Directed search, coordination failure and seller profits: an experimental comparison of posted pricing with single and multiple prices

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Abstract

We use a human–subjects experiment to examine market outcomes in two related settings involving firm pricing and directed consumer search. In both, two firms simultaneously post asking prices for a single indivisible good; two buyers observe the prices and simultaneously choose which firm to visit. In a *one–price* model, each firm posts a single asking price; in a *two–price* model, each posts two prices: a "pairwise" price (applicable when exactly one buyer visits), and a "multilateral" price (applicable when both buyers visit). Under reasonable equilibrium selection criteria, the one–price model yields a unique prediction, whereas the two–price model allows a continuum of equilibrium multilateral prices (but a unique pairwise price equal to that in the one–price model). While the multilateral price allows sellers the possibility of taking advantage of competition between buyers, our experimental results show that multilateral prices are actually *lower* than either pairwise prices or prices in the one–price treatment. We also find that allowing a distinct multilateral price has no apparent effect on seller profits, and leads to a small increase in the likelihood of coordination failure. Finally, price dispersion is higher in the two–price treatment than in the one–price treatment.

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1 Introduction

The concept of search has been a versatile one in economics. Theoretical models incorporating some type of search have been used to explain such disparate phenomena as the emergence of money as a medium of exchange (Kiyotaki and Wright, 1989; 1993), price dispersion in goods markets (Salop and Stiglitz, 1977; Burdett and Judd, 1983), unemployment and job vacancies (Pissarides, 1985) and discrimination by consumers or firms (Borjas and Bronars, 1989; Black, 1995). Much of the early work on search in markets (e.g., consumers and producers, or workers and firms) assumed that search is *undirected*: an agent of one type is equally likely to meet any of the agents of the other type. This approach has been innovative, not least in highlighting the notion that people trade with each other as much as against budget constraints. However, it has faced criticisms along lines summarised by Howitt (2005): "[i]n contrast to what happens in search models, exchanges in actual market economies are organized by specialist traders, who mitigate search costs by providing facilities that are easy to locate. Thus, when people wish to buy shoes they go to a shoe store; when hungry they go to a grocer; when desiring to sell their labor services they go to firms known to offer employment" (p. 405).

Such criticisms argue in favour of *directed* instead of undirected search for realistic modelling. In a seminal paper, Burdett, Shi and Wright (2001) (which we will often abbreviate BSW) analysed a stylised market with directed search. In the simple version of their setup, there are two buyers who each want to buy one unit of an indivisible good, and two sellers who each want to sell one unit of that good. Sellers set prices, and then each buyer chooses which seller to visit (this last assumption is what distinguishes directed from undirected search). Even though buyers are costlessly informed of the price (and location) of each seller, there is a chance of inefficiency due to coordination failure: both buyers might show up at the same seller's location, in which case one customer is unable to purchase the good, and since no buyer showed up at the location of the other seller, that seller is unable to sell.

Coles and Eeckhout (2003) (CE) argue that while price posting is widely used in trading mechanisms, these models typically restrict sellers to commit to a single price, regardless of how many buyers show up to purchase the good. CE extend the model by allowing sellers to post prices contingent on demand, such as advertising a higher price should more than one buyer desire the good. In the two–buyer, two–seller case, each seller posts a price pair (p_1, p_2), where p_1 is the "pairwise" price charged if only one buyer shows up and thus buys the good, while p_2 is the "multilateral" price charged if two buyers visit at the same time. They suggest that such a pricing mechanism "admits an auction scenario" (p. 266), letting the seller – in essence – force multiple buyers to compete amongst themselves for the good, leading to an increase in seller profit. However, CE show that while their model implies a unique pairwise price p_1 (indeed, equal to the price chosen in BSW's model), the multilateral price p_2 can lie anywhere between the seller's minimum acceptable price and the buyer's maximum acceptable price. Thus, seller profits can be lower than as well as higher than under a single price.

This multiplicity of equilibria means that little can be said, based on the theory itself, regarding systematic qualitative differences between BSW's one–price model and CE's two–price model. We attempt to resolve some of this indeterminacy by means of a laboratory experiment in which human subjects interact – in the role of buyers or sellers – in environments based on these two models. We have three main results. (1) Allowing distinct pairwise and multilateral prices does not alleviate the coordination problem arising from directed search, as observed market efficiency is actually lower in the two–price treatment compared to the one–price treatment. (2) Contrary to CE's conjecture, firms are (on average) not able to use the multilateral price to increase their profits, since multilateral prices tend to be below (rather than above) either pairwise prices in the two–price treatment or prices in the one–price treatment. (3) Price dispersion is higher in the two–price treatment than in the one–price treatment, suggesting that the multiplicity of equilibria in the CE model is as severe a problem empirically as it is theoretically.

