Sequential Price Setting: Theory and Evidence from a Lab Experiment*

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Abstract

In the Varian (1980) model of price competition, a change from simultaneous to sequential price setting dramatically changes equilibrium strategies and pay-offs, and in the unique symmetric equilibrium prices are pushed up to the monopoly price. In addition there exists an asymmetric equilibrium with lower average prices. Our main contribution is to test these predictions in the laboratory. Our experimental data strongly support the qualitative model predictions. However, there is a non-negligible fraction of players that set low prices in accordance with the asymmetric equilibrium, which is puzzling. We show that the puzzle to a large extent can be resolved by introducing competitive preferences in the model.

Keywords: Laboratory experiment; information frictions; price competition; sequential price setting; competitive preferences.

JEL: C91; D43; L13.

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1 Introduction

The timing of pricing decisions may impact prices markedly. When price setting is simultaneous, sellers have strong incentives to undercut each other, pulling prices down. However, if one of the sellers sets the price after the other sellers have set their prices, this may alter the price-setting incentives of the other sellers dramatically.

In order to investigate the role of sequencing in pricing games, we study a model with price competition based on Varian (1980), with the twist that one of the sellers sets its price after the other sellers have set their prices. As shown in Deneckere and Kovenock (1992), this twist fundamentally changes the equilibrium strategies and pay-offs, and in the unique symmetric equilibrium prices are dramatically higher than when prices are set simultaneously. Prices are actually pushed up to the monopoly price. In addition there exists an asymmetric equilibrium with lower average prices.

Although the effects of sequential pricing in the Varian model are particularly stark, the main mechanism is more general. Sellers in pricing models with search frictions face a trade-off between exploiting price-insensitive consumers and attracting price-sensitive consumers. Sequencing of the price setting decisions tilts this trade-off in the direction of exploiting price-insensitive consumers, as the price-sensitive consumers tend to be picked up by the price follower anyway. Due to its simple structure and strong predictions, the Varian model seems particularly well suited to test experimentally the behavioural effects of price sequencing in search models.

Reasonable empirical questions are whether sellers recognize and respond to the incentives of the model and what equilibrium sellers coordinate on, if they coordinate at all. Our main contribution is to test the model predictions in the laboratory. Our experimental data strongly support the qualitative model predictions. In particular we observe a significant rise in prices when going from simultaneous to sequential price setting, all else constant. However, a non-negligible fraction of players set low prices in accordance with the asymmetric equilibrium, which is puzzling. We show that the puzzle to a large extent can be resolved by introducing competitive preferences in the model.

In the Varian model, sellers set prices independently and simultaneously for a homogeneous product, and buyers are either informed about the prices or not. The informed buyers visit the seller with the lowest price, while the uninformed buyers visit sellers randomly. In equilibrium, sellers randomize over prices, and as the fraction of uninformed buyers goes to zero, the equilibrium price converges to zero. In this set-up, suppose one of the sellers, which we label the *entrant*, sets her price after observing the prices of other sellers (which we label the *incumbents)*, without these sellers being able to respond. In the unique symmetric equilibrium of the model, incumbents set their prices equal to the reservation price of the buyers, while the entrant undercuts this price. The result holds regardless of the number of sellers and the fraction of uninformed buyers (as long as there is at least one uninformed buyer in the market). Hence, if one seller is allowed to be a price follower, this may fundamentally change the role of competition, and lead to monopoly prices, notwithstanding that the equilibrium with simultaneous price setting may be arbitrarily close to the competitive outcome.

These theoretical results are confirmed by data. In particular, we observe a significant rise in prices when price setting is sequential, all else constant. That is, sequential price setting, with one seller being an entrant, pushes prices toward monopoly levels. Moreover, this observed price increase is independent of both the number of uninformed buyers and the total number of incumbents in the market, supporting the qualitative predictions of the unique symmetric equilibrium. Furthermore, we observe individual price postings quantitatively consistent with equilibrium play. That is, the entrants best respond in 87 percent of all games and in 91 percent of games in the latter half of the experiment, while the incumbents post prices that are part of a Nash equilibrium in 80 percent of all games and in 88 percent of the latter games.

Although individual choices are largely consistent with equilibrium play, average price-setting is nonetheless below the monopoly level. The main reason is that a non-negligible fraction of play is consistent with the asymmetric equilibrium in which one incumbent sets a low price. At the market level, observed behavior is consistent with the symmetric equilibrium in 47 percent of all games, and in 56 percent of the latter games, while observed behavior is consistent with the asymmetric equilibrium in 8 percent of all games and in 12 percent of the latter games. Finally, observed behavior is consistent with miscoordination–in which more than one incumbent set the low price–in 1 percent of all games.

The non-negligible fraction of asymmetric equilibrium play observed is, perhaps, somewhat puzzling. After all, a money-maximizing incumbent has nothing to gain by successfully instigating such an equilibrium while much to lose by causing miscoordination. We therefore extend the model by allowing for competitive preferences (or, if you like, aversion to unfavorable inequality). With competitive preferences, some incumbents will with a strictly positive probability play according to the asymmetric equilibrium and set a low price so as to increase their pay-offs relative to the entrant. We show that this extension goes a long way towards resolving this puzzle. The presence of such preferences extends naturally to a market context, and could be rationalized among real-world business managers subject to remuneration contracts based on the firm's relative performance. In the asymmetric equilibrium, the incumbent seller setting the low price succeeds in getting the largest market share while none of the other sellers perform much better in terms of expected profits.

Related literature

Sequential pricing has been analyzed extensively in the IO literature. The model we employ (without competitive preferences) can be considered as a slightly modified and stripped-down version of the model in Deneckere and Kovenock (1992), who study price leadership in the Varian model. A model with similar features can be found in for instance Roy (2000). There also exists a series of papers analyzing duopoly models of price leadership with differentiated products. In these models a second-mover may enjoy an advantage depending on the slope of the firms' reaction functions (see e.g., Gal-Or 1985; Dastidar 2004; von Stengel 2010).

Brown and MacKay (2023) document empirically that price followers (interpreted as firms in the market that update prices most frequently) systematically set lower prices than price leaders (firms in the market that update prices less frequently) in the online over-the-counter market for allergy medicines in the U.S.[1] There are also several papers that investigate incumbent firms' price responses to the potential threat of entry. The findings are mixed: prices may decrease, remain unchanged, or increase before entry (see e.g., Grabowski and Vernon 1992; Geroski 1995; Goolsbee and Syverson 2008: Ellison and Ellison 2011; Tenn and Wendling 2014; Kwoka and Batkeyev 2019). Price decreases may be interpreted as attempts to deter entry, whereas price increases may be interpreted as strategies to accommodate entry in line with our findings.

There is a large experimental literature on price competition. The standard in this literature is that all buyers are informed and there is simultaneous price setting (i.e., Bertrand competition).[2] We are only able to find two experimental studies that investigate sequential price competition.[3]

[1] When there is a second-mover advantage (as in our model), firms have an incentive to set price last, and several papers focus on the endogenous timing of pricing decisions (see e.g., Hamilton & Slutsky 1990; Van Damme & Hurkens 2004; Amir & Stepanova 2006; Madden & Pezzino, 2019).

[2] For empirical investigations of price leadership using field data see e.g., Wang (2009), Lewis (2012), and Byrne & de Roos (2019).

[3] Datta Mago & Dechenaux (2009) investigate endogenous price leadership building on the framework of Hamilton & Slutsky (1990). They find that a substantial degree of firm size asymmetry is needed for price leadership to emerge in posted-offer markets.

Kübler & Müller (2002) (KM) compare simultaneous price setting with sequential price setting in a Bertrand duopoly with differentiated products. Their model predicts higher prices with sequential price setting, and this is partly confirmed in their experiment. Although complementary, the studies differ in important aspects. The force against marginal-cost pricing in our model is uninformed customers, while in their model it is product differentiation. Hence our paper, in contrast with the KM paper, speaks to the broader search literature. Maybe more importantly, the strategic differences between simultaneous and sequential price setting are more pronounced in our model, in which the followers' best response is to undercut the leader slightly and hence follow any price change by the leader one-to-one. In KM's model, by contrast, the followers' best responses balance a trade-off between price and volume sold, and a higher price of the leader influences this trade-off but less than one-to-one in prices. The more direct response by followers may explain why our empirical results are stronger and more in line with theory. In addition our model opens up for multiple equilibria in the presence of competitive preferences, which is interesting in its own right and has predictive power. We also have a richer experimental design.

Dijkstra (2015) investigates tacit price collusion in indefinitely repeated duopoly games with and without exogenous price leadership. The environment is distinctly different from ours: While products are homogenous, all buyers are informed and the focus is on the play of equilibria that support collusion in a repeated game setting. Our study does not investigate collusion and our underlying game is one shot.[4]

There exists a small literature that examines price-setting games in which buyers have differentiated information regarding prices in the lab. In particular, Morgan et al. (2006) test the simultaneous pricing model of Varian and find strong support for the comparative static predictions, with results comparable to those from our treatments without sequential pricing. Cason and Friedman (2003) and Cason et al. (2021) examine the noisy sequential-search model of Burdett and Judd (1983); Cason and Datta (2006) and Cason and Mago (2010) examine the sequential search model of Robert and Stahl (1993) with advertising; Helland et. al (2017) examine the capacity constraints model of Lester (2011).[5]

The remainder of the article is organized as follows: Section 2 outlines the theoretical framework, and section 3 presents our experimental design and procedures. In section 4 we report the results from our experiment, while section 5 offers a brief conclusion.

2 Model

In this section we define the theoretical framework we intend to test through our experiments. The framework is based on the models of Varian (1980) and Deneckere and Kovenock (1992).

2.1 Simultaneous price setting

We first set out the key features of the original model of Varian (1980) to facilitate comparisons with a sequential price setting. Let there be U uninformed buyers, N informed buyers, and S sellers. Sellers are not capacity constrained, and set their prices p simultaneously and independently. The shadow value of a unit of the good to the seller is zero, and sellers are risk neutral. The buyers' willingness to pay for the good is normalized to 1. Informed buyers buy from the seller that offers the lowest price. If more than one seller offer the lowest price, the informed buyers choose one of them at random. Uninformed buyers pick any seller at random.

In appendix A.1 we show that in a symmetric equilibrium, the distribution of prices is given by

[4] An experimental literature on entry deterrence (through limit pricing or investment in capacity) also exists (see Brandts & Potters 2018, section 5, for a survey).

[5] There is alsa a literature that investigates different aspects of the Diamond (1971) paradox in the lab. See for instance Grether et al. (1988), Davis and Holt (1996) and Abrams et al. (2000).

$$F(p) = 1 - \left(\frac{1-p}{p}\frac{U}{SN}\right)^{1/(S-1)} \qquad \text{with } p \in [p_0, 1].$$

It is straightforward to verify that the lower bound of the support is given by $p_0 = \frac{U}{U+SN}$. Note that the sellers are indifferent between setting $p = p_0$ and selling to all the informed buyers as well as U/S of the uninformed buyers (in expectation), and setting $p = 1$ and selling to U/S of the uninformed buyers only. Note also that as the fraction of uninformed buyers goes to zero, the price distribution converges to zero.

