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Can Real-Effort Investments Inhibit the Convergence of Experimental Markets?*

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Abstract

Evidence shows that real-effort investments can affect bilateral bargaining outcomes. This paper investigates whether similar investments can inhibit equilibrium convergence of experimental markets. In one treatment, sellers' relative effort affects the allocation of production costs, but a random productivity shock ensures that the allocation is not necessarily equitable. In another treatment, sellers' effort increases the buyers' valuation of a good. We find that effort investments have a short-lived impact on trading behavior when sellers' effort benefits buyers, but no effect when effort determines cost allocation. Efficiency rates are high and do not differ across treatments.

Keywords: Property Rights; Real Effort; Posted Offer Markets; Random Shock; Surplus Creation;

JEL Classification: C90, D4, L10.

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1. Introduction

One of the most prominent results from the last forty years of research in experimental economics is that subjects in laboratory markets trade at prices that are remarkably close to competitive market predictions (Plott, 1989; Smith 1982).¹ A characteristic of these experiments is that sellers' production costs and buyers' values for the goods are exogenously determined by the experimenter and randomly allocated to subjects. However, in the field both production costs and buyers' values are often determined in part by sellers' decisions, such as their investments in research and development.

This paper examines whether investments in 'real' effort made by sellers that determine buyers' values or sellers' costs (but do not affect the competitive market prediction) can influence outcomes in an experimental market.² One reason why such investments might matter is that some individuals may care about the equity of an outcome. In particular, the *equity principle* states that a person's earnings should be in proportion to that person's input.³ If a seller invests in improving the quality of a good, then buyers that care for equity should be willing to reward the seller by paying a higher price. This may have a persistent effect on market outcomes as it provides an incentive to all sellers to make similar investments.

Recent experiments on bilateral bargaining have provided evidence consistent with the notion that the equity principle is an important determinant of economic behavior. More

¹ The predictive power of equilibrium theory has been shown to be robust to changes in subject pool characteristics (Ball and Cech, 1996; Kachelmeier and Shehata, 1992), the existence of extreme earnings inequities (Smith and Williams, 1990; Cason and Williams, 1990) and the provision of information about buyers' values and sellers' costs (Franciosi, Kujal, Michelitsch, Smith, and Deng 1995; Kachelmeier, Limberg and Schadewald, 1991; Kachelmeier and Shehata, 1992).

² The adjective 'real' is commonly used by experimental economists to distinguish between experiments in which subjects have to work for their endowments (or their role in the game) and experiments in which subjects do not actually work and their 'effort' is captured by a (usually convex) strictly increasing cost function. To avoid repetition, in this paper we use the terms 'effort' and 'real effort' interchangeably.

³ See Konow (2003) for an extensive review of the theoretical and empirical literature on the equity principle and other related concepts.

specifically, a number of studies (reviewed in detail in the next section) have shown that investments in effort not only raise the demands of the parties making the investments, but also that their trading partners recognize their entitlement to a higher share of the generated surplus. The question that arises, therefore, is whether concerns for equity due to costly investments in effort can affect prices in a competitive experimental market.

The experiment presented in this paper consists of three treatments. In the BASELINE treatment, similar to previous experiments, production costs and buyers' values are exogenously determined and randomly assigned to sellers and buyers. In the other two treatments sellers participate in a real-effort tournament. In the COSTS treatment, sellers' production costs depend on their relative performance in the tournament, and also on a random productivity shock. In the VALUES treatment, sellers' effort can increase the values of buyers, generating potential efficiency gains.

Investments in effort do not affect the competitive or Nash equilibrium price and quantity obtained under the standard assumption of own-payoff maximization. However, if buyers care about equity, prices may be higher in the COSTS and VALUES treatments than in the BASELINE. The reason is that for an outcome to be equitable, earnings should be an increasing function of a person's relative effort. The equilibrium outcome in the COSTS treatment could be viewed as inequitable because buyers do not exert effort in the experiment and they earn substantially more than sellers in equilibrium. Moreover, even if buyers define equity over the set of sellers only, and prefer an outcome in which sellers are rewarded according to sellers' relative effort, the presence of a random shock implies that the final outcome may be inequitable.⁴ Equity considerations could also affect market outcomes in the VALUES treatment,

⁴ For some evidence on self-serving definitions of equity see Konow (2000), McDonald, Nikiforakis, Olekalns and Sibly (2009), and the references therein. For a general discussion on interdependent preferences see Sobel (2005).

particularly since the product of the sellers' efforts is fully captured by the buyers.

Previous experimental studies have provided evidence that fairness considerations can have an effect on market prices, but this effect is short-lived (Franciosi et al. 1995; Kachelmeier et al. 1991). In contrast to the present experiment, however, costs and values were exogenously determined in these earlier experiments. This implies that in the previous research fairness concerns refer to preferences for *equality* and not *equity*. Therefore, whether or not concerns for equity can affect market outcomes is an open question. The observation that firms operating in competitive markets voluntarily adopt environmentally friendly technologies or fair-trade standards could be seen as evidence that some firms believe that equity concerns can affect market prices.⁵

Experiments have shown that factors which affect bilateral bargaining outcomes, such as public information about individual payoffs and extreme earnings inequities, have less impact on the operation of laboratory markets (see footnote 1). For this reason, our experiment incorporates specific features to increase the likelihood that real-effort investments will affect market outcomes. First, we use the posted-offer trading institution. Previous experiments have shown that the posted-offer institution favors the side that is posting prices (e.g. Plott and Smith, 1978); in our case, the sellers. As Ruffle (2000) points out, the trading rules in posted-offer markets resemble those in ultimatum games where social preferences (and real effort) are known to have a strong effect on observed outcomes. Second, we induce market supply and demand so that buyers earn considerably more than sellers in equilibrium. This difference in earnings, combined with the fact that only sellers exert effort, could lead to higher prices due to equity concerns.

⁵ These investments are often used as a marketing tool to increase a firm's profit margin, particularly in competitive markets where it can be difficult to sell a product solely on the basis of quality and cost (Johnson, 1997; p.16). These investments may also reduce operating costs in the long or short run (Porter and van der Linde, 1995); for example, pollution abatement can reduce carbon taxes paid per unit of production, and investments in management standards can also reduce production costs by improving work morale and reducing delays in production.

Third, in the COSTS treatment a random shock in sellers' productivity affects the allocation of production costs. Fourth, in the VALUES treatment sellers do not benefit from the effort they undertake; only buyers do. The positive externality generated by sellers could make buyers more willing to accept higher prices as the competitive price may not be considered a fair compensation for sellers' effort. Finally, information about buyers' values, sellers' costs, effort and productivity shocks is made public. Public information regarding sellers' costs and buyers' values is known to slow convergence to equilibrium (Franciosi et al., 1995). Furthermore, the public nature of information highlights the asymmetric distribution of the surplus between buyers and sellers, and amplifies any concerns about equity (Borck, Engelmann, Müller and Normann, 2002).

Despite the use of these experimental design features, we find that transaction and posted prices are not overall different in the COSTS and VALUES treatments relative to the BASELINE. Hence, investing in effort does not allow sellers to obtain profits significantly higher than predicted by competitive price theory, which remains a good predictor of market outcomes. This is the case even though in the VALUES treatment, buyers are willing to pay higher prices initially to buy from sellers who increased their values. Therefore, our results indicate that the competitive pressure of the market eliminates the allocative consequences of any concerns traders may have about equity.

