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

Timothy N. Cason, Lata Gangadharan and Nikos Nikiforakis

Abstract
This paper investigates whether investments in effort that affect the allocation of production costs but not market supply can inhibit equilibrium convergence of experimental markets. In the main treatment, sellers participate in a real-effort game. Their relative performance in the game and a random productivity shock determine their production costs. Despite using a design that increases the likelihood that effort investments trigger concerns about fairness, we find that prices converge to equilibrium predictions at rates similar to those in a treatment where production costs are randomly allocated. Efficiency rates are high and do not differ across treatments. Interestingly, buyers exhibit a preference for buying from sellers that have higher costs.

Keywords: Property Rights; Real Effort; Posted Offer Markets; Random Shock; Investment
JEL Classification: C90, D4, L10.

* Funding from an Early Career Research Grant and a Faculty of Economics and Commerce Research Grant, University of Melbourne helped us conduct this experiment. Part of this research was conducted while Cason was a visiting fellow with the Department of Economics, University of Melbourne. Doug Davis, Nikos Georgantzis, Charlie Plott, Bradley Ruffle, Bart Wilson, and seminar participants at Monash University provided helpful comments. We are responsible for any errors, of course. Experimental instructions as well as the software code are available at http://www.economics.unimelb.edu.au/nnikiforakis/research.htm.

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1. Introduction

One of the most prominent results from the last forty years of laboratory economics research is that subjects in market experiments trade at prices that are remarkably close to competitive market predictions (Plott, 1989; Smith 1982). 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).

This paper reports results from a laboratory experiment that investigates whether investments in real effort that affect the allocation of production costs amongst sellers but not the aggregate supply, can affect the performance of competitive markets. We examine behavior in two treatments. In the ‘Random Cost’ treatment production costs are randomly assigned to sellers. In the ‘Earned Cost’ treatment sellers participate in a real-effort tournament.1 Sellers’ production costs depend on their relative performance in the tournament and a random productivity shock. The effort exerted by the sellers and the impact of the productivity shock is public information.

Competitive price theory maintains that factors which do not affect demand or supply will not have an impact on market outcomes. This implies that the opportunity to invest in effort in our experiment should not alter trading behavior since market supply is the same across treatments. However, a number of laboratory experiments (reviewed in the next section) have provided evidence that investments in real effort can affect economic outcomes

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1 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 (e.g. Fehr et al. 1993). In the latter case, subjects’ ‘effort’ is exogenously determined and captured by a (usually convex) strictly increasing cost function. To avoid repetition, in this paper we use the terms ‘effort’ and ‘real effort’ interchangeably.
even when this is not predicted by theory. These findings suggest that not only do investments in effort raise the demands of the parties making the investments, but also that subjects recognize that effort exerted by one party creates ‘property rights’ over the division of the generated surplus. Therefore, the random allocation of costs in laboratory markets might yield different results compared to situations where sellers determine their own production costs. It is quite plausible, for example, that buyers believe sellers are entitled to a higher profit margin due to the costly effort they exerted. Such beliefs may have a persistent effect on market outcomes. In this case, sellers have an additional incentive to invest in effort to enable them to demand a higher share of the surplus.

The hope that investments in effort can create property rights might partly explain why firms operating in competitive markets make costly investments that are likely to be viewed favorably by consumers. Examples of such investments include the voluntary adoption of environmentally friendly technologies, ISO management standards, or fair-trade standards. 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.