2.2 Sequential price setting

Now suppose that of the S sellers in the economy, one seller, labeled the entrant, sets the price after observing the prices of the other sellers, labeled the incumbents. We assume that $S > 2$.[6] The incumbents set their prices simultaneously, and are not allowed to change their price after observing the entrant's price choice. The timing of the game can be summarized as follows:

1. The incumbents set their own price simultaneously and independently.
2. The entrant observes the $S - 1$ prices set by the incumbents, and then sets its own price.
3. The informed buyers buy from the seller with the lowest price. If more than one seller sets the lowest price, the buyers visit each of them with the same probability. Uninformed buyers choose a seller at random.[7]

The game is solved by backward induction. Let $p^I_{\min}$ denote the lowest price set by any of the incumbents at stage 1. Suppose $p^I_{\min} > p_0$. Then the optimal action for the entrant is to set its price marginally below the lowest price among the incumbents, $p = p^I_{\min} > p_0$, and attract all informed buyers. Suppose then that $p^I_{\min} \leq p_0$. The entrant then strictly prefers to set $p = 1$. It follows that the optimal response of the entrant is

$$p^E = \left\{ \begin{array}{cl} p^I_{\min} - \varepsilon & \text{if } p^I_{\min} \in [p_0, 1] \\ 1 & \text{if } p^I_{\min} \leq p_0 \end{array} \right|$$

We say that an equilibrium is *symmetric* if it prescribes that all incumbent sellers choose the same strategies. Given the response by the entrant, optimal strategies for the incumbent sellers are to set $p = 1$; if all the other incumbents set $p = 1$, it is not profitable for a single incumbent to deviate and set $p \in (p_0, 1)$, as it will be undercut by the entrant. Deviating to p_0 is not strictly profitable either. Hence there exists a symmetric equilibrium at which all the incumbents set $p = 1$ and the entrant undercuts. Furthermore, it follows easily that this is also the unique symmetric equilibrium.

Proposition 1 *The game has a unique symmetric equilibrium, in which all the incumbents set $p = 1$ and the entrant sets the price marginally below and attracts all the informed customers. There also exist asymmetric equilibria, in which exactly one of the incumbents sets the price p^0 and all other incumbents and the entrant set $p = 1$.*

[6] If $S = 2$, the model is still well defined. However, our notion of a symmetric equilibrium (see below) has no meaning if there is only one incumbent seller.

[7] Here we deviate from Deneckere and Kovenock (1992), who assume that the informed buyers buy from the entrant when there is a tie involving her. Their tie-breaking rule makes the presentation of the model simpler, as the entrant attracts the informed buyers by setting the same price as the incumbent instead of "marginally below". However, we found our tie-breaking rule more appealing to use in the experiment, where the subjects choose prices from a discrete set anyway. For consistency between the model and the experiment we use the same tie-breaking rule when presenting the model.

In the unique symmetric equilibrium, prices posted by the incumbents and the entrant are insensitive to the number of incumbent sellers in the market and to the fraction of informed buyers.

In the asymmetric equilibrium, all players get the same payoff. The incumbents' payoffs are the same as in the symmetric equilibrium, while the entrant is worse off. However, if two (or more) incumbents *miscoordinate* (and both set $p = p_0$), they are worse off than in any of the equilibria.

2.3 Competitive preferences

As will be clear below, we do find that the participants in the experiment occasionally play the asymmetric equilibrium. Inspired by this, we explore the model when the agents have behavioural preferences. More specifically, we assume that the agents may have preferences over relative outcomes (competitive preferences). As will be clear below, this will be important for explaining our empirical results.

We consider a preference structure represented by the following utility function:

$$EU_i = E\pi_i - \frac{\alpha_i}{S-1}\sum_{j=1}^{S}\max[E\pi_j - E\pi_i, 0],$$

where π_i is profit (monetary pay-off), $\alpha_i \geq 0$ is a preference parameter, and the summation is over all sellers. In the following we label sellers with $\alpha_i > 0$ as behavioural sellers.[8]

The equilibrium in the game is summarized in the following proposition:

Proposition 2 *Suppose one or more of the incumbents are behavioural. With simultaneous price setting, the set of equilibria is independent of α. With sequential pricing, the following holds:*
a) The asymmetric equilibrium with non-behavioural preferences, in which one incumbent sets p_0 with probability 1, and the other incumbents as well as the entrant sets $p = 1$, is still an equilibrium.
b) The symmetric equilibrium with non-behavioural preferences, in which all incumbents set $p = 1$ and the entrant marginally undercuts is no longer an equilibrium.
c) Suppose all sellers are behavioural, with the same preference parameter α. Then there exists a unique symmetric equilibrium. In this symmetric equilibrium, the incumbents randomize. They set a high price $p = 1$ with probability $z > 0$, and a low price $p \leq p_0$ with probability $1 - z$, where

$$z = \left(\frac{p_0}{p_0 + \alpha/(S-1+\alpha)}\right)^{\frac{1}{S-2}}. \tag{1}$$

If they set a low price, they randomize on an interval below p_0. If all incumbents set $p = 1$, the entrant marginally undercuts. Otherwise the entrant sets $p = 1$.

The proof is given in appendix *A*.2. However, the results are very intuitive. With no entrants, all sellers get the same expected profit in equilibrium, and behavioural preferences do not matter for equilibrium play.

The entrant always gets at least as much as the incumbents, hence behavioural preferences will not influence the entrant's play. With one or more behavioural incumbents, the asymmetric equilibrium

[8] This formulation differs from the common formulations in the literature, as players in our set-up are assumed to value their payoffs from an *ex ante* perspective. This twist simplifies our calculations considerably while the interpretation remains the same. Players have aversion to unfavorable inequality, or competitive preferences. As such the formulation can be viewed as a special case of Fehr & Schmidt (1999), with $\alpha \geq 0$ (the utility weight on unfavorable inequality) and $\beta = 0$ (the utility weight on favorable inequality). Alternatively, it can be viewed as a special case (a linear version of the original ERC, negative reciprocity specification) of Bolton & Ockenfels (2000). Evidence on the reasonableness of such a specification is provided by De Bruyn & Bolton (2008).

where exactly one incumbent sets p_0 and the other sellers set $p = 1$ gives all sellers the same expected pay-off. It follows that the asymmetric equilibrium is still an equilibrium. Hence result *a)* follows.

Result *b)* is quite interesting. If at least one of the incumbents is behavioural, then the symmetric equilibrium with non-behavioural preferences where all incumbents set $p = 1$ is no longer an equilibrium. The reason is that if all incumbents play $p = 1$, a behavioural incumbent will be better off setting p_0, thereby obtaining the same monetary pay-off, and eliminating the pay-off difference between herself and the entrant.

Last, consider result *c)*. If all incumbents are behavioural, they will prefer to set a high price if the other incumbents set a low price, and a low price if all the others set a high price. Hence they will randomize and set the high price with probability given by (1). If they set a low price, there is a strictly positive probability that another incumbent also sets a low price. The standard undercutting-argument in the Varian model then applies, and the equilibrium distribution cannot have a mass point, say at p_0. If it had, a seller could discretely increase the probability of attracting the informed buyers by reducing the price marginally below p_0, thereby increasing its profit (recall that the entrant sets $p = 1$ in this case). This explains why there is a distribution below p_0 (however thin). Note that $z = 1$ when $\alpha = 0$, and that z goes to $\frac{p_0}{p_0+1}$ when α goes to infinity.

We want to explore heterogeneity in seller preferences. To that end, suppose sellers can be of two types: behavioural, with a strictly positive α (the same for all the behavioural agents), or profit-maximizing, with $\alpha = 0$. The probability that a randomly drawn seller is behavioural is denoted q. Both α and q are common knowledge. Hence, each incumbent seller's beliefs are that the probability that each of the other incumbent sellers are behavioural is q, and that the draws are independent. We assume that the behavioural incumbents get a utility penalty if the entrant gets a higher monetary pay-off than themselves, but not if the other incumbents (who have the same choice set) do.

Corollary 1 *Suppose sellers differ in preferences as described above. In the unique symmetric equilibrium of the pricing game, behavioural incumbents set $p = 1$ with probability $\bar{z}$, and a low price $p \leq p_0$ with probability $1 - \bar{z}$, where*

$$\bar{z} = \max\left(\frac{z - 1 + q}{q}, 0\right) \tag{2}$$

where z is given by (1).

The proof is given in the appendix. When the $\bar{z} \geq 0$ constraint does not bind, the unconditional probability that an incumbent sets a high price is z, i.e., the same probability as when all agents are behavioural. The fact that only a fraction q of the incumbents are behavioural induces the behavioural agents to increase the probability of setting a low price proportionally.[9] If there are too few behavioural sellers, the behavioural sellers strictly prefer to set a low price, and do so with probability 1.

3 Experiment

The centerpiece of our design is to test the striking predictions regarding the effects of sequential pricing in the Varian-model framework. To do this we run separate sessions with simultaneous and with sequential price setting in accordance with the model above. That is, with sequential pricing one seller observes the other sellers' prices before it posts its own price. In the instructions to the experiment we used the term "Entrant" for the second mover and "Incumbents" for first movers. This is for convenience only. There is no difference between entrants and incumbents except for the sequencing of their price setting decisions. Sample instructions are available in appendix *C*.

[9] When $\bar{z} > 0$ we have that $1 - \bar{z} = \frac{1-z}{q}$

To focus on sellers' pricing behavior, we implement the model by human subjects posting prices while robot buyers make automated purchasing responses. The experiment consists of seven treatments in total. In the first six treatments (the small markets) there are one hundred robot buyers and three human sellers (S) in a market. These treatments vary along two dimensions: The number of uninformed robot buyers (U) and whether there is sequential pricing (Yes) or not (No). In our last treatment (the large market, L) we double the number of human sellers in a sequential price setting.

Prices are integers in the interval $[0, 100]$ and cannot be revised once posted. Robot buyers make their purchases after all prices are posted. Each robot buys exactly one unit. Uninformed robot buyers are divided equally among sellers. Informed robot buyers purchase at the lowest price in the market, and are divided equally among sellers that tie on the lowest price.[10] Sellers have marginal costs of zero and 100 units for sale, so per period profits equal the product of the price posted and the number of units sold.

3.1 Design

Our experiment is designed to test the model's directional predictions on price posting (see proposition 1). Without competitive preferences (α equals zero), incumbents have nothing to gain by setting the price equal to p_0. On the contrary, they face a risk of miscoordination by doing so if more than one agent sets p_0. Thus, at the outset we would not expect to see asymmetric equilibrium play with prices at p_0.[11]

Table 1 provides an overview of the design. Column 1 gives the notation for our treatments, with superscripts indicating sequential pricing Y or not N (simultaneous pricing) and subscripts indicating the number of uninformed buyers U. Columns $2-4$ display the treatment variations. Columns $5-6$ provide the resulting indifference prices p_0, and expected posted prices in the symmetric equilibrium $E(p)$. For future reference the expected posted prices in the asymmetric equilibrium, $E(p')$, are also included in column 7. Finally, columns 8 and 9 display information about the scale of the experiment.

	U	S	Sequential	p_0	$E(p)$	$E(p')$	Blocks	Subjects
T_{15}^{N}	15	3	No	5.6	32.3	68.5	8	72
T_{30}^{N}	30	3	No	12.5	45.7	70.8	8	72
T_{60}^{N}	60	3	No	33.3	67.6	77.8	8	72
T_{15}^{Y}	15	3	Yes	5.6	100	68.5	8	72
T_{30}^{Y}	30	3	Yes	12.5	100	70.8	10	90
T_{60}^{Y}	60	3	Yes	33.3	100	77.8	8	72
L_{30}^{Y}	30	6	Yes	6.7	100	83.8	6	108

Table 1: *Design overview.*

Regarding prices, the table shows that expected posted prices in the asymmetric equilibrium are equal with simultaneous and sequential pricing. In the symmetric equilibrium, expected posted prices are substantially lower with simultaneous pricing than with sequential pricing. The expected *transaction prices* (where prices are weighted by the expected number of sales, not reported in the table) show a slightly different pattern. With simultaneous pricing, they are the same in the asymmetric and symmetric equilibria. With sequential pricing, they are strictly lower in the asymmetric than in the symmetric equilibria.

[10] If equal division does not result in an integer number, the smallest remainder is distributed randomly on sellers that tie for the lower price.

[11] Posting p_0 is a best response strategy if the incumbent seller in question assigns zero probability to the event that one of the opponents play p_0.

Assuming $\alpha = 0$ and an inclination among participants to play the symmetric strategy, we have the following directional hypotheses:

1. Posted prices are higher when pricing is sequential compared to simultaneous for any share of uninformed buyers.
2. Posted prices with sequential pricing are insensitive to the number of uninformed buyers.
3. Posted prices with sequential pricing are insensitive to the number of incumbent sellers in the market.
4. Posted prices with simultaneous price setting are monotonically increasing in the number of uninformed buyers and monotonically decreasing in the number of sellers.