2. Previous Experimental Studies with Real-Effort Investments

A number of studies have investigated the impact of real-effort investments on behavior in bilateral exchanges. The consensus seems to be that investments in effort trigger equity considerations and increase the share of the surplus received by the investors.

Some early experiments used investments in effort to allocate roles to subjects. Hoffman, McCabe, Shachat and Smith (1994), for example, show that proposers in an ultimatum game and in a dictator game keep a larger part of the endowment for themselves when the role of the proposer is allocated on the basis of performance in a general knowledge quiz.⁶ Interestingly, the lower offers in the ultimatum game do not lead to higher rejection rates. Hoffman and Spitzer (1985) find similar results in a cooperative bargaining game.

In more recent experiments effort investments determine the available surplus that can be divided between subjects, but not the allocation of roles. Examples of such studies are Ruffle (1998), Cherry, Frykblom and Shogren (2002), Parrett (2006) and Oxoby and Spraggon (2008). Ruffle (1998) studies behavior in dictator as well as ultimatum games. ‘Receivers’ compete with each other in a real-effort task that determines the surplus the ‘allocators’ will be asked to split. If an allocator is matched with a receiver whose performance placed him at the top half of receivers, the allocator had a \$10 surplus to split. If the receiver performed poorly, then the allocator had a \$4 surplus to split. Ruffle’s dictator game results indicate that allocators reward the high-performing receivers by giving them more than allocators give to receivers in a control treatment where the same \$10 surplus is generated by a random draw. Most importantly, the high-performing receivers obtain offers in the ultimatum game that are not higher than they are in the dictator game. This shows that rewarding offers in Ruffle (1998) are motivated by fairness considerations and not by strategic considerations. Further, as in the case of Hoffman et al. (1994), rejections are rare. Parrett (2006) studies behavior in dictator games following closely the design of Ruffle (1998) and obtains similar results. Cherry, Frykblom and Shogren (2002)

⁶ In an Ultimatum Game a proposer must divide an endowment between herself and a responder by making a take-it-or-leave-it offer. If the responder accepts the offer, the proposed split is implemented. If the responder rejects the offer, both parties earn zero profits. The Dictator Game is similar to the Ultimatum Game. The only difference is that the responder cannot reject the proposer’s offer which is always implemented.

report that proposers in a dictator game who invest in effort that determines the surplus are extremely unlikely to share it with recipients. A similar result is reported in Oxoby and Spraggon (2008). Oxoby and Spraggon also show that when receivers exert high effort their median offer received exceeds 50 percent of the surplus.

Finally, effort investments have been used to determine whether subjects are allowed to participate in the experiment. Examples include Fahr and Irlenbusch (2000) in which subjects have to crack a minimum number of walnuts in order to participate, and Garcia-Gallego, Georgantzis and Jaramillo-Gutiérrez (2008) in which ‘employee’ subjects have to fill 20 envelopes with a single-page letter if they accept the ‘employer’s’ offer. Fahr and Irlenbusch (2000) find that second movers in a trust game send back more money when first movers invest in effort.⁷ Garcia-Gallego et al. (2008) find that when responders in a multi-round ultimatum game must exert effort, proposers (who are randomly matched in every period with a new responder) make more generous offers. Despite these higher offers, rejection rates increase.

In summary, these studies show the importance of equity concerns in bilateral bargaining. Not only do effort investments raise the demands of those investing in effort, but also these demands are acknowledged by other parties who voluntarily compensate them. The aim of the present study is to see whether these investments have similar effects in a competitive market.

3. Experimental Design and Procedures

The experiment consists of three treatments. In all treatments, five buyers and five sellers participate in a market. All agents have a trading capacity of one unit. Figure 1 summarizes the induced supply and demand. Competitive equilibrium prices are in the interval (5.50, 6.00), and

⁷ In the Trust Game the proposer has an endowment and she must decide what percentage of it to pass to the responder. The amount passed is tripled. The responder must then choose how much of the received amount to send back to the proposer.

the equilibrium quantity traded is 4 units.⁸ Trading follows standard posted-offer rules. Once sellers are informed about their own cost, each chooses independently a price for her good. Buyers observe the prices posted by the sellers and their corresponding costs and shop in a sequence following an order which varies randomly from period to period. Buyers' values are randomly allocated (from the stationary demand shown in Figure 1) in each of the 30 trading periods. The BASELINE treatment is similar to previous market experiments in which costs and values are randomly allocated to sellers and buyers. The main difference is that subjects are given information about the specific values and costs in the market. Costs are randomly reallocated every 10 trading periods, while values are allocated in every period.

The COSTS treatment

In the COSTS treatment, production costs are allocated based on the sellers' relative performance in the Encryption Task (Erkal, Gangadharan and Nikiforakis, 2009) and a random productivity shock. The Encryption Task is repeated every 10 periods. Sellers are asked to encrypt words by substituting the letters of the alphabet with predetermined numbers using an 'encrypting key.' All sellers are presented with the same words in the same sequence. For each word a seller encrypts correctly she receives a point. After seven minutes the total number of points is calculated for each seller. While sellers participate in the effort stage, buyers must wait in the lab and are allowed to read magazines, study, etc. Buyers cannot communicate with each other or with sellers during this time and must remain in their cubical.

The random productivity shock works as follows. At the end of the effort task, a number is randomly drawn separately for each seller from a uniform distribution between 0 and 0.5. The number represents a fractional reduction in points. For example, if a seller has encrypted 50

⁸ Prices consistent with a Nash equilibrium are in a more narrow interval [5.99, 6.00].

words and the drawn number is 0.36, then his points will be decreased to 32. Sellers are then ranked based on the number of points they have *after* the productivity shock. The seller with the highest number of points is assigned the lowest production cost; the seller with the second highest number of points is assigned the second lowest production cost, and so on.⁹

The productivity shock introduces a potential inequity in the market. Production costs allocated based on relative performance compensate the hardest working sellers by allocating them lower costs and hence a higher profit margin relative to other sellers. Therefore, in the absence of a productivity shock outcomes could be perceived as equitable by buyers despite the fact the sellers' surplus in equilibrium is about half that of the buyers who do not exert any effort (E\$10 for buyers vs. E\$5.50 for sellers). The productivity shock implies that the earnings of a seller will sometimes not be in proportion to his effort, and, thus the outcome will be inequitable.

Prior to making their purchases, buyers observe the sellers' production costs, the number of words each seller encrypted, their productivity shocks, the seller ranking before and after the shock, the posted prices, and the sequence in which each unit is sold.¹⁰

The VALUES treatment

In the VALUES treatment sellers' effort in the encryption task can increase the buyers' surplus. In particular, the default values of the five buyers are 5.50, 6.00, 6.30, 6.60, and 6.90. For every seller that encrypts 35 words the value of the third unit (i.e. 6.30) increases by 0.40, the value of the fourth unit (i.e. 6.60) increases by 0.80, and the value of the fifth unit (i.e. 6.90) increases by 1.20. Therefore, for every seller that meets the target of 35 words, buyers' values increase by

⁹ The random shock allows us to study how luck affects behavior. Erkal, Gangadharan and Nikiforakis (2009) examine the relationship between pro-social behavior and luck. They find that subjects who are negatively affected by a productivity shock are not more likely to receive a monetary transfer than other subjects, but receive a higher amount conditional on a transfer.