As mentioned above, factors that appear to trigger concerns about fairness and affect bilateral bargaining, such as public information about individual payoffs and extreme earnings inequities, have been shown to have less impact on the operation of laboratory markets. For this reason, we designed this experiment to give fairness considerations arising from real-effort investments their best chance at affecting market outcomes. First, we use the
posted-offer trading institution. Sellers post a single “take-it-or-leave-it” price, while buyers must decide whether to accept or reject offers without being able to negotiate. Previous experiments have shown that the posted-offer institution favours the side that is posting prices (e.g. Plott and Smith, 1978); in our case, the sellers. Furthermore, 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 trigger concerns about fairness. Third, in the Earned Cost treatment a random shock in sellers’ productivity affects the allocation of production costs. In particular, each seller’s real-effort output could be reduced by up to 50 percent. In the absence of such shocks, low production costs compensate (at least partly) hard working sellers for their effort by giving them a higher profit margin relative to their peers. However, the shock in productivity implies that sellers might not be ‘fairly’ compensated for their effort, which could provide a more legitimate claim to a disproportionate share of the exchange surplus. Finally, information about buyers’ values, sellers’ costs, effort (when applicable), and productivity shocks is made public. Francosi et al. (1995) show that when information regarding sellers’ costs and buyers’ values is common knowledge, convergence to equilibrium takes longer. The public nature of information could have highlighted the asymmetric distribution of the surplus between buyers and sellers and amplified any concerns about fairness (Borck, Engelmann, Müller and Normann, 2002) and the way in which sellers are compensated for their effort.

Despite the use of an experimental design that increases the likelihood that investments in effort will influence market outcomes, we find that transaction and posted
prices are not different across the Earned Cost and Random Cost treatments. 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. Although real effort investments might make sellers feel as if they are entitled to a higher profit than the one they make in equilibrium, our results indicate that the competitive pressure of the market eliminates their ability to capitalize on those entitlements.

The buyers exhibit some interesting behavioral patterns. For example, when two sellers post the same price, a large majority of buyers buy from the high-cost seller. Surprisingly, this is the case in both treatments. Earlier market experiments could not identify a preference for high-cost sellers because costs were usually private information. We also find that some buyers choose to purchase from sellers who do not post the lowest available price, if the seller with the lowest price has a lower cost and would therefore earn a higher profit. These “spiteful” revealed preferences to reject lower-cost sellers in favour of higher-cost sellers can reduce market efficiency and sellers’ gains from exchange. Taken together, these observations provide additional evidence that as far as buyers are concerned, greater investments in effort by sellers do not create property rights.

2. Previous Studies with Real-Effort Investments

Our paper is the first to study the impact of real-effort investments in experimental markets. A number of previous studies have investigated the impact of such investments on behavior in bilateral exchanges. The consensus seems to be that investments in effort trigger fairness 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 and Spitzer (1985) and Hoffman, McCabe, Shachat and Smith (1994) find that individuals who earn their right to be in control of the division of the surplus based on their
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) and Parrett (2006). 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 with the same $10 surplus generated by a random draw. Allocators also punish those who perform poorly by giving them less than allocators give to receivers with randomly-determined $4 surpluses. 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, 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) report that proposers in a dictator game who invest in effort that determines the surplus are extremely unlikely to share it with recipients.

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2 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 discussed next is similar to the Ultimatum Game. The only difference is that the responder cannot reject the proposer’s offer which is always implemented.
Finally, effort investments have also 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 be allowed participation, and Garcia-Gallego, Georgantzis and Jaramillo-Gutiérrez (2008) in which subjects have to fill 20 envelopes with a single-page letter if an offer is accepted. Fahr and Irlenbusch (2000) find that second movers in a trust game send back more money when first movers invest in effort.³ Garcia-Gallego, Georgantzis and Jaramillo-Gutiérrez (2008) find that when responders in a multi-round ultimatum game are the ones exerting effort, proposers (who are randomly matched in every period with a new responder) make more generous offers. Despite the higher offers, rejection rates increase.