2 Theory

Here, we describe the one–price and two–price models in greater detail. The models in this section are isomorphic to those of Burdett, Shi and Wright (2001) and Coles and Eeckhout (2003), respectively. The minor changes we make are in order to parallel our experimental setup, and do not affect the theoretical analysis in any non–trivial way.

There are two buyers and two sellers. Sellers are able to produce up to one unit of a homogeneous, indivisible good at an avoidable cost of 10; buyers derive a value of 20 from consuming up to one unit of the same good. Sellers begin by simultaneously posting prices. There are two possibilities: in the *one–price* game (corresponding to BSW's model), each seller posts a single price, regardless of how many buyers visit; in the *two–price* game (corresponding to CE's model), each seller posts two prices, a "pairwise price" which applies when exactly one buyer visits, and a "multilateral" price which applies when both buyers visit. Buyers observe all prices, then simultaneously choose which seller to visit. If the buyers visit different sellers, both are able to buy, and both sellers are able to sell (in the two–price game, at the pairwise price). If both buyers visit the same seller, then a randomly chosen buyer is able to buy (in the two–price game, at the multilateral price) from that seller, while the other buyer and seller cannot trade.

Burdett, Shi and Wright (2001) show that in the one–price game, a large number of subgame perfect equilibria exists. However, only one satisfies the additional conditions of symmetry and robustness and doesn't place extreme demands on buyers' ability to coordinate; in this equilibrium, both sellers post a price of 15 (halfway between seller cost and buyer value), and buyers mix, visiting either seller with equal probability.[1] Coles and Eeckhout (2003) similarly show that in the two–price game, sellers choose a pairwise price of 15 in all subgame perfect equilibria satisfying certain additional conditions.[2] There is a continuum of such equilibria, all with both firms choosing the same multilateral price in (10, 20], and buyers again visiting either seller with equal probability.[3]

So, there is little theoretically to distinguish the two models. In both, firms choose a pairwise price of 15, and since buyers choose either seller with equal likelihood, the expected efficiency is 0.75. The distribution of surplus between buyers and sellers can differ in the two models, due to the multilateral prices' being able to vary between 10 and 20; however, there exist equilibria of the two–price game corresponding to almost any possible distribution of gains from trade – in particular, either buyers or sellers can capture the majority of the surplus – as compared to the one–price game, where both sides are predicted to share the surplus equally.

3 Methods

Because of the difficulty in obtaining clear–cut theoretical predictions for differences between the one–price and two–price models, we conduct a laboratory experiment in order to determine empirically whether any such differences arise. Our main treatment variable is whether sellers are able to charge different prices depending on whether one or two buyers visit them ("two–price" treament) or are constrained to post a single price ("one–price" treatment). There were a total of thirteen experimental sessions, with 128 subjects in all. Each session lasted for forty rounds, split into two halves. Some subjects played twenty rounds of the one–price game, followed by twenty rounds of the

[1] Loertscher (2010) shows that this equilibrium is also the only one that satisfies a law–of–demand condition.

[2] The conditions are: symmetry for firms, pure strategies for firms, and symmetry for buyers.

[3] Coles and Eeckhout point out that this continuum of equilibria includes the one–price case where both firms set both prices equal to 15, along with the "auction" case where both firms set a multilateral price of 20, capturing all of the surplus from the trade that is made.

two–price game; for others, the order of games was reversed (see Table 1); this variation of orderings was done so that any difference between the games could be attributed to a treatment effect rather than learning from one game to the other. Subjects remained in the same role (buyer or seller) in all rounds, but the composition of the groups

Table 1: Treatment information

Game, rounds 1–20	Game, rounds 21–40	Independent groups	Subjects
one–price	two–price	7	64
two–price	one–price	6	64

(containing two buyers and two sellers) was randomly drawn in each round, so that a given subject was grouped with different people from round to round; this was done primarily to lessen the likelihood of repeated–game effects like reputation building or dynamic collusion.