3.2 Implementation

In all treatments the same game is played 60 periods in succession. Small markets are formed randomly from fixed matching blocks of 9 human sellers in each new period. Large markets are formed randomly from fixed matching blocks of 18 human sellers in each new period. Unique subjects are used in each treatment. In small markets with sequential pricing each subject is the entrant (one of the two incumbents) in one (two) sequence(s) of 20 consecutive periods. In large markets each subject is the entrant (one of the five incumbents) in one (five) sequence(s) of 10 consecutive periods. Subjects are randomly allocated to sequences at the beginning of the experiment. In the analysis we regard average behavior in a matching block over all 60 periods as an independent observation.

The number of matching blocks was determined in a pilot. With $\bar{p}(\cdot)$ denoting the average posted price in treatment $(\cdot)$, the pilot collected data on the treatment effect $\left[\bar{p}(T^Y_{30}) - \bar{p}(T^N_{30})\right]$. Based on the observed treatment effect and the variances of the pilot, a power of 90 percent or more requires 4 blocks per treatment (given a 5 per cent significance level and a Wilcoxon rank sum test).[12] Since the theoretical difference in expected prices is shrinking as one moves from $\left[\bar{p}(T^Y_{30}) - \bar{p}(T^N_{30})\right]$ to $\left[\bar{p}(T^Y_{60}) - \bar{p}(T^N_{60})\right]$ (see Table 1), we decided to err on the safe side and aimed for 8 blocks in all treatments. The two extra blocks collected in T^Y_{30} is a result of an administrative error. Because of the onset of the corona pandemic, we only managed to collect data for 6 blocks in the large market treatment before lock-down. A pre-study plan for the experiment, including our pilot, was posted at the AEA RCT-registry on 25/04/2019.[13] The plan covered the small markets. This plan was updated with the large market treatment (L^Y_{30}) on 12/02/2020.

Sessions were conducted in the Research Lab at BI Norwegian Business School in Oslo, and at the LEE lab at the University of Copenhagen in the period May 2019 to March 2020.[14] Subjects were recruited from the general student populations of BI Norwegian Business School and the University of Oslo, and the University of Copenhagen respectively.[15] Recruitment and subject management was administered through ORSEE (Greiner 2015). On arrival subjects were randomly allocated to cubicles (to break up social ties). Written instructions were handed out and read aloud by the administrator (to achieve public knowledge of the rules). All decisions were taken anonymously in a network of computers. After

[12] Calculations were performed using the software in Bellemare et al. (2016).

[13] `https://www.socialscienceregistry.org/trials/4094`

[14] See appendix B.5 for more details on session locations, and analysis showing that different locations does not produce different results.

[15] One may of course ask how representative observed behavior in these samples is. Mounting evidence shows that behaviors in convenience samples (CSs) are generally representative of the general population; of students who do not self-select into lab experiments; and of workers in online labor markets, such as, Mechanical Turk (Yariv & Snowberg 2021). Moreover, behaviors in CSs often compare well to that of professionals, such as traders and managers (Fréchette 2016; Ball & Cech 1996). Taking this research into account, we believe our results are informative of a mechanism that may also be important in real posted price markets.

each period, subjects received minimal feedback consisting of posted prices in the current market, own payoff from the current period, and own cumulative payoff. The protocol was implemented in zTree (Fischbacher 2007).

A total of 558 subjects participated in the experiment. In total 10.080 pricing games were played, in which a total of 33.480 prices were posted. On average subjects in the Norwegian sessions earned 26 USD while subjects in the Danish sessions earned 30 USD.[16]

4 Results

In what follows we present our results in four sections. The first section describe the time paths of play. The second section addresses the directional hypotheses under the assumption that the unique symmetric equilibrium is played assuming $\alpha = 0$ (no behavioural preferences). The third section opens up for asymmetric pure strategy equilibrium play and classifies behavior in terms of near equilibrium play using individual level data. The fourth section analyses the data assuming $\alpha > 0$.

4.1 Time paths of play

Figure 1 presents time paths of play. Solid black lines display average posted prices over the 60 periods of the experiment, broken down by treatments. Dashed red lines indicate the expected price posted in the symmetric equilibrium. Recall that in the symmetric equilibrium of the simultaneous pricing games prices are posted according to a mixed strategy on a support that shrinks from below as the number of uninformed buyers increases. The result is an increase in expected prices as the number of uninformed buyers increase. As noted, in the sequential pricing games prices posted in the symmetric equilibrium are point prices ($p = 100$ for incumbents and $p = 100 - \varepsilon$ for the entrant) that are insensitive to the size of the market and the number of uniformed buyers.

[16] In the experiment, all prices and profits were denominated in an experimental currency unit (ECU). The exchange rates between ECU and the local currency in the different sessions were set so as to yield comparable expected variable earnings across sessions. At the end of the experiment, subjects were paid in the local currency based on total earnings in ECU from all games played. Payments were rounded to the nearest Krone, Norwegian and Danish, respectively. Subjects were paid privately in cash upon exiting the lab. The higher Danish total earnings reflect a mandatory show-up fee in the LEE lab. The resulting variable earnings are comparable in the two locations of the experiment.

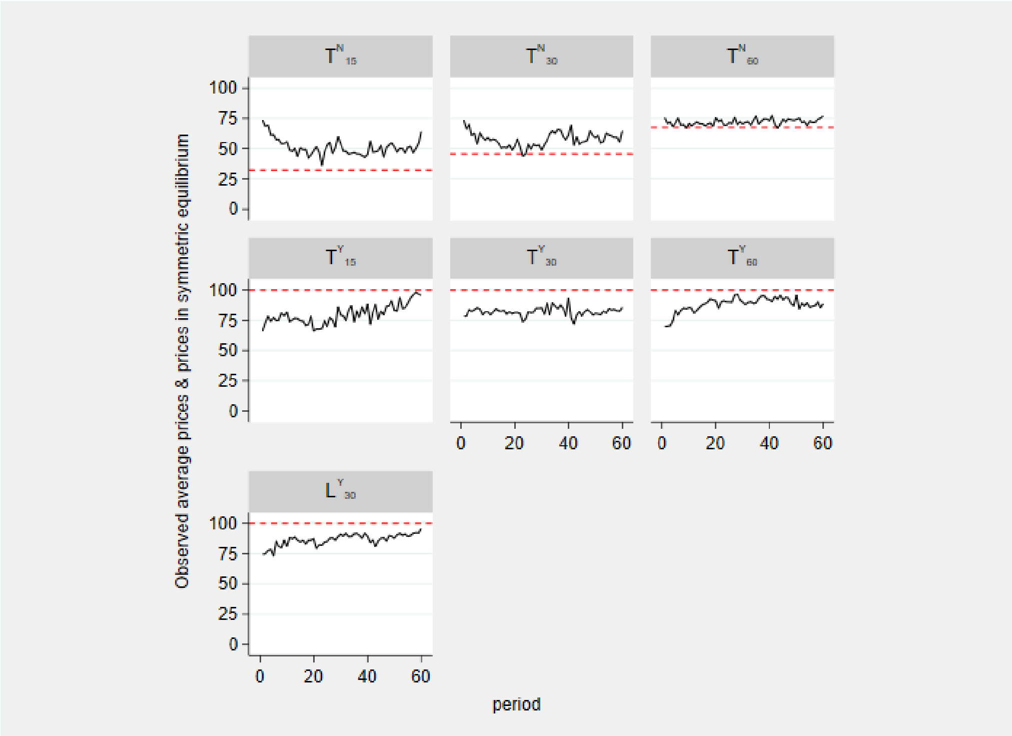

Figure 1: *Time paths of play.*

By eyeballing Figure 1 it appears that with simultaneous pricing and 15 and 30 uninformed buyers, prices approach from above to a level higher than the symmetric Nash prices, whereas with 60 uninformed buyers prices are close to the symmetric Nash from period one onwards. With sequential pricing, prices seem to approach the symmetric Nash equilibrium from below in the small market with 15 uninformed buyers, and in the large market with 30 uninformed buyers. In the small market with 30 uniformed buyers prices hover below the symmetric Nash. Finally, in the small market with 60 uninformed buyers prices seem to approach to a level somewhat below the symmetric Nash. In appendix B.1 we lend support to these impressions by formally testing whether behavior is moving closer the Nash price in each matching block.

4.2 Treatment differences

In our analysis of treatment effects we follow a conservative approach and use the full data set. Appendix B.2 contains parallel tests using data from the last half of the experiment (periods $31 - 60$). Results remain qualitatively the same. Figure 2 displays the average posted prices (bars) over all 60 periods per treatment as well as expected prices in the symmetric equilibrium (circles). The left panel shows posted prices for small markets without sequential pricing for varying numbers of uninformed robot buyers (15, 30, 60). The right panel displays the corresponding information for markets with sequential pricing. In what follows treatment differences are analyzed using matching blocks as units of observation and Wilcoxon rank sum tests (reporting exact p-values).[17] We comment on the large markets in the text.

[17] Details of these tests (including average posted prices per block as raw data), are provided in appendix B.2.

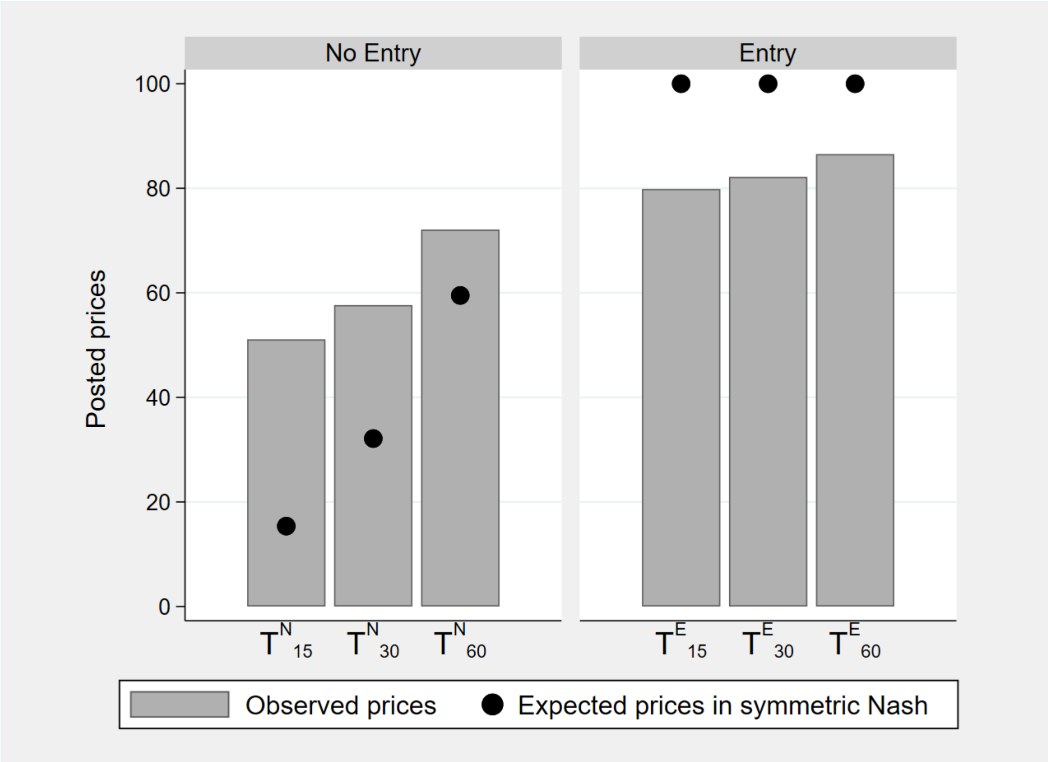

Figure 2: *Observed mean prices and expected prices in symmetric equilibrium*

Figure 2 summarizes the findings in Figure 1. There are substantial deviations from the symmetric equilibrium in all treatments. For treatments with simultaneous pricing, average prices lie $5-19$ price points above the symmetric equilibrium, while they lie $14-20$ price points below the symmetric equilibrium with sequential pricing. We find that the model predictions deviate from actual behavior when the competitive environment is close to Bertrand competition. This was expected. Similar results are obtained in earlier studies (e.g. Helland et al 2017), and are rationalized by the fact that the gains from playing the equilibrium strategy are very low while the potential gains from deviating if others also deviate are large.[18] With sequential pricing, the lower than equilibrium prices may to some extent be explained by the fact that the agents can only err on the downside relative to equilibrium behavior. More importantly however, the deviations between observed prices and equilibrium prices can also be due to asymmetric equilibrium play. We return to the latter below.