In summary, these studies show that not only do effort investments raise demands of investors in bilateral exchange, but also that the demands are acknowledged by other parties who sometimes voluntarily compensate them as in the case of Fahr and Irlenbusch (2000) and Ruffle (1998). 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 two treatments. In both 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 the equilibrium quantity traded is 4 units.⁴ Trading follows standard posted-offer rules. Once sellers are informed about their own cost, each chooses independently a price for her good. Buyers observe all prices and shop in sequence following an order which varies

³ 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. For a detailed discussion of the dictator, ultimatum and trust game see Camerer and Fehr (2004).
⁴ Prices consistent with a Nash equilibrium are in a more narrow interval [5.99, 6.00].
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 two treatments differ with respect to how sellers’ production costs are allocated. In the baseline treatment (Random Cost), similar to previous market experiments, costs are randomly allocated to sellers. In order to parallel the Earned Cost treatment, these costs are randomly reallocated every 10 trading periods. In the Earned Cost treatment, production costs are allocated based on the sellers’ relative performance in the Encryption Task (Erkal, Gangadharan and Nikiforakis, 2009). The Encryption Task is a real-effort task, which 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’ which can be seen in Figure 2. All sellers are presented with the same words in the same sequence.

For each word a seller encrypts correctly in the Earned Cost treatments she receives a point. After seven minutes the total number of points is calculated for each seller and is used to determine the sellers’ ranking. Their ranking, however, does not depend only on relative performance, but also on a random productivity shock. In particular, at the end of the effort task, a number is randomly drawn 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 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. 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.
As discussed in the introduction, the productivity shock is included to increase the legitimacy of certain sellers’ perceived entitlements to higher prices and a larger share of the exchange surplus. In a competitive market the lower production cost compensates the hardest working sellers by giving them a higher profit margin relative to their peers. Therefore, subjects might think that the market outcome is ‘fair’ despite the fact that the sellers’ aggregate exchange surplus is about half that of the buyers who do not exert any effort (E$10 for buyers vs. E$5.50 for sellers). The highest-performing seller is often not rewarded with the lowest production cost due to the productivity shock, however, and subjects might perceive this as unfair and permit this seller to trade at a price higher than the market clearing price. This in turn could cause prices to deviate persistently from equilibrium.5

Prior to making their purchases, buyers in the Earned Cost treatment 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.6 Figure 3 displays the purchasing screen seen by buyers.

In total, 100 subjects participated in the experiment (50 in each treatment). We conducted 10 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, shown in the appendix for the Earned Cost treatment, were read orally 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 participation, subjects received AU$41.30 on an average. 7 This amount includes a show-up fee of AU$5. Participants in the role of a buyer earned an average of AU$48.70, while those

5 The random shock raises the issue of luck and how it affects behavior. Erkal, Gangadharan and Nikiforakis (2009) examine the relationship between pro-social behavior and luck. They find that subjects who experience bad luck are not more likely to receive a monetary transfer than other subjects all else equal.
6 Sellers know the distribution of buyers’ values, but not the value of the buyer who bought their unit. The same is true in the Random Cost treatment.
7 At the time the experiment was conducted, 10 Australian dollars could be exchanged for about 9 U.S. dollars.
allocated the role of a seller earned an average of AU$33.90. 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 Random Cost and Earned Cost treatments and then consider individual behavior. Our findings are summarised in Results 1-4. We provide corresponding evidence for each result using non-parametric tests. Unless otherwise mentioned, non-parametric tests are two-tailed Mann-Whitney U tests.

Result 1: Neither transaction nor posted prices are significantly different across treatments.

Support: Figure 4 shows the time series of median transaction prices across treatments. Figures A1 and A2 in the appendix present the median transaction prices for each individual session. Prices converge to the equilibrium from above in both treatments. Non-parametric tests fail to reject the null hypothesis that median transaction prices are the same in the two treatments in period 1 (p-value = 0.245), periods 1-5 (p-value = 0.754), periods 1-10 (p-value = 0.602) or across all periods (p-value = 0.751) using each session as an independent observation. Posted prices are also not different across treatments in period 1 (p-value = 0.745), periods 1-5 (p-value = 0.917), periods 1-10 (p-value = 0.602) or across all periods (p-value = 0.602).8

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

8 We also estimated generalised least squares models with random effects at the individual level to examine whether sellers who experience a negative shock in productivity (i.e. their rank is worse than it would have been if sellers were ranked based only on their effort) post different prices than sellers who experience positive shocks controlling for sellers’ costs and time trends. We find that the shocks do not have a significant impact on posted prices.
prices are within the equilibrium range (5.50, 6.00) and essentially remain in this range with few later exceptions. Panel A of Table 1 indicates the convergence period for the 5 sessions in each treatment. These convergence periods are not significantly different across treatments ($p$-value = 0.736).