The experimental sessions took place at the Scottish Experimental Economics Laboratory (SEEL) at the University of Aberdeen. Subjects were primarily undergraduate students from University of Aberdeen, and were recruited using the ORSEE web–based recruiting system (Greiner, 2004). No one took part more than once. The experiment was run on networked personal computers, and was programmed using the z–Tree experiment software package (Fischbacher, 2007). Subjects were asked not to communicate with other subjects except via the computer program. No identifying information was given about opponents – again, in an attempt to minimise repeated–game effects.

At the beginning of a session, subjects were seated in a single room and given written instructions for the first twenty rounds.[4] They were informed that the experiment would comprise two halves totalling forty rounds, but details of the second half were not announced until after the first half had ended. The instructions were also read aloud to the subjects, in an attempt to make the rules of the game common knowledge. Then, the first round of play began. After the twentieth round was completed, each subject was given a copy of the instructions for rounds 21–40. These new instructions were also read aloud, before round 21 was played.

Each round began with firms being prompted to choose their prices. In the one–price game, each firm chose one price, which had to be a whole–number multiple of £0.01, between £10 and £20 inclusive.[5] In the two–price game, each firm chose pairwise and multilateral prices in this range. The two–price treatment instructions explicitly stated that there were no other restrictions on these prices; in particular, the multilateral price could be more than, less than, or equal to the pairwise price. After the sellers had entered their prices, buyers observed these prices and were prompted to choose which firm to visit.[6] Once they had done so, the round ended and subjects received feedback. Firms were informed of all prices (own and rival's), how many buyers visited them, the quantity sold and profit. Buyers were informed of all prices, which firm each buyer visited, the quantity bought and profit.

At the end of the fortieth round, subjects were paid, privately and individually. For each subject, two rounds from each block of twenty were randomly chosen, and the subject was paid his/her earnings in those rounds, plus a £3 show–up fee. Subjects' total earnings averaged about £20, for a session that typically lasted about 60 minutes.

[4]Sample instructions, as well as the raw data from the experiment, are available from the corresponding author upon request.

[5]Coles and Eeckhout (2003) show that choosing a price outside [10, 20] is a dominated strategy in the two–price game; the same is clearly true in the one–price game.

[6]Within a round, the two firms in a market were labelled as "Seller 1" and "Seller 2", so that buyers could make clear which one they wanted to visit. These labels were chosen randomly in each round, so that the same firm would be called "Seller 1" about half the time and "Seller 2" the rest of the time, and buyers were not labelled at all – again, in an attempt to prevent repeated–game effects.

4 Results

Table 2 shows some treatment–wide aggregate data from the experiment. Consistent with the theoretical predictions described in Section 2, we observe no substantial difference in pairwise price between the two treatments, whereas seller revenue, seller profit and market efficiency are actually *lower* in the two–price treatment than in the one–price treatment.[7] Non–parametric statistical tests find that one cannot reject the null hypothesis that pairwise prices, seller revenue and seller profits are equal between the two treatments (Wilcoxon signed–ranks test for matched samples, session–level data, $p > 0.20$ for prices, revenues and profits).[8] On the other hand, the difference in efficiency seen in the table is significant, albeit only at the 10% level (Wilcoxon test, session–level data, $p \approx 0.074$). Additionally,

Table 2: Aggregate treatment–wide averages (standard deviations in parentheses)

	One–price game	Two–price game
Pairwise price choice (£)	15.13 (1.22)	15.15 (1.61)
Multilateral price choice (£)	—	14.64 (1.75)
Efficiency	0.761 (0.427)	0.745 (0.436)
Seller revenue (£), conditional on selling a unit	14.99 (1.12)	14.83 (1.63)
Seller profit (£), unconditional	3.79 (2.34)	3.60 (2.54)

the table shows that multilateral prices are *lower* on average than pairwise prices, and indeed lower than prices in the one–price treatment. These differences are at least marginally significant (Wilcoxon test, session–level data, $p \approx 0.055$ versus pairwise prices, $p \approx 0.007$ versus prices in the pairwise treatment).