¹⁰ Sellers know the distribution of the buyers' values, but not the value assigned to each buyer. The same is true in the BASELINE and VALUES treatments.

E\$2.40 in total, and potential trading surplus and efficiency increases. Most importantly, if three or more sellers encrypt 35 words, then the demand schedule is the same as in the other two treatments, shown in Figure 1.¹¹ Sellers' effort raises only the inframarginal values, and therefore does not affect the equilibrium prices and quantity.

As in the BASELINE, the five values are randomly allocated across buyers in each period, while production costs are randomly allocated to sellers and remain fixed for sequences of 10 periods. This implies that all buyers benefit from the sellers' effort. It also implies that sellers are not compensated for their effort. Therefore, sellers have no incentive to encrypt words in this treatment, unless they expect buyers to pay supra-competitive prices to reward them. The equilibrium outcome can be particularly inequitable if some sellers encrypt 35 words but are assigned a high cost that prevents them from trading in equilibrium. On their purchase screens buyers are given information about the sellers' offer prices, the sellers' costs, and which sellers encrypted 35 words. We chose to provide feedback about the sellers' effort in this format to highlight the positive externality generated by sellers rather than their relative effort.

In total, 150 subjects participated in the experiment (50 in each treatment). We conducted 15 sessions in total, 5 in each treatment. Participants were students at the University of Melbourne and none of them had previously participated in a market experiment. Instructions were read out aloud by an experimenter while subjects followed along on their own hardcopy. The exchange rate between experimental and Australian dollars was E\$1=AU\$0.8. For their

¹¹ The effect of effort in this treatment resembles most closely that in Ruffle (1998) and Oxoby and Spraggon (2008). The target number of words was chosen in anticipation that in most cases at least 3 sellers would encrypt the required amount of words. We did not want to have a low target as this could make the sellers' effort appear trivial. Only the first three sellers who reached the 35-word target affected buyer values, and values were not increased further if a fourth or fifth seller also encrypted 35 words. This design choice was intended to promote some heterogeneity with regards to sellers' entitlements but still (in most cases) result in the highest value array that was used in the BASELINE and COSTS treatments.

participation, subjects received AU\$47.75 on an average.¹² This amount includes a show-up fee of AU\$5. Participants in the role of a buyer earned an average of AU\$55.54, while those allocated the role of a seller earned an average of AU\$39.96. The experiments lasted approximately 90 minutes on average and were conducted using z-Tree (Fischbacher, 2007).

4. Results

We begin by comparing aggregate market outcomes in the COSTS, VALUES and BASELINE treatments (Results 1-3) and then consider individual behavior (Results 4-6). We provide corresponding evidence for each result using non-parametric tests. Unless otherwise mentioned, non-parametric tests are two-tailed Mann-Whitney U tests. We also report results from multivariate regressions where appropriate.

Aggregate Market Performance

Result 1: *Neither transaction nor posted prices are significantly different in the COSTS and VALUES treatments, relative to the BASELINE treatment.*

Support: Figure 2 shows the time series of median transaction prices across treatments. Figures A1, A2 and A3 in the appendix present the median transaction prices for each individual session. Prices converged to the equilibrium (5.50-6.00) from above in all treatments and sessions. Non-parametric tests fail to reject the null hypothesis that median transaction prices are the same in the COSTS and VALUES treatments relative to the BASELINE, even when focusing on the early periods only. The Mann-Whitney p -values are all 0.245 or higher when considering period 1, periods 1-5, periods 1-10 or across all periods. Median *posted* prices are also not different across the two effort treatments relative to the BASELINE in these period intervals (all p -values

¹² At the time the experiment was conducted, 10 Australian dollars could be exchanged for about 9 U.S. dollars, and the minimum hourly wage was \$13.60.

exceed 0.34).

Result 2: *Transaction prices converge to the equilibrium range at a similar rate across treatments.*

Support: We define the convergence period as the first period in which average transaction prices are within the equilibrium range (5.50, 6.00) and essentially remain in this range with few later exceptions. Table 1 indicates the convergence period for the 5 sessions in each treatment. Though convergence tends to take longer in the VALUES treatment, the convergence periods are not significantly different when compared to the BASELINE for either treatment (p -value = 0.462 for the COSTS treatment; p -value = 0.599 for the VALUES treatment).

Result 3: *Trading efficiency is high and does not differ significantly in the two treatments relative to the BASELINE, except in early periods in the VALUES treatment.*

Support: Figure 3 displays the time series of trading efficiency in each of the treatments. Average efficiency (that is, the percentage of the total surplus extracted) is 94 percent in both the BASELINE and the COSTS treatments. In the VALUES treatment efficiency is lower (88 percent). Panel A of Table 1 reports the trading efficiency for each session in the experiment. A Mann-Whitney test fails to reject the null hypothesis that efficiency is the same in the BASELINE and the COSTS treatments in period 1 (p -value = 0.459), periods 1-5 (p -value = 0.754), periods 1-10 (p -value = 0.917) or across all periods (p -value = 0.346). In the VALUES treatment, overall efficiency is marginally lower relative to the BASELINE (p -value = 0.076). This is due in part to lower efficiency achieved in the initial periods when the sellers were not able to encrypt enough words in the first effort stage, which led to lower buyer values and less

exchange surplus in the early periods in 2 sessions.¹³ However, comparing efficiency in the periods after period 10 (Panel B of Table 2), no statistical difference exists between the BASELINE and the VALUES treatment (p -value = 0.402).

Individual Behavior

Result 4: *Buyers in the VALUES treatment tend to prefer purchasing from sellers who met the effort target. However this preference is short-lived.*

Support: There were 141 instances where two sellers posted the *same* price in the VALUES treatment. In 51 of these cases, only one of the sellers had met the target of 35 encrypted words. Buyers bought from the seller who met the target in 39 of these cases (76 percent). In addition, there were 42 transactions in this treatment in which buyers did *not* buy from the seller with the lowest price. In 24 of these cases, only one of the two sellers had reached the effort target. The seller making the sale was the one who met the threshold in 23 of these purchases (96 percent). It appears that at least some sellers had anticipated the buyers' preference towards 'hard-working' sellers in the VALUES treatment, since sellers encrypted 35 words even in the final effort stage (period 21), and sellers who met the target posted higher prices on average (p -value < 0.01).¹⁴

Table 3 presents individual-level, random-effects regressions to investigate how effort investments affect transaction prices. Column (1) shows that sellers who met the target sold at significantly higher prices during the first half of the experiment. This effect can be seen clearly in Figure A3 where prices spike up for a few periods after periods 1, 11 and 21. Sellers' attempts

¹³ In 13 of the 15 encrypting blocks for the 5 VALUES sessions, at least 3 of the 5 sellers encrypted 35 words. In the remaining two encrypting blocks (both during the first effort stage) less than 3 sellers reached the target and the demand curve was lower. To achieve 100 percent efficiency at least 3 sellers must encrypt 35 words to raise the demand curve to its highest level, which is the fixed level used in the other two treatments.

¹⁴ The p -value is from an unreported random-effects regression that controls for sellers' costs, time trends and session random effects. In another unreported random-effects probit regression, however, we find that meeting the threshold had no impact on the probability of sellers' trading.

to charge higher prices were short-lived, however, and prices converged to equilibrium in all sessions of this treatment. As a result sellers who met the effort target were unable to trade at significantly higher transaction prices when all periods are considered (column 2). Therefore, while our design seems to trigger equity concerns for both buyers and sellers, the competitive forces in the market eliminate their longer-term impact on outcomes.