**Result 3:** Trading efficiency is high and does not differ significantly across treatments.

**Support:** Figure 5 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 treatments. Panel B of Table 1 shows that efficiency exceeded 90 percent in every session. A Mann-Whitney test fails to reject the null hypothesis that efficiency is the same in the two treatments in period 1 ($p$-value = 0.459), periods 1-5 ($p$-value = 0.754), or periods 1-10 ($p$-value = 0.917) or across all periods ($p$-value = 0.346).

Results 1 – 3 show that investments in effort made by one side of the market do not have an impact on market outcomes. Given the consistent evidence from dictator, ultimatum and trust games that effort affects the division of surplus, what seems striking in our experiment is that these investments do not even affect posted prices. One possible explanation is that the competition that exists on both sides of the market drives out any concerns about fairness that are triggered by sellers’ investments in effort. While in ultimatum games the two parties must agree on a surplus distribution in order to make a profitable exchange, in a multilateral market a buyer who believes that sellers do not deserve a premium for their effort can choose an alternative trading partner. Implicit punishment opportunities are therefore different in the two institutions (Camerer and Fehr, 2006). Our data suggest, however, that another driving factor for the lack of differences across treatments is buyers’ preference for high-cost sellers. Previous market experiments have not identified this preference because costs are usually
private information. Result 4 summarizes this finding.

**Result 4:** *In both treatments, buyers prefer buying from sellers with a higher cost, ceteris paribus.*

**Support:** Overall, there were 1099 transactions in the experiment (540 in Random Cost and 559 in Earned Cost). Table 2 shows that in 173 transactions (15.7 percent of the total) a buyer made a purchase when two or more sellers were tied for the lowest price. In 132 of these cases (76 percent) buyers chose to buy from the higher-cost seller. These rates are virtually identical in the two treatments.

This result is unexpected given that sellers invested in effort to obtain lower costs in the Earned Cost treatment. It suggests that buyers do not believe that greater investments in effort create entitlements. Instead, buyers exhibit a preference for higher-cost sellers, which reduces the sellers’ aggregate trading surplus on average. In the Earned Cost treatment, these higher-cost sellers tend to be the ones who performed worse on the effort task, so this buyer preference seems to run exactly counter to the entitlement conjecture.

One possible explanation for buyers’ preference for higher-cost sellers is inequity aversion (Fehr and Schmidt, 1999). Contrary to typical observations of inequity aversion, however, many subjects appear to prefer *increased* advantageous inequality as well as decreased disadvantageous inequality. In particular, when two or more sellers are tied for the lowest price, buyers who have one of the two highest valuations on the demand curve, who already earn more than any seller in equilibrium, buy from the higher-cost seller at a higher rate (82 percent) than do the lower valuation buyers (69 percent). It is possible that these high-valuation buyers may seek to decrease inequity if they are able to purchase from the

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9 Our interpretation is supported by the subjects’ responses in a post-experimental questionnaire. For example, 58 percent of buyers disagreed with the statement that “A seller who encoded the most words deserved to be able to charge a higher price than the other sellers.” In addition, 63 percent of buyers agreed with the statement that “The seller who encoded the most words should not charge a higher price as s/he is anyway getting the higher profit amongst sellers.”
high-cost sellers who otherwise may not sell that period. However, since these advantaged buyers tend to lower aggregate seller earnings when they make such purchases, this behavior is also consistent with spite.\textsuperscript{10}