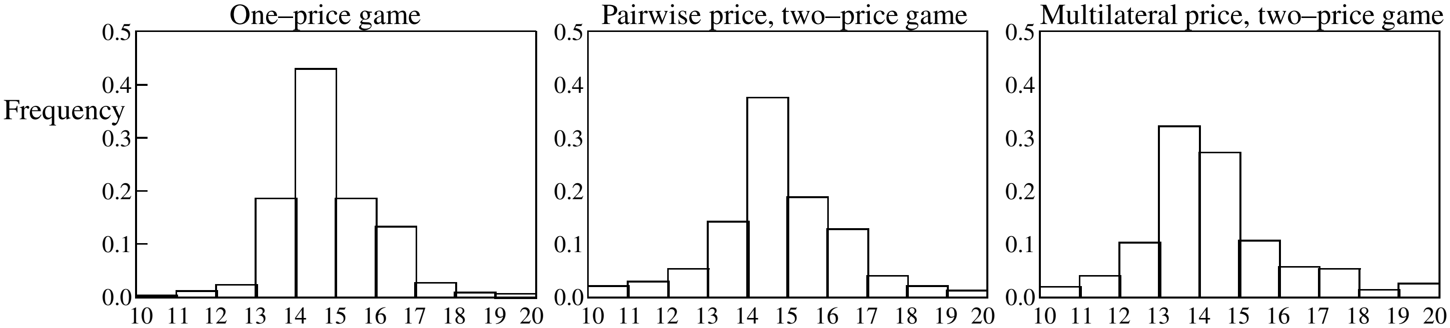
The other noteworthy results involve the *dispersion* of prices, rather than their absolute level. Table 2 indicates that dispersion of both pairwise and multilateral prices in the two–price game is higher than price dispersion in the one–price game. More detail can be seen in Figure 1. The distribution of prices in the one–price game is fairly tight, with a mode between 14 and 15. Pairwise prices in the two–price game are centred in the same interval, but their distribution has wider tails (suggesting more dispersion). The distribution of multilateral prices also has wide tails, but its mode is between 13 and 14. Both the difference in dispersion between pairwise price and one–price treatment and that between multilateral price and one–price treatment are significant ($p \approx 0.011$ and $p \approx 0.020$ respectively).[9]

[7] In these models, efficiency depends solely on whether trades occur, irrespective of what the transaction price is. Thus, efficiency can be defined in a natural way as the actual quantity traded divided by the maximum possible quantity traded, yielding a value between zero and one, and an obvious measure of the level of coordination failure is one minus this value. Note also that we distinguish in the table between mean seller profit (unconditional) and mean seller revenue conditional on selling a unit; the latter is equal to the mean transaction price.

[8] See Siegel and Castellan (1988) for descriptions of the non–parametric statistical tests used in this paper. We note that these tests tend to err on the conservative side, as they treat an entire group over all rounds as a single observation. However, we believe this is appropriate, since more disaggregated data cannot be considered to be independent of each other. We also note that additional tests using the data from the last ten rounds of each game yielded similar results to the ones reported here for all twenty rounds of each game, suggesting that even after subjects have gained experience in the environment, results are qualitatively the same.

[9] The effects of this price dispersion are also seen in sellers' revenues (equal to transaction prices) and sellers' profits, both of which have significantly higher variance in the two–price treatment than in the one–price treatment ($p < 0.001$ and $p \approx 0.009$ respectively). We also note that even though price dispersion of multilateral prices is substantial, there is weak evidence that subjects do manage a limited amount of coordination. Perhaps the best indicator of this comes from Spearman measures of association: a non–parametric analogue to the correlation coefficient. When this measure is computed for individual groups, we find that for only two of thirteen groups is it even positive, and for only one of these is it significantly more than zero ($p \approx 0.05$). Aggregating over groups, however, its value of approximately 0.21 is highly significant ($p < 0.001$). While we must be careful interpreting this measure here (since it combines observations that are not independent) the

Figure 1: Histogram of prices – one–price game, two–price game (pairwise and multilateral prices)



Price *(note: the height of the column between price n and price $n+1$ is proportional to the frequency of price choices in the interval $(n, n+1]$ (except in the case of $[10, 11]$)*

On the other hand, we do not find significant differences in dispersion between the pairwise and multilateral prices within the two–price treatment ($p > 0.20$), even though the theoretical prediction of the CE model (unique pairwise price of 15, continuum of multilateral prices between 10 and 20) suggests that multilateral prices might have been expected to have higher dispersion.

5 Discussion

We conduct a laboratory experiment to understand behaviour in two posted price, directed search environments. In the one–price model (based on Burdett, Shi and Wright, 2001), sellers post a single price, which buyers observe before deciding which firm to visit. The two–price model (based on Coles and Eeckhout, 2003) is similar, except that sellers post both a pairwise price (in effect when one buyer visits) and a multilateral price (in effect when multiple buyers visit). For the two–seller, two–buyer case we focus on, theoretical analysis provides few general implications; the multiplicity of equilibria in the two–price model prevents qualitative predictions about prices or seller profits between the models. Experimental methods are thus well suited to overcoming this indeterminacy.

