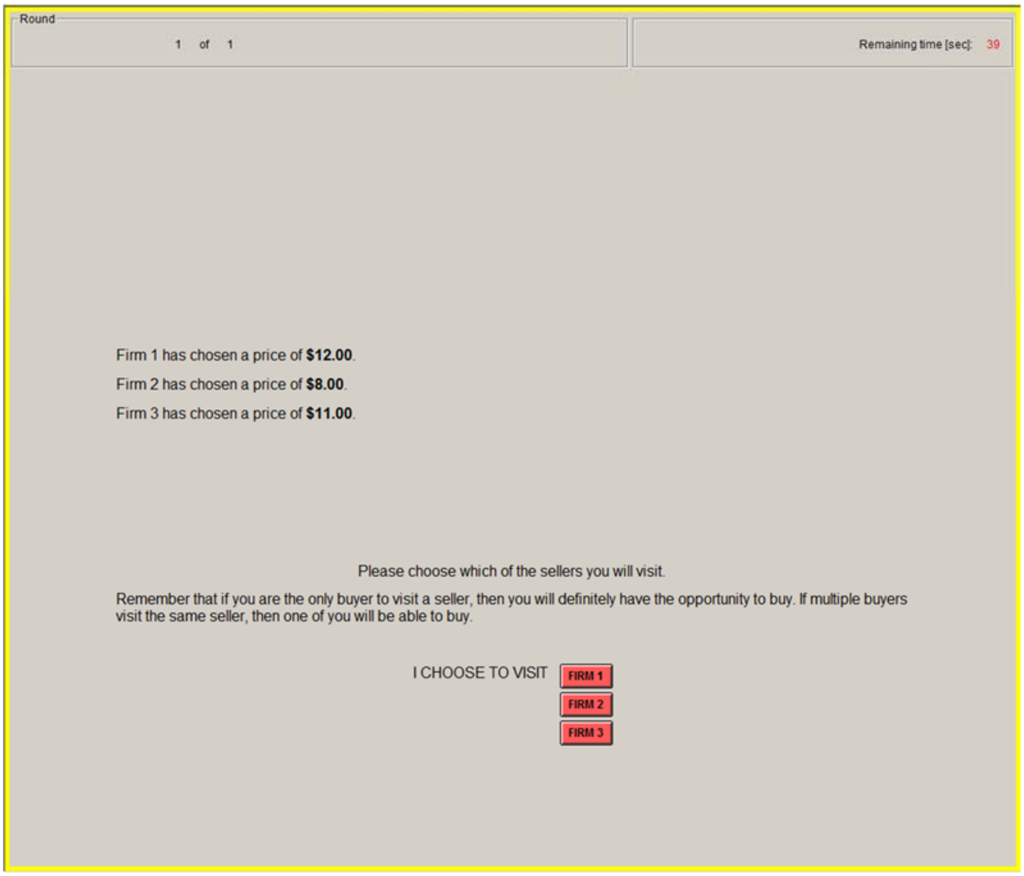
Once you have chosen a gamble, you will be shown another screen containing a questionnaire. You will receive an additional $10 for answering all of the questions. Once everyone has finished the questionnaire, you will be shown your results from this part and the previous part of the experiment.