Judged as directional predictions, theory fares exceedingly well in the experimental data. First, prices are significantly higher when there is sequential pricing compared when there is not for any share of uniformed buyers: $\left[\bar{p}(T^Y_{15}) - \bar{p}(T^N_{15})\right] = 28.8$; $\left[\bar{p}(T^Y_{30}) - \bar{p}(T^N_{30})\right] = 24.6$; and $\left[\bar{p}(T^Y_{60}) - \bar{p}(T^N_{60})\right] = 14.4$, with $p < 0.001$ for each comparison. The very low p-values indicate that the power calculation in our pilot succeeded.[19] We conclude that sequential pricing causes prices to move towards monopoly levels.

Second, there is no significant differences in prices over the share of uninformed buyers in markets with sequential pricing: $\left[\bar{p}(T^Y_{30}) - \bar{p}(T^Y_{15})\right] = 2.3$, $(p = 0.573)$; $\left[\bar{p}(T^Y_{60}) - \bar{p}(T^Y_{30})\right] = 4.3$, $(p = 0.237)$; and $\left[\bar{p}(T^Y_{60}) - \bar{p}(T^Y_{15})\right] = 6.6$, $(p = 0.105)$. As the share of uninformed buyers increases, there is a modest increase in observed prices. However, the observed increases are not significant at conventional levels,

[18] Helland et al. (2017) find that in simultaneous pricing duopolies, deviation from the symmetric equilibrium becomes less pronounced as the number of uninformed buyers increases. This pattern is consistent with a quantal response equilibrium in which errors become more costly as the number of uninformed decreases. We note that a similar pattern is observed in the triopolies of Figure 1.

[19] A detailed argument for this statement is found in Benjamin et al. (2018).

and far from significant at the stricter levels promoted by Benjamin et al. (2018) for new experimental findings (i.e., a significance threshold of 5/1000 rather than the conventional 5/100).

Third, there is no significant differences in prices over the small and the large markets with sequential pricing: $\left[\bar{p}(L_{30}^{Y}) - \bar{p}(T_{30}^{Y})\right] = 5.9$, with $p = 0.181$. The null of identical price posting in small and large markets cannot be rejected at conventional levels.

Finally, we observe substantial and significant price increases as the number of uninformed buyers increases in markets without sequential pricing: $\left[\bar{p}(T_{30}^{N}) - \bar{p}(T_{15}^{N})\right] = 6.5$; $\left[\bar{p}(T_{60}^{N}) - \bar{p}(T_{30}^{N})\right] = 14.5$; and $\left[\bar{p}(T_{60}^{N}) - \bar{p}(T_{15}^{N})\right] = 21.0$, with $p < 0.001$ for all comparisons. Theoretical and empirical CDFs of prices for our treatments without sequential pricing are displayed in appendix B.3. We note that the shape of the empirical CDFs agrees with the shape of the theoretical distributions, and that the empirical distributions obey the lower bound of the support (p_0) remarkably well.

4.3 Individual level analysis

Recall that observed average prices are below the symmetric equilibrium price in the games with sequential pricing (see Figures 1 and 2). Can this result be explained by asymmetric equilibrium play in which one incumbent sets $p = p_0$? Figure 3 displays the distribution of prices set by incumbents over all periods in treatments with sequential pricing. The dashed lines mark p_0. The picture is remarkably similar across all treatments: there is a large spike close to the monopoly price of 1, and a much smaller but still sizable distribution of prices in a small interval around p_0, and not many occurrences of price choices elsewhere. We take this picture to be broadly consistent with overall equilibrium play.

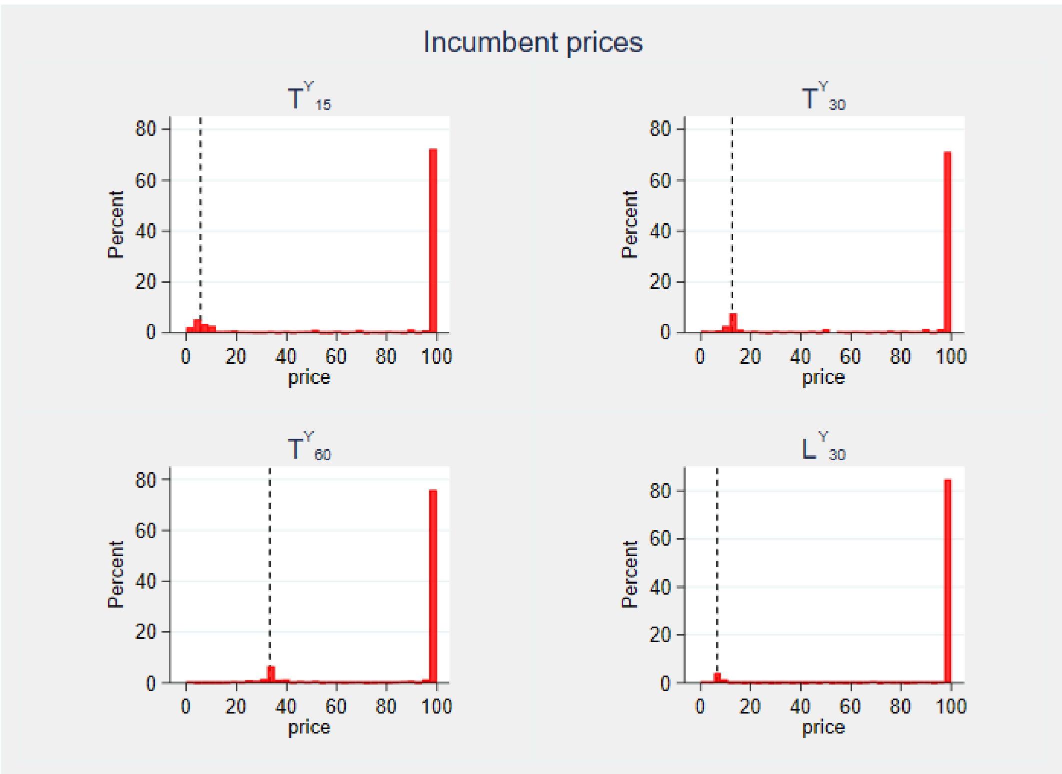

Figure 3: *Distribution of incumbent prices under sequential pricing.*

In what follows we use individual level data to classify decisions and games in our treatments with sequential pricing in terms of *near* Nash behavior, thereby providing direct evidence on the composition of aggregate prices. For the classification we assume play of pure strategies. This assumption is relaxed below, where we allow for mixed strategies.

In the classification we follow a cautious path in allowing for a deviation of only 1 price point from true Nash behavior. As above, let p^E be the price posted by the entrant, p^I the price posted by an incumbent, p^I_{min} the lowest price posted by an incumbent, and p_0 the indifference price in a market. Our definitions of near Nash behavior and near Nash equilibrium play for our chosen deviation threshold are then:

- *Entrant best response (EBR)*: Entrant's price p^E is defined as entrant best response if $p^E \geq 99$ when $p^I_{min} < p_0 + 1$; or if $p^I_{min} - 1 \leq p^E < p^I_{min}$ when $p^I_{min} > p_0 - 1$.
- *Incumbent Nash strategy (INS)*: Incumbents' price p^I is defined as an incumbent Nash strategy if $p^I = p_0 \pm 1$; or if $p^I \geq 99$.
- *Symmetric Nash equilibrium outcome (SE):* The outcome of a game is counted as a symmetric Nash equilibrium (SE) if all incumbents post prices $p^I \geq 99$ and the entrant plays best response.
- *Asymmetric Nash equilibrium outcome (AE)*: The outcome is counted as an asymmetric Nash equilibrium (AE) if at most one incumbent posts a price $p^I = p_0 \pm 1$, the other incumbent(s) post(s) prices $p^I \geq 99$, and the entrant plays best response.
- *Miscoordination outcome (MC)*: The outcome of a game is counted as a miscoordination (MC) if more than one incumbent posts a price $p^I = p_0 \pm 1$, and the entrant plays best response.

Our choice of cut-off is, of course, debatable. In appendix B.4 we run the analysis allowing for a more liberal deviation of 5 price points from Nash behavior. This leads to a classification with a moderate increase in near Nash behavior. However, the patterns of near Nash behavior (see below) are retained with the more liberal deviation threshold.

Figure 4 displays the proportions of (EBR) and (INS) (i.e., individual decisions) while Figure 5 shows the proportions of equilibrium consistent play (SE), (AE) and (MC) on the market level (i.e., games). For both figures, data are aggregated over all four treatments with sequential pricing. While grey bars use all data red bars use data from the last half of the experiment (periods $31 - 60$).

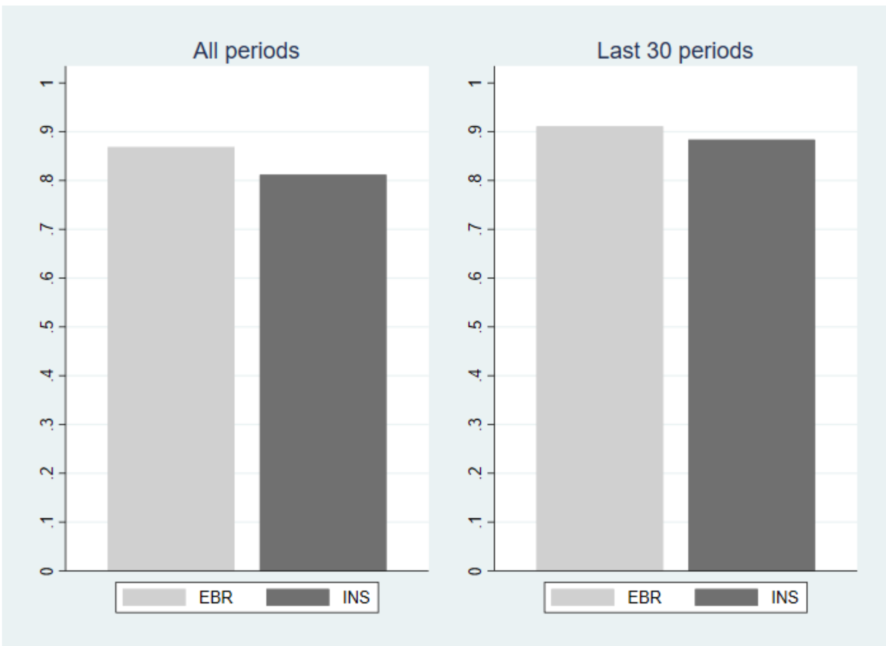

Figure 4: *Fractions of individual price postings consistent with equilibrium strategies: entrant best response (EBR) and incumbent Nash strategy (INS). 1 price point deviation allowed.*