Result 5: *Sellers who are negatively affected by the random productivity shock in the COSTS treatment are not compensated by buyers through higher transaction prices.*

Support: The productivity shock in the COSTS treatment implies that sometimes sellers would be ‘unlucky’ and be assigned higher production costs than they would receive if there was no productivity shock. Columns (3) and (4) of Table 3 show that in this treatment, unlucky sellers are not compensated by higher transaction prices in the market.¹⁵ This means that if effort investments trigger equity concerns in the COSTS treatment, they are not strong enough to overcome the competitive pressures of the market.

Result 6: *All else equal, in all treatments buyers prefer buying from sellers with higher costs.*

Support: Overall, there were 1625 transactions in the experiment. Table 4 shows that in 314 transactions (19 percent of the total) a buyer made a purchase when two or more sellers were tied for the lowest price. In 231 of these cases (74 percent) buyers chose to buy from the higher-cost seller. The fact that these rates are similar in all three treatments might seem surprising since low-cost sellers in the COSTS treatment are those exerting the most effort. In addition, of the 1311 transactions in which sellers were not tied for the lowest price, the right side of Table 4 shows that buyers purchase from a seller who did *not* post the lowest price 118 times. That is, in

¹⁵ Results from an unreported random-effects regression reveal that *posted* prices in the COSTS treatment are also not affected by the good or bad luck (productivity shock) experienced by individual sellers. Similarly, from unreported random-effects probit regressions, we find that luck has no impact on the probability of sellers’ trading.

9 percent of these transactions buyers choose to reduce their own earnings in order to buy from a higher-priced seller. In 104 of these 118 higher-price purchases (88 percent) buyers buy from a higher-cost seller. Combining these 104 purchases with the 231 instances in which buyers select a higher-cost seller when prices are equal, in 21 percent of all transactions ($231 + 104 = 335$ out of 1625) buyers exhibit a preference for purchasing from higher-cost sellers.

5. Discussion

The equity principle states that individuals should be rewarded according to their efforts. Experiments in bilateral bargaining show that equity concerns arising from investments in effort can affect outcomes. We conducted a laboratory experiment investigating whether similar investments in effort might influence the operation of competitive posted-offer markets due to concerns for equity or other types of interdependent preferences.

We find that when the benefits of sellers' effort are entirely captured by buyers through increased product values, hard-working sellers ask for higher prices which buyers are willing to accept. However, competition amongst sellers lowers prices over time. As a result, investments in effort do not have a lasting impact on market outcomes. These findings, therefore, indicate that concerns about equity are short lived, similar to concerns about equality (e.g. Franciosi et al., 1995). Competitive price theory remains a good predictor of behavior.

When the benefits of the sellers' effort are captured by sellers through reduced production costs, we find that buyers do not show a preference for hard-working sellers, and also that hard-working sellers do not expect to be able to charge higher prices. This is interesting given that sellers' surplus in equilibrium is substantially smaller than buyers' surplus. In addition, sellers who experience a negative productivity shock and are thus assigned a relatively

higher production cost are not compensated by the buyers through higher prices.

Finally, in over 20 percent of all transactions buyers expressed a preference to buy from higher-cost sellers. In some cases they expressed this preference even when this required them to pay a higher price. Buyers' preference for high-cost sellers may have created additional incentives for low-cost sellers to lower prices, promoting faster convergence to equilibrium.

One must always exercise caution when generalizing from the controlled environment of the laboratory to naturally occurring markets. An interesting question to ask in future work is whether investments made by sellers in environment-friendly technologies, organic products, or other types of investments intended to increase buyer values would also have a short-lived impact on market outcomes. In some instances, unlike in our experiment, buyers may also value the non-monetary and the long-run benefits of these investments. Future research could address ways of capturing these kinds of valuations in an experiment and examine if they can affect the performance of competitive markets.

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Tables:

Table 1: Convergence Period of Median Transaction Prices (sessions ordered lowest to highest)

	Individual Sessions				
BASELINE Treatment	8	9	10	11	28
COSTS Treatment	1	6	9	11	15
VALUES Treatment	7	10	16	25	28

Table 2: Market Efficiency

Panel A: Overall Market Efficiency, in Percent (sessions ordered lowest to highest), Periods 1-30

	Individual Sessions				
BASELINE Treatment	90.2	94.0	95.3	95.4	95.4
COSTS Treatment	93.1	93.5	94.7	94.7	94.9
VALUES Treatment	79.1	83.7	86.0	94.2	94.9

Panel B: Overall Market Efficiency, in Percent (sessions ordered lowest to highest), Periods 11-30 Only

	Individual Sessions				
BASELINE Treatment	90.9	95.2	95.4	97.8	100.0
COSTS Treatment	94.8	95.1	95.3	96.9	97.3
VALUES Treatment	86.0	90.9	95.2	96.6	96.9

Table 3: Transaction Price Random Effects Regressions

Variables	VALUES Treatment		COSTS Treatment	
	Periods 1-15 (1)	Periods 1-30 (2)	Periods 1-15 (3)	Periods 1-30 (4)
Target Met	0.359*** (0.101)	-0.001 (0.053)		
Productivity Shock			0.091 (0.097)	0.068 (0.051)
Cost	0.116** (0.053)	0.048** (0.022)	0.172*** (0.050)	0.171*** (0.025)
1/Period	0.615*** (0.104)	0.930*** (0.086)	0.594*** (0.108)	0.858*** (0.075)
Constant	5.576*** (0.270)	5.878*** (0.122)	5.219*** (0.250)	5.071*** (0.130)
Observations	237	526	245	559
Number of Sellers	25	25	25	25

Standard errors in parentheses; Random effects are at the individual level; “Target Met” takes the value of 1 if a seller encrypted 35 words and 0 otherwise; “Productivity Shock” takes the value of 1 if a seller was assigned a higher production cost than that prescribed by his relative effort and 0 otherwise; *** p<0.01, ** p<0.05, * p<0.1

Table 4: Buyer Purchases from Lower- and Higher-Cost Sellers

	No. of Transactions	Transactions with Tied Prices			Transactions with Unique Minimum Available		
		Total	Buy from Higher Cost	Buy From Lower Cost	Purchase At Minimum	Purchase Buy from Lower Cost	Non-Minimum Buy from Higher Cost
BASE-LINE	540	105	81 (77%)	24 (23%)	410	3 (12%)	22 (88%)
COSTS Treat.	559	68	51 (75%)	17 (25%)	440	2 (4%)	49 (96%)
VALUES Treat.	526	141	99 (70%)	42 (30%)	343	9 (21%)	33 (79%)
Totals	1625	314	231 (74%)	83 (26%)	1193	14 (12%)	104 (88%)

Figures:

Figure 1 - Stationary Aggregate Supply & Demand Used in All Sessions

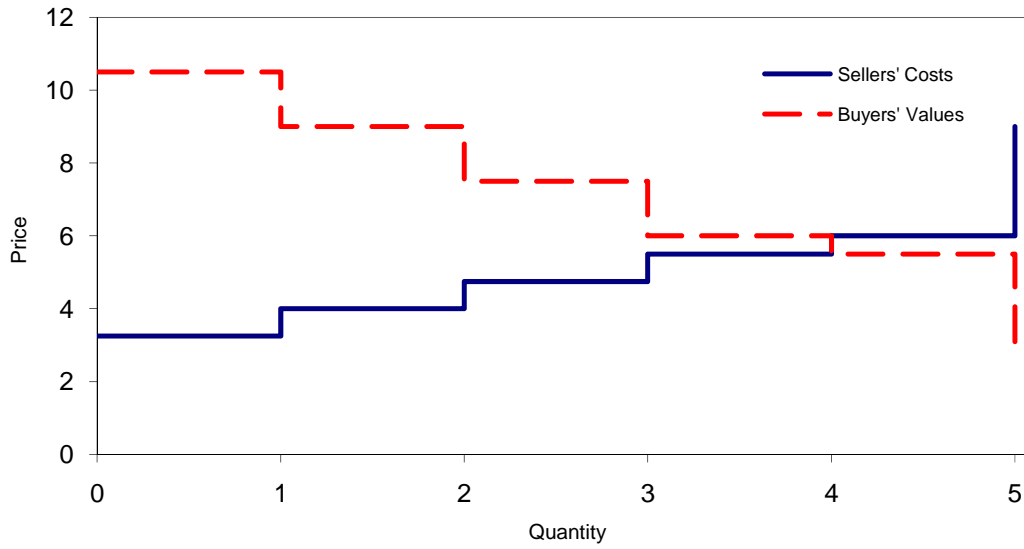


Figure 2 – Median Transaction Prices

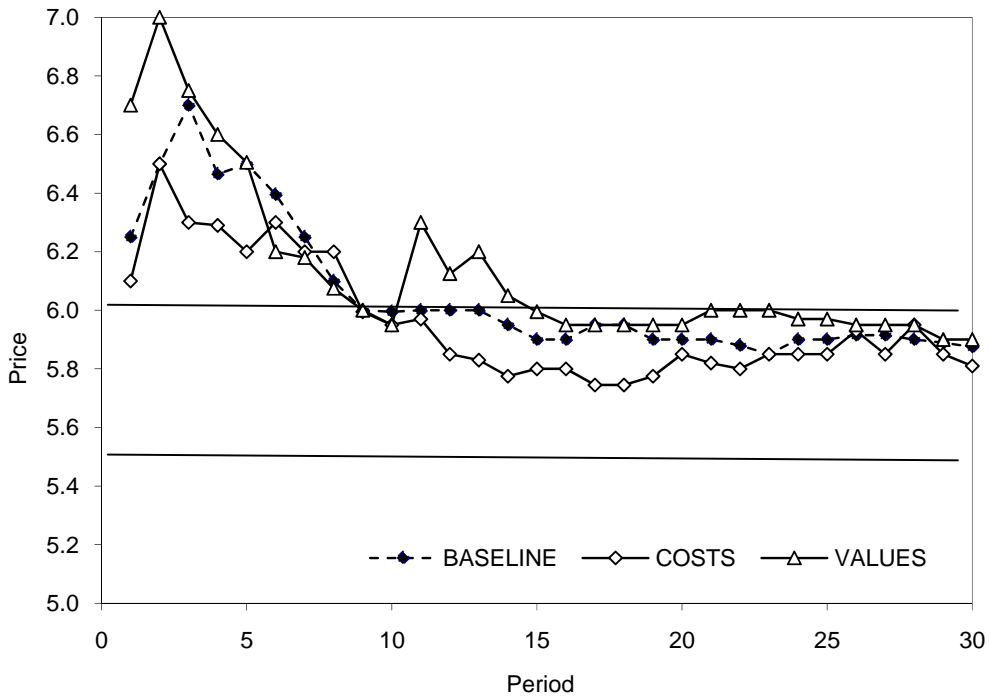
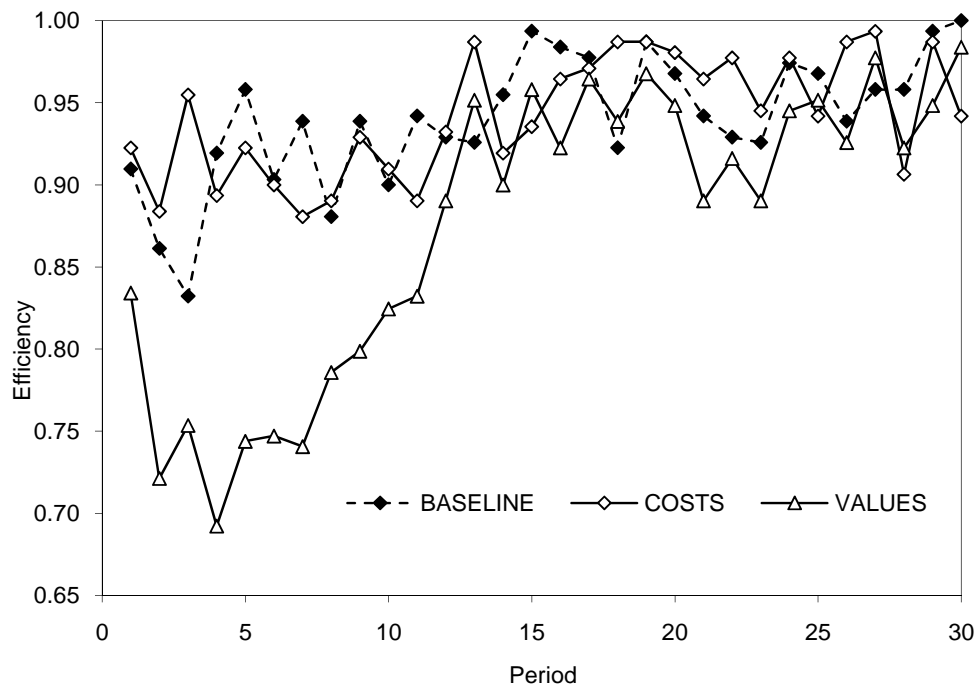