Our main experimental results are as follows. Allowing distinct pairwise and multilateral prices – i.e., moving from the BSW setting to the CE setting – does not alleviate the coordination problem arising from directed search, as observed market efficiency is actually slightly (and weakly significantly) lower in the two–price treatment compared to the one–price treatment. Also, contrary to CE's conjecture about firms' use of the multilateral price to extract more surplus, it does not lead to increased seller profits, since on average, multilateral prices in the two–buyer treatment tend to be below (rather than above) either pairwise prices in that treatment or prices in the one–price treatment. Finally, we do not observe sellers converging on a single multilateral price (or even a tight distribution of them), suggesting that the multiplicity of equilibria in the CE model is as severe a problem empirically as it is theoretically.

We recognise the risk in drawing broad conclusions based on the results of a single empirical test; we therefore hope that other researchers will be encouraged to replicate and extend our results. Should our results prove to be robust, they carry implications for researchers interested in directed search, and perhaps a message for theorists in general. A ubiquitous and important trade–off in theoretical modelling is the one between simplicity and realism: models can be made to better describe reality only at the cost of becoming more complicated and less tractable. Coles and Eeckhout's extension of Burdett, Shi and Wright's model is one example. Real firms often do have the ability

combination of no significance within groups, with significance in the aggregate, suggests that subjects achieve some a degree of convergence to a price that varies across groups – as one might expect given the multiple equilibria.

to adjust prices according to current demand for their products, and one might expect (as CE originally conjecture) that such adjustments can enhance firms' profits. However, CE show theoretically that this need not be the case: allowing distinct pairwise and multilateral prices can lead to higher, lower or equal profits. Our results suggest that empirically as well, giving firms this flexibility has little effect on market outcomes, and to the extent that there is an effect, both firms and efficiency suffer (suggesting that in the longer term, firms might well revert to a single price anyway). In other words, any gain in realism from this extension does not seem to offset the loss in parsimony.

References

Black, D.A. (1995), "Discrimination in an equilibrium search model", *Journal of Labor Economics* 13, pp. 309–334.

Borjas, G.J. and S.G. Bronars (1989), "Consumer discrimination and self–employment", *Journal of Political Economy* 97, pp. 581–605.

Burdett, K. and K.L. Judd (1983), "Equilibrium price dispersion", *Econometrica* 51, pp. 955–970.

Burdett, K., S. Shi and R. Wright (2001), "Pricing and matching with frictions", *Journal of Political Economy* 109, pp. 1060–1085.

Coles, M.G. and J. Eeckhout (2003), "Indeterminacy and directed search", *Journal of Economic Theory* 111, pp. 265–276.

Fischbacher, U. (2007), "z–Tree: Zurich toolbox for ready–made economic experiments", *Experimental Economics* 10, pp. 171–178.

Greiner, B. (2004), "An online recruitment system for economic experiments", in Kremer, K. and V. Macho eds., *Forschung und wissenschaftliches Rechnen*. GWDG Bericht 63. Göttingen: Gesellschaft für Wissenschaftliche Datenverarbeitung, pp. 79–93.

Howitt, P. (2005), "Beyond search: fiat money in organized exchange", *International Economic Review* 46, pp. 405–429.

Kiyotaki, N. and R. Wright (1989), "On money as a medium of exchange", *Journal of Political Economy* 97, pp. 927–54.

Kiyotaki, N. and R. Wright (1993), "A search–theoretic approach to monetary economics", *American Economic Review* 83, pp. 3–77.

Loertscher, S. (2010), "Matching with frictions, and the law of demand", working paper, University of Melbourne.

Pissarides, C.A. (1985), "Short–run equilibrium dynamics of unemployment, vacancies, and real wages", *American Economic Review* 75, pp. 676–690.

Salop, S. and J. Stiglitz (1977), "Bargains and ripoffs: a model of monopolistically competitive price dispersion", *Review of Economic Studies* 44, pp. 493–510.

Siegel, S. and N.J. Castellan, Jr. (1988), *Nonparametric Statistics for the Behavioral Sciences*, McGraw–Hill, New York.