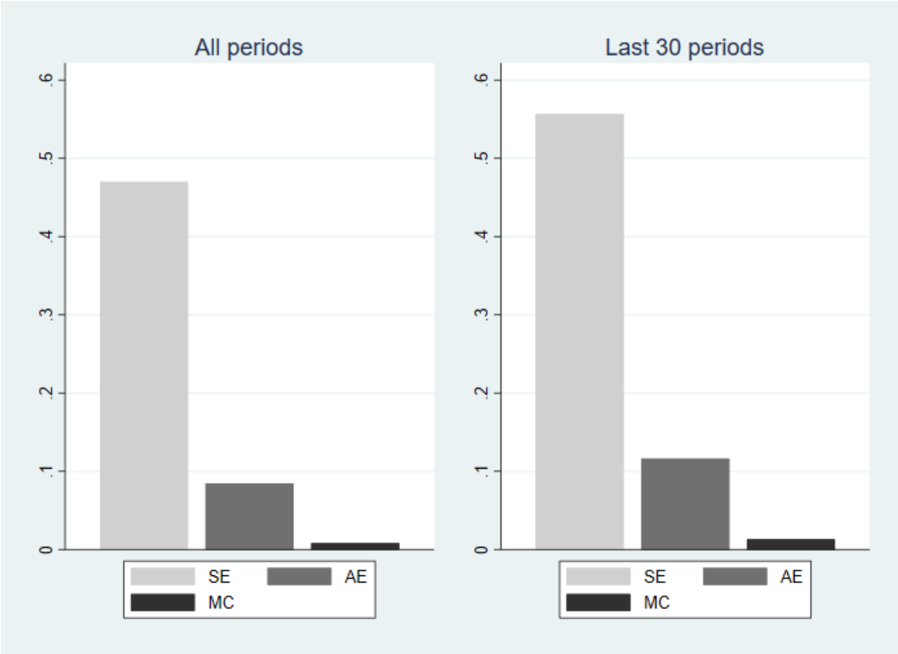

Figure 5: *Fractions of markets consistent with: symmetric Nash equilibrium (SE), asymmetric Nash equilibrium (AE), and miscoordination (MC). 1 price point deviation allowed.*

From Figure 4 we appreciate that, even with a very conservative cut-off at 1 price point, entrants play best response in 87 percent of all games, and in 91 percent of games in the latter half of the experiment. Incumbents post prices that are part of a Nash equilibrium in 80 percent of decisions when all periods are considered, and in 88 percent of decisions in the latter half of the experiment.

Figure 5 shows that observed market behavior is consistent with the unique symmetric equilibrium being played in 47 percent of all games, and in 56 percent of games in the latter half of the experiment. Moreover, observed behavior is consistent with the asymmetric equilibrium being played in 8 percent of all games, and in 12 percent of games in the latter half of the experiment. Finally, observed behavior is consistent with miscoordination in 1 percent of all games and in the latter half of the experiment.

4.4 Analysis with competitive preferences

Our individual level analysis raises a natural question: Why do we observe a relatively large proportion of asymmetric equilibrium play? After all, pure money maximizers have nothing to gain by successfully instigating coordination on the asymmetric equilibrium, and much to lose if such an attempt fails. Can competitive preferences rationalize our observations of price choices consistent with asymmetric equilibrium play?

In appendix $B.6$ we document that most subjects always choose the high price, whereas a minority mix between setting the low and the high price. This observation fits well with the model with heterogeneous preferences described in section 2.3, in which each seller is behavioural with a given probability q, and all behavioural sellers have the same value of α. The equilibrium properties of this model specification are characterized in Corollary 1, stating that the behavioural sellers randomize between setting $p = 1$ with probability $\bar{z}$ and a price at or just below p_0 with probability $1 - \bar{z}$.[20]

[20] Conditional on setting a low price, the expected posted price of a behavioural seller is very close to p_0 for reasonable parameter values. For instance, for treatment T^Y_{30}, $p_0 = 12.5$ while the expected price when playing low is 12.1. In what follows we simplify the analysis slightly and assume that the sellers, when setting a low price, set $p = p_0$. See appendix $A.3$ for details.

In what follows we calibrate q and α using observations from the latter half of the experiment only. To this end, we first categorize subjects as behavioural or not based on their price choices as incumbents. Subjects that always choose $p \geq 99$ are labeled non-behavioural, whereas subjects that at some point during the experiment choose $p = p_0 \pm 1$ are labeled behavioural.[21] We then calculate the empirical frequency $1 - \hat{q} = \frac{\text{non-behavioural subjects}}{\text{behavioural subjects + non-behavioural subjects}}$ treatment-by-treatment. Next, we calculate the empirical frequency $\hat{z} = \frac{\hat{p}_{high}}{\hat{p}_{low}+\hat{p}_{high}}$ conditional on subjects being labeled as behavioural, where $\hat{p}_{low}$ and $\hat{p}_{high}$ are frequencies of observed prices $p = p_0 \pm 1$ and $p \geq 99$, respectively.

We calculate $\hat{z}$ treatment-by-treatment as an average over behavioural subjects' individual frequencies. Table 2 reports for each treatment the fraction $\hat{q}$ of behavioural incumbents and the frequency $1 - \hat{z}$ at which these incumbents play the asymmetric equilibrium strategy.

	$\hat{q}$	$1-\hat{z}$
T^Y_{15}	0.36	0.26
T^Y_{30}	0.36	0.34
T^Y_{60}	0.29	0.21
L^Y_{30}	0.26	0.21

Table 2: *Frequencies.*
Based on last 30 periods.

We then proceed by calibrating α for the behavioural incumbents. We do this by choosing α so as to minimize the sum $\sum_i(\tilde{z}_i - [(1-\hat{q}_i) + \hat{q}_i\hat{z}_i])^2$ over treatments i, where $\tilde{z}_i$ is the *ex ante* equilibrium probability of an incumbent playing p_{high} given α and $\hat{q}_i$.[22] We calibrate α jointly for the small markets, which yields $\alpha = 0.02$. We also calibrate α separately for the large market, and obtain $\alpha = 0.08$ in this market (T^L_{30}).[23]

To explore the properties of the calibrated model, let $E[p^{mix}]$ denote incumbents' *ex ante* expected posted prices given the treatment-specific value $\hat{q}$ and the calibrated value of α. Furthermore, let AE^{eq} denote the corresponding probability that asymmetric equilibrium is played (in which exactly 1 incumbent seller sets a low price). Finally, let AE^{Share} denote the empirical counterpart to AE^{eq}, the observed number of outcomes consistent with asymmetric equilibrium play over the total number of outcomes consistent with any (attempted) equilibrium play, $AE^{Share} = \frac{AE}{SE+AE+MC}$. The numbers are reported in Table 3, all for the latter half of the experiment.

	α	$E[p^{mix}]$	Observed	AE^{eq}	AE^{Share}
T^Y_{15}	0.02	87.7	86.0	0.23	0.14
T^Y_{30}	0.02	94.8	82.2	0.11	0.20
T^Y_{60}	0.02	98.7	89.7	0.04	0.13
L^Y_{30}	0.08	95.3	92.0	0.20	0.21

Table 3: *Calibration results.*
Based on last 30 periods.

Including competitive preferences for a subset of the sellers induces asymmetric play, which in turn reduces expected equilibrium prices and brings the model's theoretical predictions more in line with observed prices. Our interpretation is that the model with the calibrated competitive preference parameter

[21] The probability that a randomly drawn incumbent seller sets the high price 30 times in a row is given by $1-q+q\bar{z}^{30} \approx 1-q$. The approximation is very tight for relevant values of $\bar{z}$, for instance is $\bar{z}^{30} = 0.001$ for $\bar{z} = 0.8$. We therefore ignore the term $q\bar{z}^{30}$.

[22] MatLab codes are available upon request.

[23] These values are lower than the corresponding values obtained in Fehr and Schmidt (1999). The differences may reflect that our experiment is in a market context whereas Fehr and Schmidt's estimates are based on bilateral ultimatum games.

α for behavioural incumbents goes a long way in rationalizing our observation that a substantial share of price choices are consistent with asymmetric equilibrium play.

5 Conclusion

In this paper we analyze sequential price setting in the Varian (1980) model framework. Compared with simultaneous pricing, a sequential price setting dramatically changes the incentives of the sellers and hence the equilibrium outcome of the price posting game. In the symmetric equilibrium of the model, which we expect rational income-maximizing agents to play, sequential pricing pushes prices toward monopoly levels. There also exist asymmetric equilibria in which prices do not increase.

We test the model's predictions in the laboratory. Our experimental data strongly supports the qualitative model predictions. In particular we observe a significant rise in prices of sequential pricing, all else constant. However, there is a non-negligible fraction of players that set low prices in accordance with the asymmetric equilibrium, which is puzzling. We show that the puzzle to a large extent can be resolved by introducing competitive preferences in the model. The reason is that incumbent sellers then have an incentive to set low prices in accordance with the asymmetric equilibrium, as this reduces the difference between their own payoffs and that of the entrant.

Overall, our interpretation of the experimental results is that the subjects understand and respond to the different incentives the model with and without sequential pricing give rise to. The observation that the subjects play the asymmetric equilibrium with a non-negligible probability may indicate a (weak) tendency for competitive preferences in the subject sample.

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Appendix

Appendix overview

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  - A.1 Simultaneous pricing;
  - A.2 Proof of Proposition 2;
  - A.3 Proof of Corollary 1.
- ◦ B Data appendix:
  - B.1 Dynamic regressions;
  - B.2 Treatment tests;
  - B.3 Price distributions in treatments with simultaneous pricing;
  - B.4 Classifying near Nash behavior permitting 5 price points deviation;
  - B.5 Location analysis;
  - B.6 Subject heterogeneity.
- ◦ C Instructions appendix:
  - C.1 Instructions for treatment T_{30}^{N}- With simultaneous pricing, 30 uninformed buyers, and 3 sellers;
  - C.2 Instructions for treatment T_{30}^{Y}- With sequential pricing, 30 uninformed buyers, and 3 sellers.

A Model Appendix

A.1 Simultaneous pricing

This section solves out the price dispersion equilibrium when there is no sequential pricing.

Let $\mu^{n,N}(p_s, p_{-s})$ denote the (expected number of) buyers to a seller who sets the price p_s when the opponents' vector of prices is p_{-s}. Then $\mu^{n,N}(p_s, p_{-s}) = N + U/S$ if p_s is the strictly lowest price and $\mu^{n,N}(p_s, p_{-s}) = U/S$ if one of the opponents sets the strictly lowest price (if more than one seller set the lowest price, the informed buyers are divided equally between the sellers). Varian (1980) shows that the symmetric equilibrium entails a mixed strategy given by the c.d.f. $F(p)$ with support $p \in [p_0, 1]$.[24] A seller that sets $p = 1$ only sells to uninformed buyers, and obtains a profit of U/S. From the definition of a mixed-strategy equilibrium it follows that all prices in the support of F give rise to the same profits. Hence

$$(U/S + N(1 - F(p_s))^{S-1})p_s = U/S \tag{3}$$

The left-hand side shows the pay-off when setting a price p_s. Independent of the price, the seller will sell in expectation to U/S uninformed buyers. If it sets the lowest price, it will in addition sell to N informed buyers, and this happens with probability $(1 - F(p))^{S-1}$. The right hand side shows the expected pay-off when setting $p_s = 1$. Solving for $F(p)$ gives:

$$F(p) = 1 - \left(\frac{1-p}{p}\frac{U}{SN}\right)^{1/(S-1)} \quad \text{with } p \in [p_0, 1]. \tag{4}$$

Let p_0 denote the lowest price in the support of F. A seller that sets p_0 sets the lowest price with probability 1. From (3) it then follows that $p_0 = \frac{U}{U+SN}$. It follows directly that the expected posted price as well as the expected transaction price is a decreasing function of the fraction of informed to uninformed buyers N/U.

A.2 Proof of Proposition 2

We first want to show that with simultaneous pricing the set of equilibria is independent of α.

First, consider an equilibrium for $\alpha = 0$. In the equilibrium allocation, everyone get the same expected payoff, and hence α does not influence payoffs. Furthermore, a deviation is profitable with $\alpha > 0$ if and only if it is profitable with $\alpha = 0$. Hence the $\alpha = 0$ equilibria are still equilibria with $\alpha > 0$.