Buyers also exhibit spiteful behavior in some purchases from higher-priced sellers. Of the 926 transactions in which sellers were not tied for the lowest price, the right side of Table 2 shows that buyers purchase from a seller who does not have the lowest price 76 times (25 and 51 in Random Cost and Earned Cost, respectively). That is, in 8.2 percent of the transactions (5.8 percent and 10.4 percent in Random Cost and Earned Cost, respectively) buyers incur a monetary cost in terms of reduced earnings, to choose a higher-priced seller.\textsuperscript{11} In 71 of these 76 higher-price purchases (93 percent) buyers seek to buy from a higher-cost seller. Combining these 71 purchases with the 132 instances in which buyers select a higher-cost seller when prices are equal, in 18.5 percent of all transactions (132 + 71 = 203 out of 1099) buyers behave as if they prefer sellers to have lower earnings, sometimes at a personal cost to themselves.\textsuperscript{12}

It is worth noting that sellers seemed to be aware of the buyers’ preferences for higher-cost sellers. In one session, for example, in periods where all sellers posted prices in the equilibrium range, the sellers adopted the convention whereby the one with the lowest cost posted the lowest price, the one with the second lowest cost posted the second lowest price, and so on. In one instance in which a seller deviated from this convention and charged the same price as the seller with the immediately higher cost, buyers did not buy his unit.

\textsuperscript{10} Spite is defined by Webster’s dictionary as “a mean or evil feeling toward another, characterized by the inclination to hurt...” It is distinguished behaviorally from negative reciprocity by being unconditional, and not a response to being treated poorly by another.

\textsuperscript{11} An unreported logit regression of purchases at prices above minimum shows that the difference is not statistically significant across treatments. Demographic characteristics such as the gender of the subject and the number of years living in Australia also have no impact on whether the buyer purchases at a price above the minimum price.

\textsuperscript{12} This did not stop subjects from increasing their investment in effort with each repetition of the real-effort task as sellers with a lower production costs had higher earnings. In fact, 49 out of 50 sellers increased the number of words they encrypted with each repetition. The average number of encrypted words prior to periods 1, 11, and 21 was 33.5, 41.3, and 46.8, respectively. The increase is highly significant (Wilcoxon, \textit{p}-value<.01) for each of the pairwise comparisons.
This suggests that a norm for more equitable profits amongst sellers emerged and that deviations from this norm were punished.

5. Discussion

This paper reports a laboratory experiment investigating whether investments in effort that affect the allocation of production costs to sellers, without affecting aggregate market supply (or demand), have an influence on the operation of competitive posted-offer markets. We made numerous experimental design choices to increase the likelihood that effort might affect market outcomes: First, we used a posted-offer institution, which is known to favour the side of the market that is posting prices, at least in the short run. Second, induced supply and demand were such that the buyer surplus was approximately double the seller surplus - even though only sellers had to exert effort. Third, the allocation of production costs was affected by a random shock in sellers’ effort productivity. This ensured that sellers did not always get their ‘deserved’ lower costs from higher effort. Fourth, information about buyers’ values, sellers’ costs, effort, and productivity shock was made public. Finally, a relatively small number of traders (five on each side of the market) was used. This reduces competition on the supply side and could prevent prices from converging to the equilibrium range.

Even in this favourable environment, investments in effort do not have an impact on market outcomes. Our results, therefore, contribute to previous evidence showing that factors that affect bilateral bargaining such as extreme earnings inequities (Smith and Williams, 1990; Cason and Williams, 1990) do not inhibit equilibrium convergence of laboratory markets. Competitive price theory remains a good predictor of behavior.

What could account for the fact that real effort investments do not have an impact in our experiment? One likely explanation is that the competitive pressures that exist in the
market drive out the potential impact of a plausible entitlement effect due to effort investments that is observed in bilateral bargaining (e.g. Hoffman et al., 1994).