Figure 3 – Trading Efficiency



APPENDIX

Figure A1 – Median Transaction Prices by Group in the BASELINE treatment

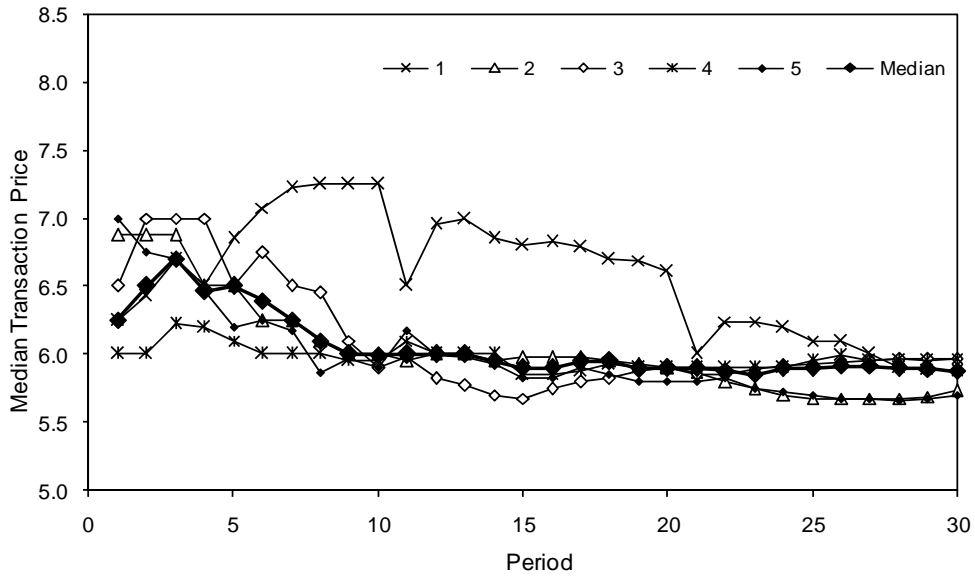


Figure A2 – Median Transaction Prices by Group in the COSTS Treatment

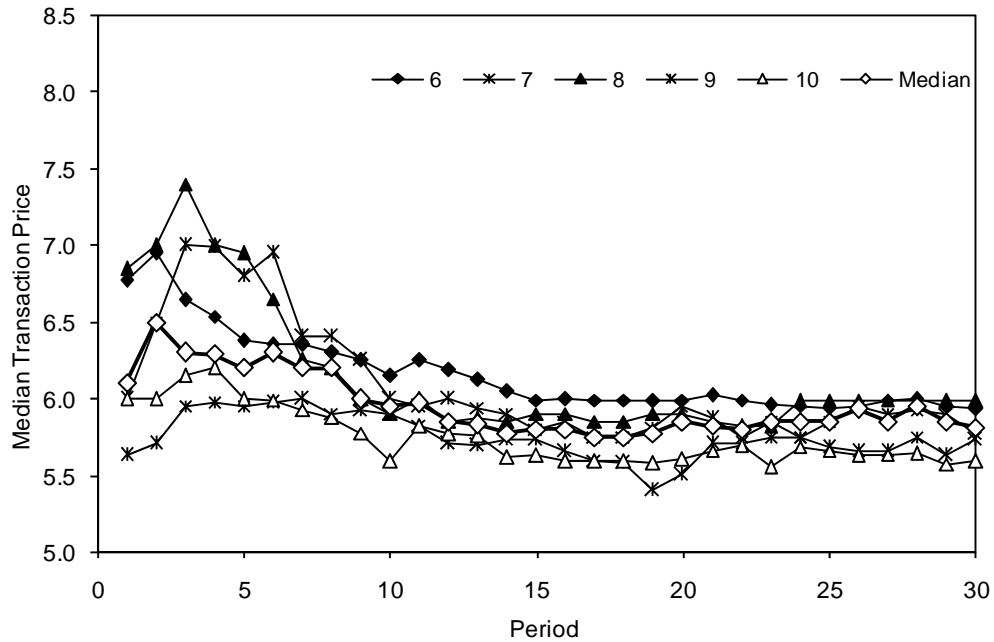
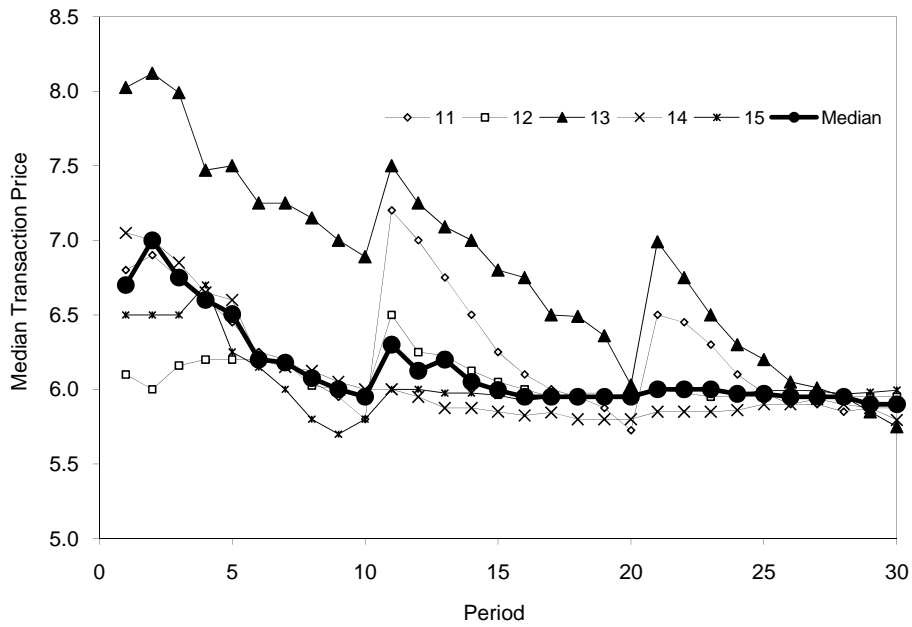


Figure A3 -- Median Transaction Prices by Group in the VALUES Treatment



Appendix (For referees' consideration; not intended for publication)

Instructions

These are the instructions for VALUES treatment. Instructions for the BASELINE and COSTS are available from the authors upon request.

Thank you for agreeing to take part in this study. Please read the following instructions carefully. A clear understanding of the instructions will help you make better decisions and increase your earnings.

The instructions which we have distributed to you are for your private information. Please do not communicate with the other participants during the experiment. Should you have any questions please ask us.

During the experiment we shall not speak of Dollars, but of Experimental Currency Units (ECU). Your entire earnings will be calculated in ECUs. At the end of the experiment the total amount of ECUs you have earned will be converted to Australian Dollars at the rate of **1 ECU = 0.8 Australian Dollars** and will be immediately paid to you in cash. In addition, at the beginning of the experiment we will give every participant 5 Australian Dollars.

At the beginning of the experiment participants will be randomly placed in different markets. Each market consists of 5 buyers and 5 sellers. At the same time you will be randomly allocated to the role of a buyer or a seller. You will remain in the same market and retain your role for the whole experiment. This means that you will always interact with the same group of people. The experiment lasts 30 periods and each period is divided into a number of stages.

Brief description

In this section we offer an overview of the experiment. In the next section you will receive a detailed description about the experiment.

(i) Trading

There are 5 buyers and 5 sellers in each market who trade a fictitious good. Each seller can sell at most one unit in every period and each buyer can buy at most one unit per period. At the beginning of each trading period the sellers post the price at which they wish to sell their unit. Once all sellers make their decisions the prices will be published for all to see. Then, each buyer can accept any offer available. Buyers can choose from the offers in a sequence that is randomly determined by the computer.

(ii) Earnings

Buyers and sellers can only earn income by trading. Those who do not trade have zero earnings for that trading period. A higher sales price leads to higher earnings for a seller. A lower sales price leads to higher earnings for a buyer.

In particular, a buyer earns the difference between his value of the good and the trade price. A buyer's value will be *randomly* selected in each period from a set of values. The buyers' set of values can change as a result of effort exerted by sellers in a task. Details about this task are given in the following section. While the set of values for the buyers will be known, the value of a buyer in a given period will only be revealed to that buyer and not to the other buyers or sellers.

A seller earns the difference between the trade price and her cost of production. A seller's cost will be randomly determined but will remain constant for each set of 10 periods.

At the end of the period all buyers and sellers will be informed about the trading prices. In addition, each participant will learn how much he or she has earned in that period and in the experiment up to that point.

Note: Once the experiment starts and the computer determines your role as buyer or seller you will be given a record sheet. You must use the record sheet in every period to keep track of your earnings.