Suppose then that there exists an equilibrium for $\alpha \neq 0$ that is not an equilibrium for $\alpha = 0$. In this equilibrium the expected payoffs must differ between the agents (otherwise it would have been an equilibrium for $\alpha = 0$). Hence the equilibrium must by asymmetric. An agent can always set $p = 1$ and sell to the uninformed and get a monetary payoff of $\frac{U}{S}$. Consider an asymmetric equilibrium in which some agents get a strictly higher monetary payoff π'. Let p' denote the infimum of the support of this agent, which then gives a pay-off of π'. Then it must be optimal for the agent with a strictly lower pay-off to set $p' - \varepsilon$ for some ε and get a monetary payoff strictly higher than $\frac{U}{S}$, which contradicts equilibrium.

We will continue to show a)-c).

a) The asymmetric equilibrium gives the entrant and the incumbents the same expected payoffs. Hence the utility of deviating is as if $\alpha = 0$. Since the asymmetric equilibrium is an equilibrium with $\alpha = 0$, the claim follows.

[24] Varian (1980) also shows that $F(p)$ has no mass points so that ties are a measure zero event. It is also straight-forward to show that the supremum of the support is equal to 1.

b) In the symmetric equilibrium for $\alpha = 0$, the entrant gets a higher monetary pay-off than the incumbents. If all the other sellers set $p = 1$, an incumbent behavioural seller would like to deviate and set p_0, as that would eliminate the differences in expected incomes without reducing the agent's monetary payoff. Hence the symmetric equilibrium with $\alpha = 0$ is not an equilibrium if at least one seller has $\alpha > 0$.
c) Consider a seller in a symmetric equilibrium as described in the proposition. Suppose a seller sets $p = 1$. The probability that all the other sellers set $p = 1$ is z^{S-2}. The payoff if they do is $\bar{\pi} - \frac{\alpha}{S-1}(\bar{\pi} + N - \bar{\pi}) = \bar{\pi} - \frac{\alpha}{S-1}N$, where $\bar{\pi} = U/S$. If one or more of the other incumbents set a low price, the payoff is $\bar{\pi}$. Hence the payoff if setting $p = 1$ is

$$U^1 = \bar{\pi} - z^{S-2}\frac{\alpha}{S-1}N. \tag{5}$$

Suppose instead that the seller sets p low. The seller will get the same payoff if setting p^0 or randomizing below p^0. The probability that the seller sets the lowest price if setting p_0 is z^{S-2}. Hence it follows that the expected monetary payoff when setting a low price is (since the pay-off is $\bar{\pi}$ if $z = 1$)

$$\pi^l = \bar{\pi} - (1 - z^{S-2})p_0 N \tag{6}$$

The entrant will set $p = 1$ and get an expected payoff of $\bar{\pi}$. Hence the utility if setting p low is (since all the other incumbents get the same payoff in expected terms)

$$\begin{aligned} U^2 &= \pi^l - \frac{\alpha}{S-1}(\bar{\pi} - \pi^l) \\ &= \bar{\pi} - (1 + \frac{\alpha}{S-1})(1 - z^{S-2})p_0 N. \end{aligned} \tag{7}$$

In equilibrium we must have that $U^1 = U^2$. It follows that

$$\bar{\pi} - z^{S-2}\frac{\alpha}{S-1}N = \bar{\pi} - (1 + \frac{\alpha}{S-1})(1 - z^{S-2})p_0 N,$$

or

$$z^{S-2} = \frac{p_0}{p_0 + \alpha/(S-1+\alpha)}. \tag{8}$$

It follows that $z = 1$ when $\alpha = 0$, and that z goes to $\frac{p_0}{p_0+1}$ when α goes to infinity.
Finally, the distribution of prices below p_0 must be such that

$$[z + (1-z)(1 - F(p))]^{S-2}pI + p\frac{U}{S} = \pi^l \tag{9}$$

which gives

$$F(p) = \frac{1}{1-z}\left[1 - \left(\frac{\pi^l}{pI} - \frac{U}{SI}\right)^{\frac{1}{S-2}}\right] \tag{10}$$

From (6) and (8) it follows that

$$\pi^l = \bar{\pi} - \frac{\alpha p_0 I}{p_0(S+\alpha) + \alpha}$$

Last, the incumbent that sets a price at the bottom of the support sells to $I + U/S$ buyers, hence we must have

$$p_{\min} = p_0 - \frac{\alpha p_0 I}{p_0(S+\alpha) + \alpha}\frac{S}{IS + U}.$$

A.3 Proof of Corollary 1

Suppose now that with probability q an incumbent seller is behavioural, and with the complementary probability $1 - q$ she is not. All the behavioural sellers have the same cost parameter α.

The structure of the symmetric equilibrium is as above: with probability $\bar{z} > 0$ a behavioural seller sets $p = 1$, and with the complementary probability a low price. If setting a low price, the seller randomizes on an interval $[p_{\min}, p_0]$ according to a distribution that has no mass points. The expected utility is the same for all prices in the support. Since $\bar{z} > 0$, a non-behvioural incumbent seller always sets $p = 1$.

The probability that all the other incumbents are playing $p = 1$ is given by $(1 - q + q\bar{z})^{S-2} = \tilde{z}^{S-2}$, where $\tilde{z} = 1 - q + q\bar{z}$. The expected utility for a behavioural seller if playing $p = 1$ is thus given by

$$U^1 = \bar{\pi} - \tilde{z}^{S-2}\frac{\alpha}{S-1}N. \tag{11}$$

which is equal to (5) with z replaced by $\tilde{z}$.

The expected profit if playing down is the same if playing p_0 or a lower price, hence we consider playing p_0. The utility cost of a lower pay-off is $\frac{\alpha}{S-1}(\bar{\pi} - \pi^l)$. Hence the utility of playing down is equal to

$$U^2 = \pi^l - \frac{\alpha}{S-2}(\bar{\pi} - \pi^l),$$

which is equal to (7). In equilibrium we must have that $U_2 \geq U_1$, with equality if $\bar{z} > 0$. With equality we get that

$$\tilde{z}^{S-2} = \frac{p_0}{p_0 + \alpha/(S-1+\alpha)} \tag{12}$$

which is equal to (8) with z replaced with $\tilde{z}$.

Recall that $\tilde{z} \equiv (1-q) + q\bar{z}$. Hence $\tilde{z} \geq 1 - q$. It follows that

$$\begin{aligned}
\tilde{z} &= \max\left\{\left(\frac{p_0}{p_0 + \alpha/(S-1+\alpha)}\right)^{\frac{1}{S-2}}, 1-q\right\} \\
&= \max\{z, 1-q\}
\end{aligned}$$

where z is given by (8). Inserting $\tilde{z} \equiv (1-q) + q\bar{z}$ gives that

$$\bar{z} = \max\left\{\frac{z - 1 + q}{q}, 0\right\}$$

For a given equilibrium value of $\tilde{z}$, the distribution below p_0 is still given by (10), with z replaced by $\tilde{z}$.

We want to calculate the expected posted price Ep conditional on playing low given that $S = 2$. To that end, note that the indifference condition (9) between setting p_0 and a price in the support below p_0 can be rewritten as

$$\begin{aligned}
p_0(\frac{U}{S} + \tilde{z}N) &= p(\frac{U}{S} + \tilde{z}N + (1 - F(p))(1-\tilde{z})N) \\
&\equiv p(\hat{u} + (1 - F(p))I)
\end{aligned}$$

where $\hat{u} = \frac{U}{S} + \tilde{z}N$ and $I = (1 - \tilde{z})N$ are the number of buyers a low-price seller attracts independently of p and the number that depends on p, respectively. From the Varian model (equation 4) with $S = 2$, it follows that the expected price with $\hat{u}$ uninformed buyers per seller and I informed buyers is $Ep = \bar{p}\kappa \ln \frac{\kappa}{1+\kappa}$, where $\kappa = \frac{\hat{u}}{\hat{u}+I}$ and $\bar{p}$ is the price at the top of the support. In our case $\kappa = 18.0$ and $\bar{p} = p_0 = 12.5$, which gives that $Ep = 12.1$.

B Data appendix

B.1 Dynamic regressions

We formally address the question of whether behavior is approaching Nash prices by running dynamic regressions inspired by Noussair et al. (1995,1997). The specification employed is the following:

$$p_{it} = \sum_{i=1}^{I} \beta_{1i} D_i(1/t) + \sum_{i=1}^{I} \beta_{2i} D_i((t-1)/t) + \mu_{it},$$

were p_{it} is posted price, $i \in [1, I]$ indicates block and $t \in [1, T]$ indicates period, with $I \in \{6, 8, 10\}$ and $T = 60$. The $((t-1)/t)$ terms take the value 0 in period 1, thus β_{1i} provides an estimate of p_{i1} for block i. As t grows the $((t-1)/t)$ terms approach 1 and the $1/t$ terms approach 0, thus β_{2i} is an estimate of the asymptote of p_{iT}. The idea is to test if β_{2i} is closer to the symmetric Nash equilibrium than β_{1i}.

Table B.1.1 provides regression results. The regressions are estimated with random intercepts for unique subjects, and corrected standard errors for correlation over panels (Prais-Winsten regression).

	T^N_{15}	T^N_{30}	T^N_{60}	T^Y_{15}	T^Y_{30}	T^Y_{60}	L^Y_{30}
β_{11}	91.2	90.5	69.7	63.8	91.1	69.9	72.1
β_{21}	49.8	51.5	73.4	78.8	83.8	88.5	99.5
β_{12}	75.6	65.7	81.6	70.3	68.8	71.6	65.6
β_{22}	47.0	55.7	74.2	86.8	78.6	85.0	90.3
β_{13}	64.1	69.5	79.9	50.0	96.2	51.7	63.5
β_{23}	49.5	61.3	75.1	72.3	90.8	90.2	83.0
β_{14}	82.8	59.0	82.1	39.6	64.7	84.4	67.0
β_{24}	48.2	54.8	70.6	91.3	76.5	87.7	89.5
β_{15}	64.2	77.2	78.7	79.4	69.1	42.7	62.6
β_{25}	52.7	62.5	75.0	75.8	84.1	80.3	83.6
β_{16}	54.2	73.8	72.4	72.8	94.5	70.6	58.1
β_{26}	52.1	60.0	68.9	92.7	71.7	89.7	95.0
β_{17}	90.4	65.4	56.6	65.1	77.8	84.2	
β_{27}	50.2	51.3	72.8	80.8	94.0	96.8	
β_{18}	88.5	84.7	76.3	64.6	79.0	91.3	
β_{28}	43.4	54.4	65.8	73.1	76.2	85.6	
β_{19}	.				74.3		
β_{29}	.				89.7		
β_{110}	.				69.6		
β_{210}	.				79.6		
$E(p^*)$	32.3	45.7	67.6	100	100	100	100

Table B.1.1 *Dynamic regressions: random intercepts for unique subjects and corrected standard errors for correlation over panels*

The overall picture is that behavior in matching blocks is approaching the symmetric Nash equilibrium in most treatments. This is illustrated in Table B.1.2. In the table a positive sign indicates that β_{2i} is closer to the symmetric Nash equilibrium than β_{1i}, the asterisks indicate significance levels of the observed differences (at the ***1%, **5% or *10% levels respectively, using a χ^2 test of differences in coefficients). In T_{30}^{Y} 5 blocks move towards the symmetric Nash whereas 5 blocks move away from the symmetric Nash. In the other treatments either 7 out of 8 blocks, or all blocks, move towards the symmetric Nash. In general movements towards the symmetric Nash are frequent: 41 out of the 48 blocks move towards the symmetric Nash. Moreover, more than 1/2 of these movements are significantly different from zero at conventional levels. Movements away from the symmetric Nash are infrequent: 7 out of 48 blocks move away from the symmetric equilibrium. Only 1/7 of these movements are significantly different from zero at conventional levels.