Another reason for the fact that prices are not higher in the Earned Cost treatment might be spiteful preferences of buyers. Spiteful preferences have been observed in public good environments (Saijo and Nakamura, 1995; Cason, Saijo, and Yamato, 2002), in auctions (e.g., Cooper and Fang, 2009), and in contests (Herrmann and Orzen, 2008). To our knowledge spite has not been previously documented in posted-offer markets, although Ruffle (2000) attributes some buyer demand withholding to fairness considerations. In our experiment, in nearly 20 percent of all transactions in both treatments, buyers expressed a preference to buy from higher-cost sellers, sometimes even if that meant that they would have to pay a higher price. This created additional incentives for sellers to lower prices. Given that this behavior is observed in both treatments, we conjecture that this is the result of providing public information about sellers’ costs and buyers’ values. The buyers’ disregard for the effort exerted by sellers is in contrast to previous findings in bilateral bargaining experiments in which subjects voluntarily compensated those who exerted effort (e.g. Fahr and Irlenbusch, 2000; Ruffle, 1998).

One must always exercise caution when generalizing from the controlled environment of the laboratory to naturally occurring markets. In these markets, unlike in our experiment, buyers seem to view investments in effort favourably, as mentioned in the examples in the introduction. This could be due to the positive externalities generated by the investments in effort, a feature that we deliberately did not include in our experiment, so as to focus on the impact of fairness in these markets. An interesting question for future research therefore, is whether effort investments that create positive externalities can inhibit the operation of competitive markets.

13 Croson (1996) and Salmon and Wilson (2008) find that public information has a similar impact on outcomes in ultimatum games and auctions, respectively.
References:


Tables:

Table 1: Convergence Period of Median Transaction Prices and Overall Efficiency for the 5 Sessions in Each Treatment

Panel A: Convergence Period of Median Transaction Prices (sessions ordered lowest to highest)

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<th>Earned Cost</th>
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<tr>
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Panel B: Overall Market Efficiency, in Percent (sessions ordered lowest to highest)

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<th>Earned Cost</th>
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Table 2: Buyer Purchases from Lower- and Higher-Cost Sellers

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<th>Transactions with Unique Minimum Available Purchase</th>
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<td>Total</td>
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Figures:

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

![Graph showing stationary aggregate supply and demand](image)

Figure 2 – The Encryption Task

![Encryption task interface](image)
Figure 3 – Purchasing Screen

You are a buyer.

You are the fifth one to buy.

Your value is 9.00

<table>
<thead>
<tr>
<th>Seller ID</th>
<th>Initial points earned encoded</th>
<th>Percentage lost [%]</th>
<th>Final points</th>
<th>Initial ranking</th>
<th>Final ranking</th>
<th>Seller’s earned cost of production</th>
<th>Price asked</th>
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</table>

Figure 4 – Median Transaction Prices

Median Transaction Price

- Random-Cost
- Earned-Cost

Equilibrium range
Figure 5 – Trading Efficiency

![Trading Efficiency Chart]

- **Random-Cost**
- **Earned-Cost**
Figure A1 – Median Transaction Prices in the Random Cost treatment

Figure A2 – Median Transaction Prices in the Earned Cost treatment
Appendix (For referees’ consideration; not intended for publication)

Instructions

These are the instructions for the Earned Cost treatment. Instructions for the Random Cost treatment were appropriately adjusted and 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 = 80 cents and will be immediately paid to you in cash. In addition, at the beginning of the experiment we will give every participant A$5.

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 determined in each period and will be revealed to that buyer, but not to the other buyers or the sellers.
A seller earns the difference between the trade price and her cost of production. The cost of production is determined by the sellers in a competitive manner. Details about this task are given in the following section.

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**
Sellers are responsible for their cost of production. Their cost is determined by two factors:
-a preliminary Effort Stage.
-a random process.