Detailed Instructions for Sellers

(i) Determination of production costs

The production costs are determined randomly by the computer in periods 1, 11, and 21. **The possible costs are 3.25 ECU, 4.00 ECU, 4.75 ECU, 5.50 ECU, and 6.00 ECU.** Each of the five sellers will be assigned one of these production costs (see Figure 1 below) and will retain this cost for the next 10 trading periods. That is, if you are assigned a cost of 4.00 ECU in period 1, then you will have a cost of 4.00 ECU for periods 1-10. In period 11 you will be assigned a new cost which will remain the same for periods 11-20.

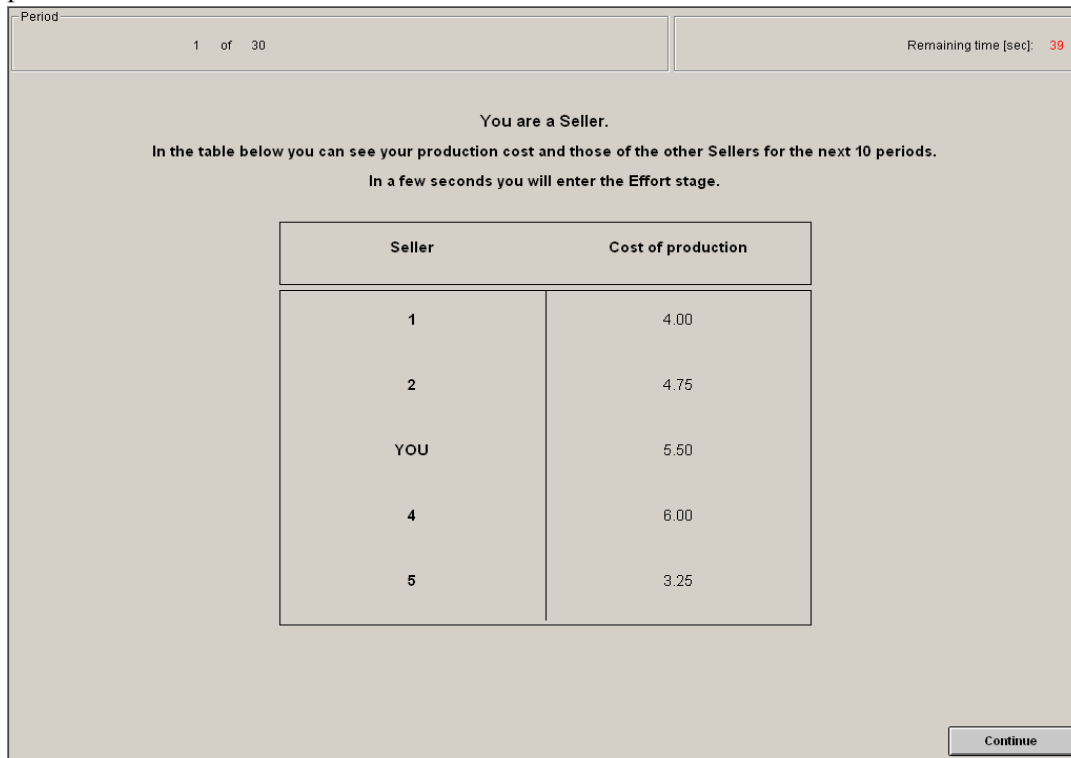


Figure 1

(ii) The Effort Stage

After sellers are informed about their production costs, they will be given a task. The sellers' performance in the task will determine the buyers' set of values for the next 10 trading periods. Buyers do not participate in the Effort Stage.

The task in the Effort Stage is the same for all sellers. Sellers will be presented with a number of words

and their task is to code these words by substituting the letters of the alphabet with numbers using Table 3 on page 9. The Effort Stage decision screen is seen in Figure 2.

Example: You are given the word FLAT. The letters in Table 3 show that F=6, L=3, A=8, and T=19.

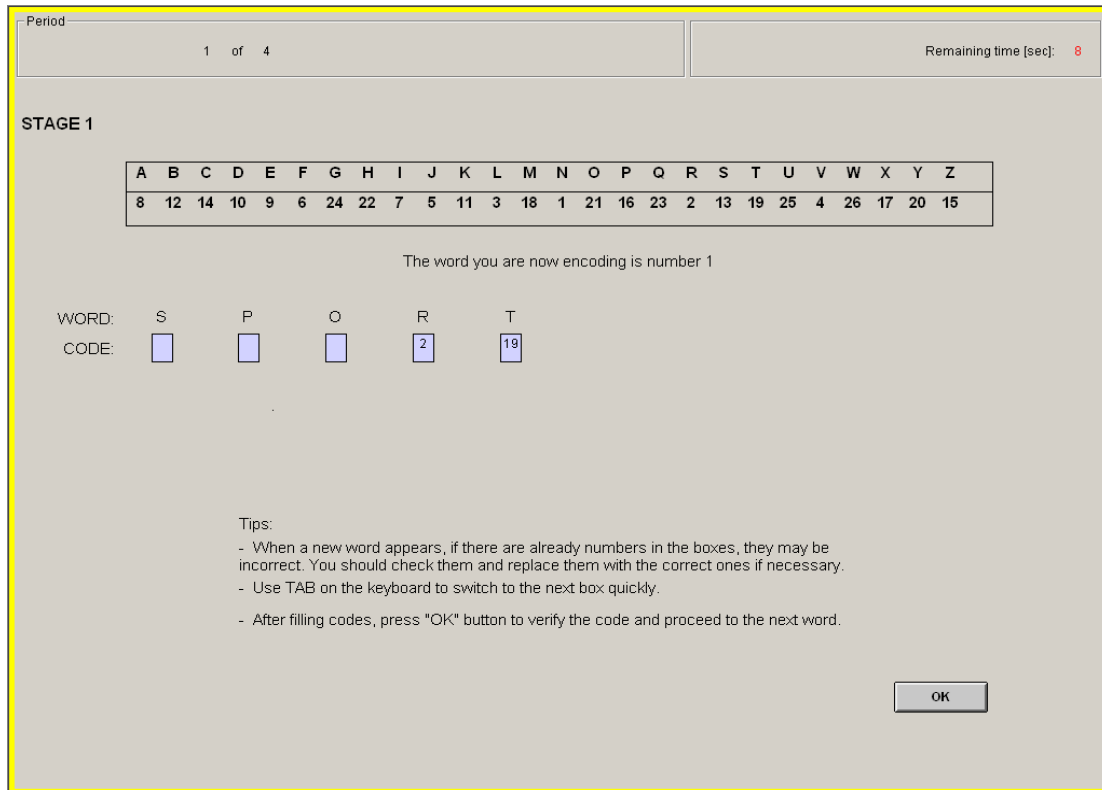


Figure 2

Once you code a word correctly, the computer will prompt you with another word to encode. Once you encode that word, you will be given another word and so on. **This process will continue for 7 minutes** (420 seconds). All group members will be given the same words to encode in the same sequence.

For every seller who encodes 35 words buyers' values will increase by 2.40 ECU in total as shown in Table 1.

Unit	1	2	3	4	5	Total change in buyers' values
Default Values	5.50	6.00	6.30	6.60	6.90	-
If <u>one</u> seller encodes 35 words	5.50	6.00	6.70	7.40	8.10	2.40
If <u>two</u> sellers encode 35 words	5.50	6.00	7.10	8.20	9.30	4.80
If <u>three or more</u> sellers encode 35 words	5.50	6.00	7.50	9.00	10.50	7.20

Table 1

At the end of the Effort Stage sellers will be informed whether each seller encoded 35 words or not, and reminded of their cost of production with a screen as in Figure 3. (Note that all the numbers included in the screen shots, except values and costs, were created randomly and should not be taken as indication of what one should do in the experiment.)