Block	T_{15}^{N}		T_{30}^{N}		T_{60}^{N}		T_{15}^{Y}		T_{30}^{Y}		T_{60}^{Y}		L_{30}^{Y}	
1	+	***	+	***	÷		+		÷		+	**	+	***
2	+	**	+		+		+		+		+		+	***
3	+		+		+		+		÷		+	***	+	**
4	+	***	+		+		+	***	+		+		+	***
5	+		+		+		÷		+		+	***	+	**
6	+		+		+		+	**	÷	*	+	**	+	***
7	+	***	+		+	*	+		+	**	+	*		
8	+	***	+	**	+		+		÷		÷			
9									+					
10									÷					
	8/8		8/8		7/8		7/8		5/10		7/8		6/6	

Table B.1.2: *Summary of pattern* β_{2i} vs β_{1i}

B.2 Treatment tests

Table B.2.1 provides the raw data for the Wilcoxon rank sum tests. Average prices over all periods are provided for each block. Numbers are ranked in ascending order in each treatment.

Block	T_{15}^{N}	T_{30}^{N}	T_{60}^{N}	T_{15}^{Y}	T_{30}^{Y}	T_{60}^{Y}	L_{30}^{Y}
1	46.6	52.2	66.6	70.2	73.6	77.2	81.4
2	49.3	54.7	69.2	72.2	75.6	83.9	81.9
3	50.5	55.1	71.3	75.8	76.3	85.9	87.7
4	50.6	56.3	71.5	77.5	77.9	86.9	88.3
5	52.0	56.7	73.2	79.4	78.7	87.1	92.1
6	52.8	60.8	74.6	85.3	82.7	87.4	97.4
7	53.4	61.9	75.1	87.3	84.4	88.0	
8	53.4	63.6	75.4	91.1	88.6	95.8	
9					91.1		
10					92.8		

Table B.2.1: *Average posted prices over all periods, broken down on treatment and block*

Table B.2.2 provides relevant treatment tests. Exact p-values and test statistics (in parenthesis). Tests use data in Table B.2.1.

	T_{15}^N	T_{30}^N	T_{60}^N	T_{15}^Y	T_{30}^Y
T_{30}^N	0.001				
	(-3.05)				
T_{60}^N	<0.001	<0.001			
	(-3.36)	(-3.36)			
T_{15}^Y	<0.001				
	-(3.36)				
T_{30}^Y		<0.001		0.534	
		(-3.55)		(-0.62)	
T_{60}^Y			<0.001	0.105	0.237
			(-3.36)	(-1.68)	(-1.24)
L_{30}^Y					0.181
					(-1.41)

Table B.2.2: *Wilcoxon rank sum tests using all periods. Exact p-values (test-statistics)*

Table B.2.3 provides the raw data for the Wilcoxon rank sum tests for periods $31 - 60$. Average prices over periods $31 - 60$ are provided for each block. Numbers are ranked in descending order in each treatment.

Block	T_{15}^N	T_{30}^N	T_{60}^N	T_{15}^Y	T_{30}^Y	T_{60}^Y	L_{30}^Y
1	44.2	52.8	65.7	70.3	72.5	82.0	81.4
2	45.0	53.1	68.8	80.6	72.9	84.5	86.4
3	48.3	56.0	72.2	83.5	76.7	87.6	89.1
4	48.5	59.1	72.9	85.1	78.5	89.6	92.6
5	50.2	62.0	74.6	85.8	78.9	89.8	94.8
6	51.1	62.9	75.9	89.8	79.7	91.1	98.3
7	51.4	63.8	76.5	92.8	90.1	93.4	
8	54.9	68.1	77.2	94.0	91.4	96.8	
9					91.7		
10					93.9		

Table B.2.3: *Average posted prices over periods 31-60, broken down on treatment and block*

Table B.2.4 provides relevant treatment tests for periods $31 - 60$. Exact p-values, test statistics (in parenthesis). Tests use the data in Table B.2.3. Comparing Tables B2.2 and B2.4 the one qualitative change is that a somewhat larger treatment difference $\left[\bar{p}(L_{30}^Y) - \bar{p}(T_{30}^Y)\right] = 7.8$ for the last half of the experiment which is significant at the 10 percent level. However, this level is far from the one promoted by Benjamin et al. (2018) for new experimental findings, and which we think it is sensible for treatment tests to abide by.

	T^N_{15}	T^N_{30}	T^N_{60}	T^Y_{15}	T^Y_{30}
T^N_{30}	0.001				
	(-3.15)				
T^N_{60}	0.001	<0.001			
	(-3.36)	(-3.26)			
T^Y_{15}	0.001				
	(-3.36)				
T^Y_{30}	<0.001			0.460	
	(-3.55)			(0.80)	
T^Y_{60}			<0.001	0.328	0.173
			(-3.36)	(-1.10)	(-1.42)
L^Y_{30}					0.073
					(-1.84)

Table B.2.2: *Wilcoxon rank sum tests using periods 31-60. Exact p-values (test-statistics)*

B.3 Price distributions in treatments with simultaneous pricing

Figure B.3.1 ($t \in [1, 60]$) and B.3.2 ($t \in [31, 60]$) display the theoretical (i.e., the mixed Nash strategy in the unique symmetric equilibrium) and observed CDFs of our treatments with simultaneous pricing. We first note that empirical distributions obey the lower bound of the support (p_0) remarkably well. Secondly, we note that the shape of the empirical CDFs agrees with the shape of the theoretical distributions. Thirdly, eyeballing the distributions the appear very stable when comparing the whole experiment with the latter half of it. Finally, and consistent with the average prices documented in the main text, observed CDFs appear very close to stochastically first dominating the theoretical distributions.

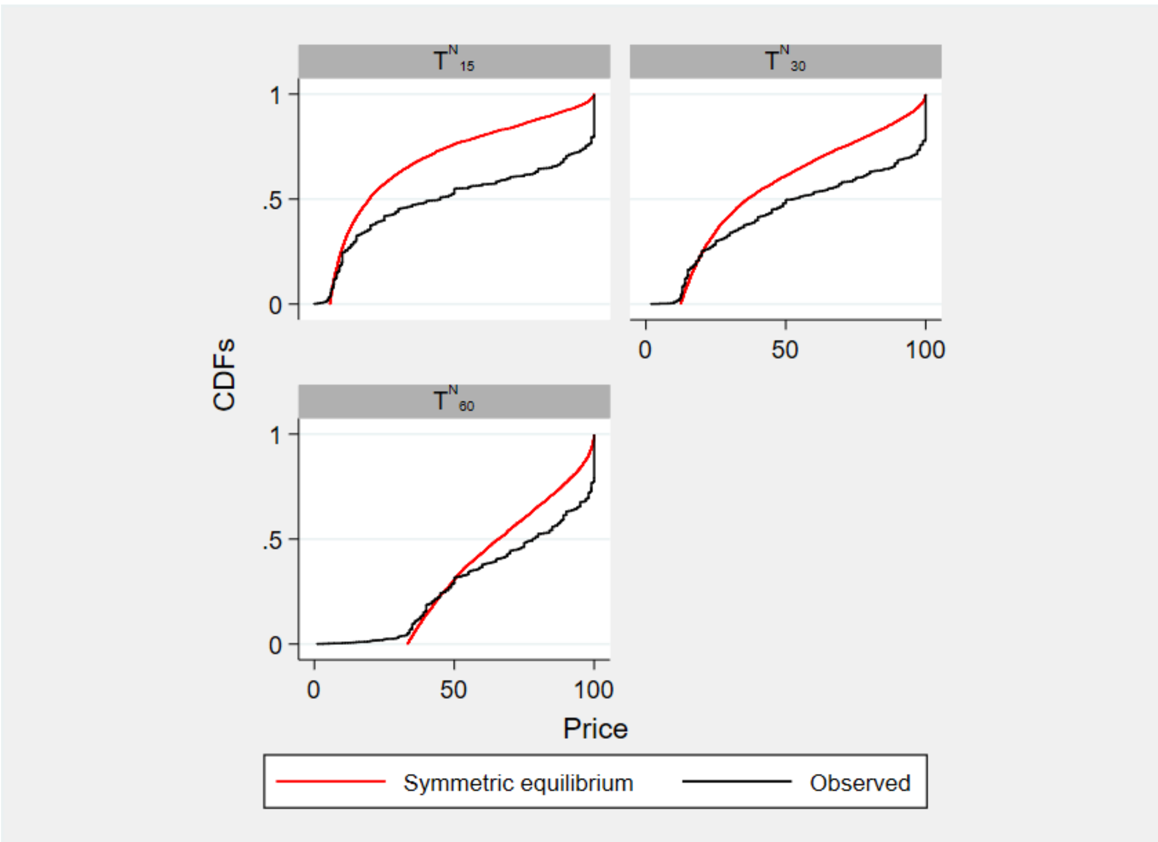

Figure B.3.1: *Nash and observed CDFs for reatments without sequential pricing, all periods*

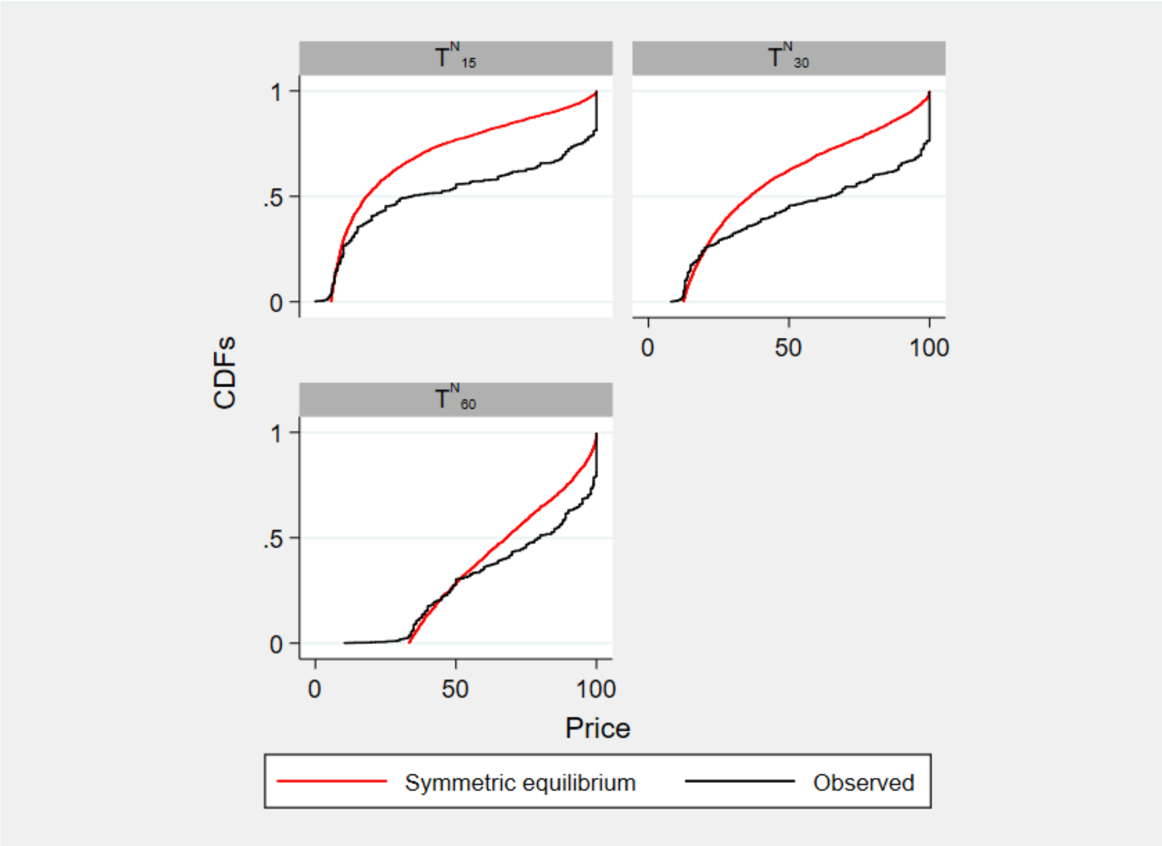

Figure B.3.2: *Nash and observed CDFs for treatments without sequential pricing, periods 31-60*

B.4 Classifying near Nash behavior permitting 5 price points deviation

Figures B.4.1 and B.4.2 classifies near Nash behavior using a more liberal threshold of 5 price points for near Nash behavior.