**In the Effort Stage**, sellers will be given a task that will determine their production cost 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 8. The Effort Stage decision screen is seen in Figure 1.

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

Figure 1

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. You will earn one Point for every word you have successfully encoded.

The **random process** works in the following way: After you have finished encoding words, the computer will generate a random number between 0 and 50. This will be done separately for each seller. All numbers between 0 and 50 are equally likely. The number chosen will determine by how much (in percentage points) a seller’s points will be reduced. In other words, you can lose from 0% up to 50% of their points. **Example:** Assume a seller has encoded 90 words and the random number generated by the computer is 34. This means that the seller’s points will be reduced by 34%. Therefore, the seller’s final number of points will equal 90*(100%-34%) = 90*66%=59.4 points.

Your production cost will depend on your relative performance amongst sellers, after the random process. That is, the seller with the highest number of final points will have the lowest cost; the seller with the second highest number of final points will have the second lowest cost and so on. If two or more sellers have the same final points, the computer will determine randomly the ranking of the tied participants. Each seller will have the same
Appendix

probability of being ranked above other sellers who have the same number of final points. Table 1 shows the exact cost of production according to each seller’s rank.

<table>
<thead>
<tr>
<th>Seller’s Rank</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Production Cost (in ECU)</td>
<td>3.25</td>
<td>4.00</td>
<td>4.75</td>
<td>5.50</td>
<td>6.00</td>
</tr>
</tbody>
</table>

Table 1

At the end of the Effort Stage sellers will be informed about the number of words each seller encoded, their initial and final points, their initial and final ranking, percentage lost, and their cost of production with a screen as in Figure 2. (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.)

![Figure 2](image)

The Effort Stage is not entered in every trading period, but only at the beginning of periods 1, 11, and 21. The ranking in period 1 determines the sellers’ costs of production for periods 1 to 10. The ranking in period 11 determines the sellers’ costs of production for periods 11 to 20. Finally, the ranking in period 21 determines the sellers’ costs of production for periods 21 to 30. The probability of points lost can be different for every effort stage.
(ii) 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 3 and then click “Make an offer”. The price might include up to two decimal points and must exceed the cost of production.

![Figure 3](image)

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, the prices asked, the seller’s cost of production, the initial and final ranking, the percentage of points lost, and the seller’s ID will be made public to buyers and sellers. The offers are, however, anonymous. That means that it is not possible to tell which seller posted which price. After all sellers have made a decision, the prices asked, the seller’s cost of production, and the number of words each seller encoded will be made public to buyers and sellers. The feedback screen is shown in Figure 4. 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’.
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 values. These are: 10.50, 9.00, 7.50, 6.00 and 5.50. Each buyer will only know his 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 5. If the buyer wishes to make no purchase from any seller this period he must click ‘Reject’.
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. Assume that Seller 1 encodes 5000 words, Seller 2 3000 words, Seller 3 11000 words, Seller 4 8000 words and Seller 5 20000 words.
   a- What will the production cost of each seller be if the random number is the same for every seller?
      a. Seller 1: $....................
      b. Seller 2: $....................
      c. Seller 3: $....................
      d. Seller 4: $....................
      e. Seller 5: $....................
   b- What will the production cost of each seller be if the random number is 50 for Seller 5 and 0 for all other sellers?
      a. Seller 1: $....................
      b. Seller 2: $....................
      c. Seller 3: $....................
      d. Seller 4: $....................
      e. Seller 5: $....................

4. 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

5. Assume the buyer has a value of 550 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 ..........................

6. Which is the correct set of values for the buyers? (Tick the correct answer)
   i. 5.5, 6.5, 7.5, 9.5, and 11.5 □
   ii. 5.5, 6.0, 7.5, 9.0, and 10.5 □
   iii. 2, 3, 4, 5, and 8 □
   iv. 2, 3, 4, 5, and 5 □
7. 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 randomly determined by the computer □

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<th>Table 3</th>
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