Period		1 of 30		Remaining time [sec]: 18	
Results from Effort Stage:					
Seller		Cost of production		35 words encoded?	
YOU		5.50		Yes	
2		6.00		Yes	
3		4.00		Yes	
4		3.25		No	
5		4.75		No	

Figure 3

The Effort Stage is not entered in every trading period, but only at the beginning of periods 1, 11, and 21. The effort exerted by sellers in period 1 determines the buyers’ set of values for periods 1 to 10. The effort exerted in period 11 determines the buyers’ set of values for periods 11 to 20. Finally, the effort exerted in period 21 determines the buyers’ values for periods 21 to 30.

(iii) Posting Prices

Once each seller learns his cost of production he will have to choose one price to post for his unit. In order to do so, sellers will have to fill in a price on the screen seen in Figure 4 and then click “Make an offer”. The price might include up to two decimal points and must exceed the cost of production.

Period	1 of 30	Remaining time [sec]: 10
<p>You are a seller</p> <p>Your ID is: 1</p> <p>You encoded 35 words.</p> <p>Your cost of production is: 5.50</p> <p>Please make your price offer <input type="text"/></p> <p style="text-align: right;">Make an offer</p>		
<p>Help Please make your price offer and click on "Make an offer".</p>		

Figure 4

To be able to distinguish your offer from that of other sellers, in periods 1, 11, and 21 you will be randomly assigned a Seller ID. This ID is independent of your production cost and will remain the same for the next 10 periods.

After all sellers have made a decision buyers and sellers will be informed about the prices asked, the seller's cost of production, whether a seller encoded 35 words and the seller's ID. The offers will, however, remain anonymous. That means that it will not be possible to tell which seller posted which price. Remember that sellers who encoded 35 words contributed to an increase in buyers' values. The feedback screen is shown in Figure 5. Notice that, in the far right column, buyers and sellers can follow the progress as buyers make their decisions in sequence. If one unit is sold, the status will change from 'Available' to 'Sold Out'.

The following table displays all available information about sellers and the offers they have made. Please wait while buyers make their choices in a sequence.

Seller ID	Seller's cost of production	Price asked	35 words encoded?*	Status of item offered
1	4.75	6.25	Yes	Available
3	5.50	9.00	No	Available
4	3.25	6.23	Yes	Available
5	4.00	6.70	Yes	Available
2	6.00	12.50	No	Available

* A seller that encoded 35 words contributed to an increase in buyers' values.

Figure 5

A seller's profit from the sale of a unit equals the difference between price and production costs. Hence, a seller earns more if she can sell at a higher price. Note that **losses** are possible. Losses can occur if a unit is sold for a price below the production cost. Sellers can, however, always avoid losses by offering a price that is not below their production cost.

Detailed Instructions for Buyers

After all sellers announce the offer prices, the buyers decide whether they wish to purchase one unit, and the seller from which they wish to purchase this unit. The sequence in which they purchase will be randomly determined by the computer in each period. That is, the computer will randomly choose between the five buyers for who will "shop" the first, second, third etc.

The buyers units have a "buyer's value" which is *randomly* determined by the computer *in each* period. **Each unit will have a different value. There are five possible default values. These are: 6.90, 6.60, 6.30, 6.00 and 5.50. However the set of values can change depending on how many sellers encode 35 words.** The table below shows how the buyers' set of values will change with sellers' effort.

Unit	1	2	3	4	5	Total change in buyers' values
Default Values	5.50	6.00	6.30	6.60	6.90	-
If <u>one</u> seller encodes 35 words	5.50	6.00	6.70	7.40	8.10	2.40
If <u>two</u> sellers encode 35 words	5.50	6.00	7.10	8.20	9.30	4.80
If <u>three or more</u> sellers encode 35 words	5.50	6.00	7.50	9.00	10.50	7.20

Table 2

As Table 2 shows if one seller encodes 35 words, the values of units 3, 4 and 5 will increase. If two sellers encode 35 words, the values of units 3, 4 and 5 will increase further. Finally, if three or more sellers encode 35 words, the set of values will be 5.50, 6.00, 7.50, 9.00 and 10.50. This implies that the total change in buyers' values will be 7.20 (=2.40+2.40+2.40). Sellers have 7 minutes to encode 35 words.

Each buyer will be informed about his default value and his actual value for the good. To purchase a particular unit, the buyer whose turn it is to buy will have to select the unit he wishes to buy from the list of available prices using the computer mouse and click 'accept'. If a buyer has already bought a particular unit the status of the unit will change from 'Available' to 'Sold out'. An example screen is shown in Figure 6. Buyers can see which seller has encoded 35 words and the sellers' production cost. If the buyer wishes to make no purchase from any seller this period he must click 'Reject'.

Period: 1 of 30 Remaining time [sec]: 0

You are a buyer.

You are the first one to buy.

Your default value was: 6.90
Your value in this period is: 10.50

Seller ID	Seller's cost of production	Price asked	35 words encoded?*	Status of item offered
1	4.75	6.25	Yes	Available
3	5.50	9.00	No	Available
4	3.25	6.23	Yes	Available
5	4.00	6.70	Yes	Available
2	6.00	12.50	No	Available

Accept Reject

* A seller that encoded 35 words contributed to an increase in buyers' values.

Figure 6

A buyer's profit at the end of the period equals the value of the unit for that buyer minus the price paid. Hence, a buyer earns more if she can buy at a lower price. Note that **losses** are possible. Losses can occur if a unit is bought for a price higher than the unit's value. Buyers can, however, always avoid losses by not paying a price that exceeds their unit's value.

Control Questions

Please answer the following questions. If you have any questions or have answered all the questions, please raise your hand and one of the experimenters will come to you.

1. Who participates in the Effort Stage? (Tick the correct answer)

- only sellers only buyers both buyers and sellers

2. What does the Effort Stage determine? (Tick the correct answer)

- buyers' values seller's costs both buyers' values and sellers' costs

3. When will the Effort stage be entered? (Tick the correct answer)

- only in period 1 in every period only in periods 1, 11, and 21

4. Assume the buyer has a value of 500 ECU and the seller a cost of 250 ECU (all numbers are unrealistic on purpose). What will the profit of the seller and the buyer be if they trade at a price of 300 ECU?

- i. The buyer's profit
 ii. The seller's profit

5. Which is the correct set of values for the buyers, assuming 3 or more sellers encode 35 words? (Tick the correct answer)

- i. 5.50, 6.50, 7.50, 9.50, and 11.50
 ii. 5.50, 6.00, 7.50, 9.00, and 10.50
 iii. 2.00, 3.00, 4.00, 5.00, and 8.00
 iv. 2, 3, 4, 5, and 5

6. Which statement from (i) and (ii) is the correct one? (Tick the correct answer)

- i. A buyer's value will be the same in each period and is determined by the buyer's effort

 ii. A buyer's value might be different in each period and is determined by sellers' effort in the effort stage.

Table 3

Letters	Numbers
A	8
B	12
C	14
D	10
E	9
F	6
G	24
H	22
I	7
J	5
K	11
L	3
M	18
N	1
O	21
P	16
Q	23
R	2
S	13
T	19
U	25
V	4
W	26
X	17
Y	20
Z	15