E Sample screenshots

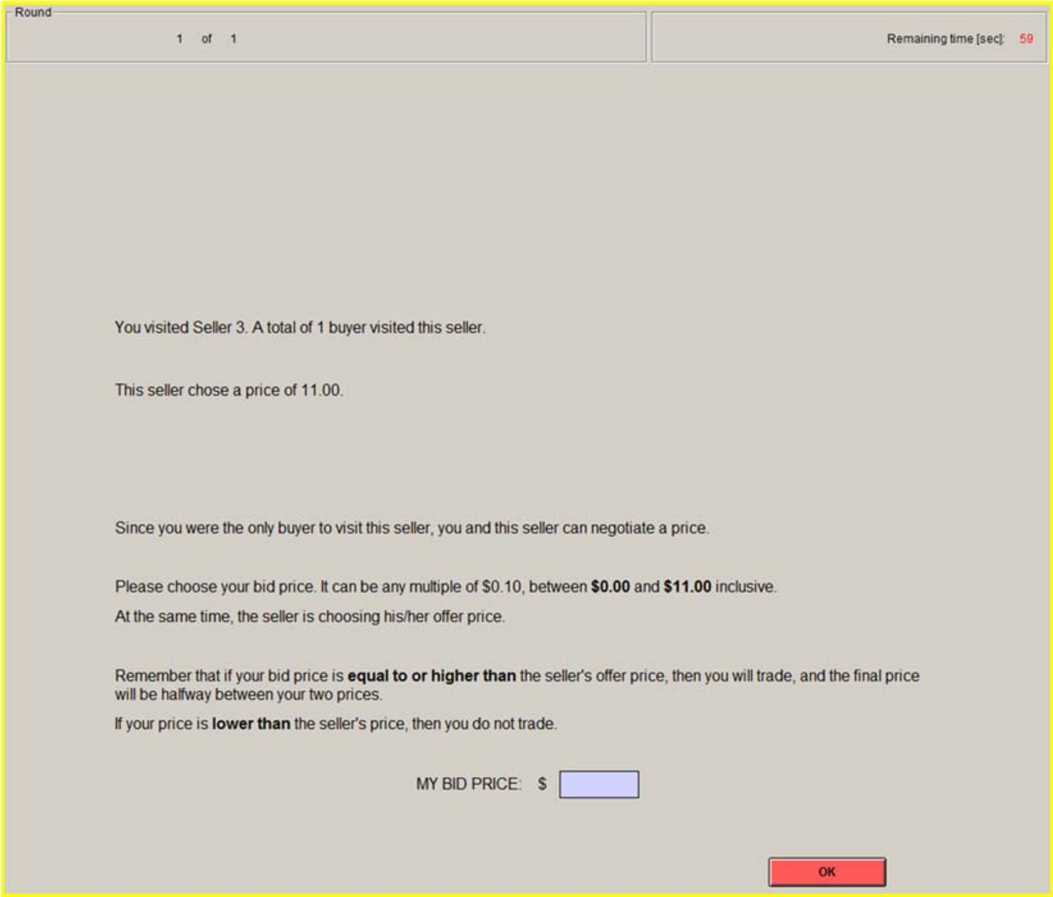
Seller price-posting choice:



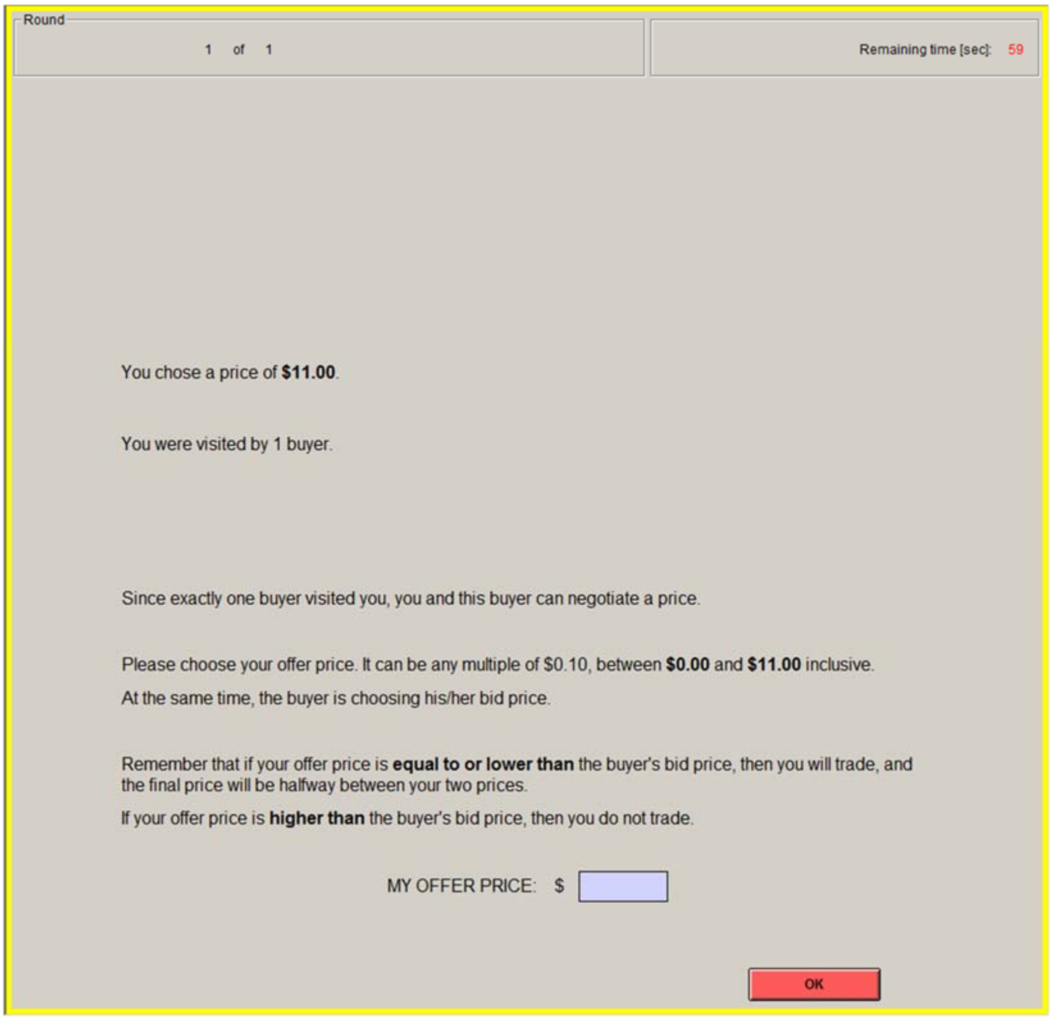
Buyer visit choice:



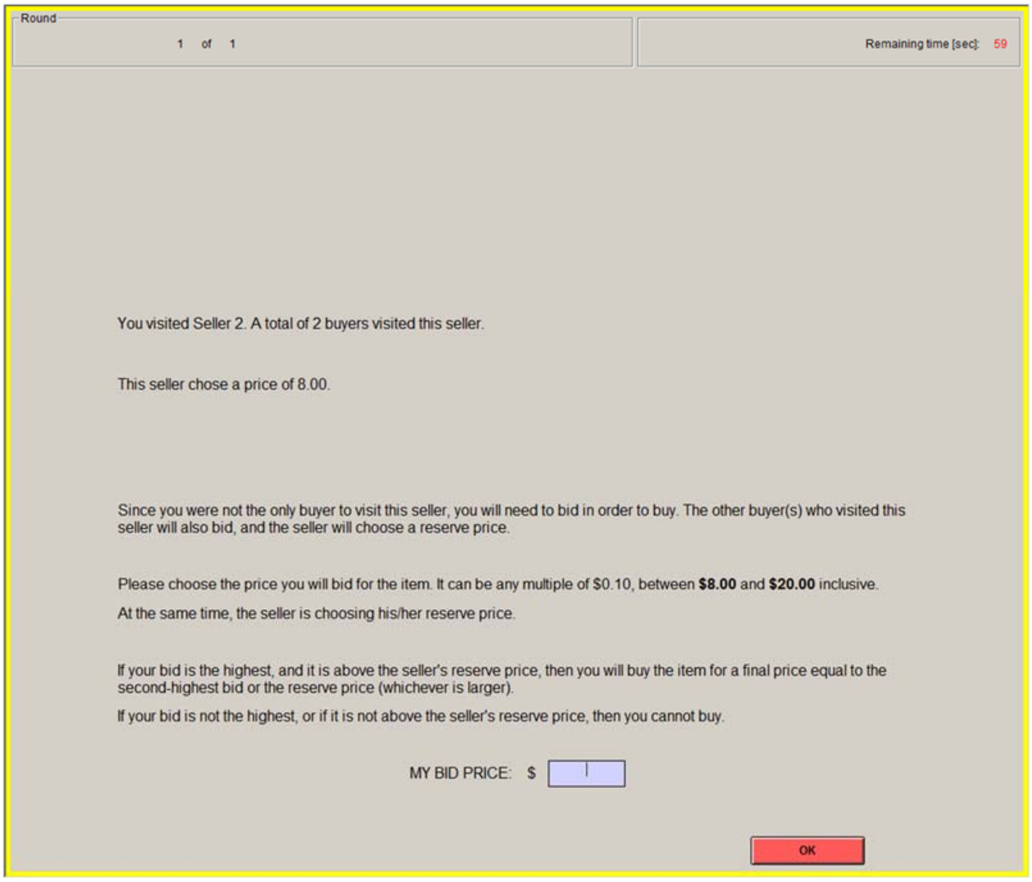
Buyer bargaining stage:



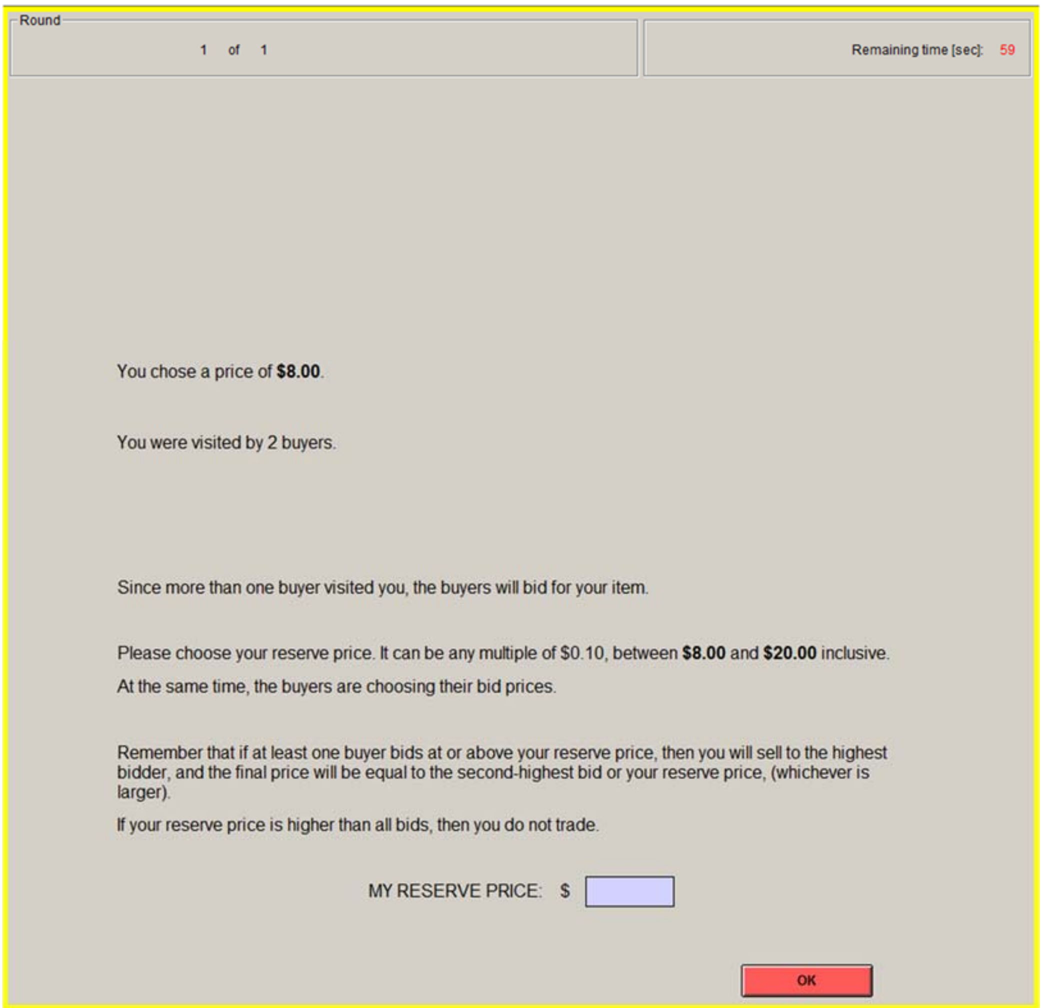
Seller bargaining stage:



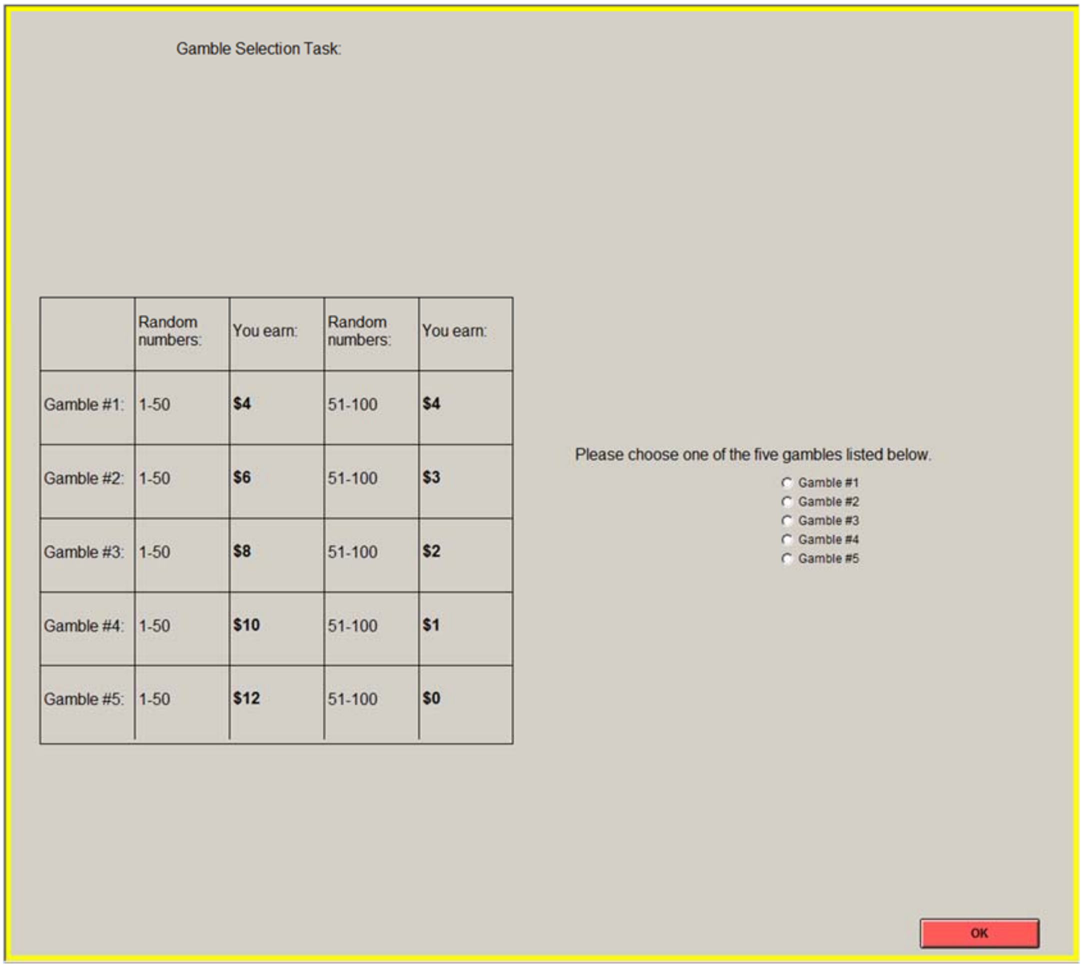
Buyer auction stage:



Seller auction stage:



Risky-choice task:


Gamble Selection Task:

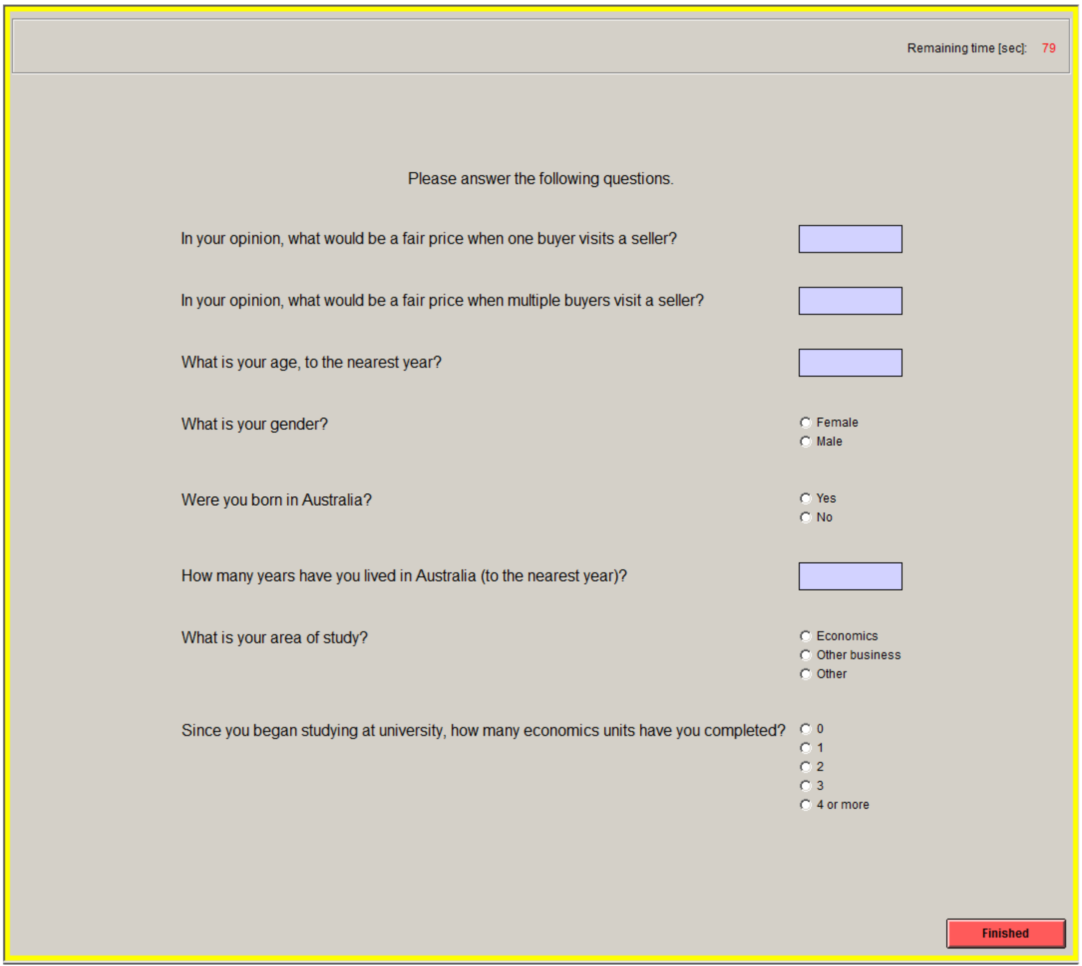
	Random numbers:	You earn:	Random numbers:	You earn:
Gamble #1:	1-50	**$4**	51-100	**$4**
Gamble #2:	1-50	**$6**	51-100	**$3**
Gamble #3:	1-50	**$8**	51-100	**$2**
Gamble #4:	1-50	**$10**	51-100	**$1**
Gamble #5:	1-50	**$12**	51-100	**$0**

Please choose one of the five gambles listed below.

- Gamble #1
- Gamble #2
- Gamble #3
- Gamble #4
- Gamble #5

OK

Questionnaire:


Remaining time [sec]: 79

Please answer the following questions.

In your opinion, what would be a fair price when one buyer visits a seller?

In your opinion, what would be a fair price when multiple buyers visit a seller?

What is your age, to the nearest year?

What is your gender?
- Female
- Male

Were you born in Australia?
- Yes
- No

How many years have you lived in Australia (to the nearest year)?

What is your area of study?
- Economics
- Other business
- Other

Since you began studying at university, how many economics units have you completed?
- 0
- 1
- 2
- 3
- 4 or more

Finished