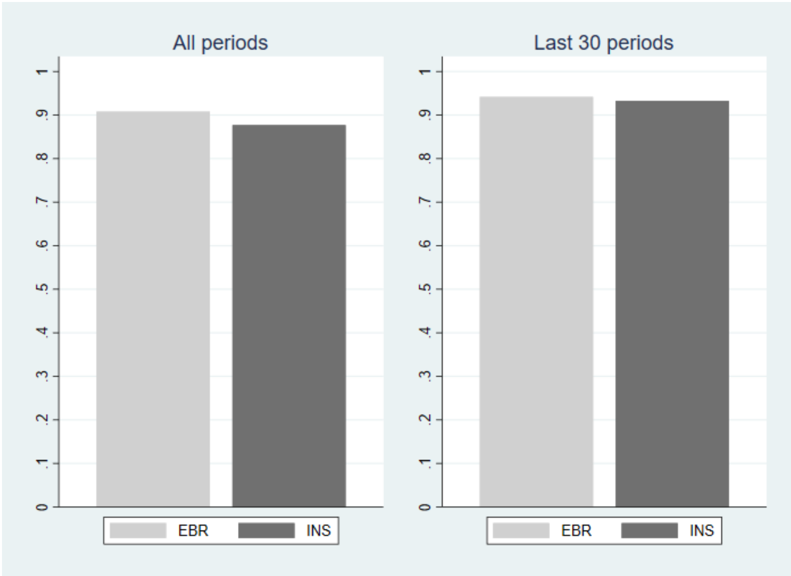

Figure B.4.1: *Fractions of individual price postings consistent with equilibrium strategies: entrant best response (EBR) and incumbent Nash strategy (INS). 5 price point deviation allowed.*

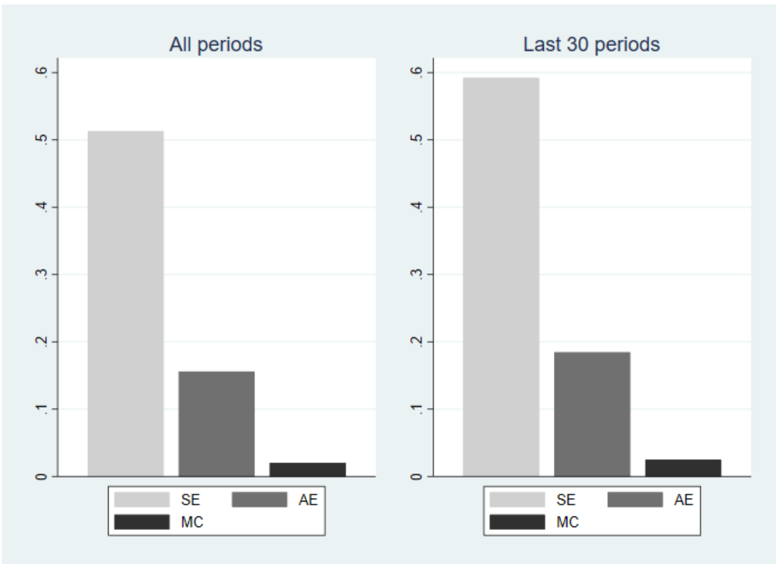

Figure B.4.2: *Fractions of markets consistent with: symmetric Nash equilibrium (SE), asymmetric Nash equilibrium (AE), and miscoordination (MC). 5 price point deviation allowed.*

Given cut-off at 5 price points, entrants best respond in 90 percent of all games, and in 94 percent of games in the latter half of the experiment. Incumbents post prices that are part of a Nash equilibrium in 87 percent of decisions when all periods are considered, and in 93 percent of decisions in the latter half of the experiment. Observed behavior is consistent with the symmetric equilibrium being played in 51 percent of all games, and in 59 percent of games in the latter half of the experiment. Moreover, observed behavior is consistent with the asymmetric equilibrium being played in 16 percent of all games, and in 18 percent of games in the latter half of the experiment. Finally, observed behavior is consistent with miscoordination in a meagre 2 percent of all games, and in 3 percent of games in the latter half of the experiment.

So, when learning has presumably played out and behavior stabilizes, almost all entrants best response, almost all incumbents post prices that are part of a Nash equilibrium, and more than 3/4 of observed behavior can be classified as equilibrium play, or attempts at equilibrium play that ended in miscoordination. Over the course of the experiment play of both the symmetric and the asymmetric equilibrium increases, though play of the symmetric equilibrium increases faster than that of the asymmetric equilibrium. Failures to coordinate on the asymmetric equilibrium are rare and do not increase much over the course of the experiment.

Table B.4.1 breaks down the classification on treatments. In the table the proportion of decisions (EBR, INS) and games (SE, AE, MC) falling in the different categories are noted for all periods ($t \in [1, 60]$) and for the last half of the experiment ($t \in [31, 60]$), and for our four treatments with sequential pricing. The last two rows provide the proportion of games that is consistent with attempted equilibrium play (SE+AE+MC). In the latter half of the experiment, around 80 percent of markets are classified as consistent with (attempted) equilibrium play.

Behavior	T_{15}^{Y}	T_{30}^{Y}	T_{60}^{Y}	L_{30}^{Y}
EBR $t \in [1, 60]$	0.90	0.91	0.88	0.95
EBR $t \in [31, 60]$	0.97	0.94	0.91	0.96
INS $t \in [1, 60]$	0.86	0.84	0.91	0.87
INS $t \in [31, 60]$	0.93	0.92	0.92	0.95
SE $t \in [1, 60]$	0.52	0.49	0.55	0.49
SE $t \in [31, 60]$	0.66	0.54	0.62	0.55
AE $t \in [1, 60]$	0.15	0.16	0.15	0.15
AE $t \in [31, 60]$	0.15	0.22	0.17	0.19
MC $t \in [1, 60]$	0.02	0.02	0.00	0.04
MC $t \in [31, 60]$	0.03	0.03	0.00	0.04
Consistent $t \in [1, 60]$	0.69	0.67	0.70	0.68
Consistent $t \in [31, 60]$	0.83	0.79	0.79	0.78

Table B.4.1: *Classification of near Nash behavior per treatment, 5 price points deviation from true Nash allowed.*

B.5 Location analysis

The majority of data was collected at the LEE lab in Copenhagen. All treatments had some or all sessions done in Copenhagen, whereas only treatments T_{30}^{N}, T_{30}^{Y}, and L_{30}^{Y} had sessions done in Oslo at the BI Research Lab. Table B.5.1 gives an overview over sessions, blocks, and subjects across the two locations.

	Oslo			Copenhagen		
	Sessions	Blocks	Subjects	Sessions	Blocks	Subjects
T_{15}^{N}	-	-	-	3	8	72
T_{30}^{N}	2	4	36	2	4	36
T_{60}^{N}	-	-	-	4	8	72
T_{15}^{Y}	-	-	-	4	8	72
T_{30}^{Y}	2	4	36	3	6	54
T_{60}^{Y}	-	-	-	3	8	72
L_{30}^{Y}	1	2	36	4	4	72

Table B.5.1: *Location overview.*

For small market treatments (i.e., all treatments except L_{30}^{Y}), data was collected in Oslo from 15th February 2019 to 6th March 2019, while data was collected in Copenhagen from 10th April 2019 to 6th June 2019. For the large market treatment, data was collected in Oslo on 11th November 2019, while data was collected in Copenhagen from 4th March 2020 to 9th March 2020. All sessions were conducted in English.

The fact that data was collected at two different locations has little impact on results, both economically and statistically. We substantiate this claim first by comparing the main results across locations for treatments T_{30}^{N}, T_{30}^{Y}, and L_{30}^{Y}, and second by reproducing the main results when we drop all observations from session done in Oslo.

The following table summarizes means and standard deviations (between blocks) of prices across the two locations for treatments T_{30}^{N}, T_{30}^{Y}, and L_{30}^{Y}.

	Oslo		Copenhagen	
	Mean	St.dev.	Mean	St.dev.
T_{30}^{N}	57.0	3.4	58.3	4.9
T_{30}^{Y}	82.2	7.0	82.1	7.4
L_{30}^{Y}	92.9	6.4	85.8	5.1

Table B.5.2: *Location result comparison.*

From the table we see that results are very comparable across locations. Further, there are no significant differences within treatments across locations using Wilcoxon rank sum tests. This latter result is arguably not so surprising given the low number of independent observations. However, we complement this analysis with an ordinary least-squares linear regression where we control for location and cluster observations on independent matching blocks. This regression yields a nonsignificant location parameter with coefficient 2.3, standard error 2.4, and p-value 0.35.

Turning to our second point, the following table provides results of treatment tests using only data collected in Copenhagen.

	T_{15}^{N}	T_{30}^{N}	T_{60}^{N}	T_{15}^{Y}	T_{30}^{Y}
T_{30}^{N}	0.028				
	(-2.21)				
T_{60}^{N}	<0.001	0.007			
	(-3.36)	(-2.71)			
T_{15}^{Y}	<0.001				
	(-3.36)				
T_{30}^{Y}		0.010		0.573	
		(-2.56)		(-0.65)	
T_{60}^{Y}			<0.001	0.105	0.345
			(-3.36)	(-1.68)	(-1.03)
L_{30}^{Y}					0.610
					(-0.64)

Table B.5.3: *Wilcoxon rank sum tests using all periods and only data collected at the LEE lab. Exact p-values (test-statistics).*

Table B.5.3 corresponds to Table B.2.2 which contains the results of the nonparametric tests reported in the main text. Comparing the two tables, it is clear that results when all observations from sessions done in Oslo are dropped are qualitatively the same as when using the full data set.

B.6 Subject heterogeneity

There are substantial differences in how often subjects in the role of incumbent sellers set the high price. Figure B.6.1 reports frequencies of incumbents' ratio of high price to low price across treatments. The price ratio is calculated as $\frac{\hat{p}_{high}}{\hat{p}_{low}}$, where $\hat{p}_{low}$ and $\hat{p}_{high}$ are frequencies of observed prices $p = p_0 \pm 1$ and $p \geq 99$, respectively.

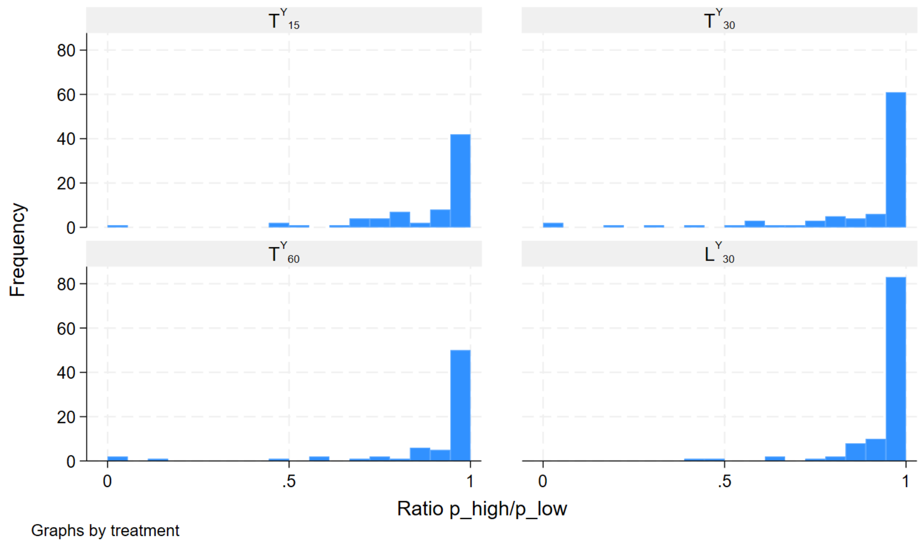

Figure B.6.1: *Frequencies of incumbents' high to low price ratio across treatments.*

The difference in price ratios between subjects yields heterogeneity in equilibrium-type outcomes. Figure B.6.2 displays frequencies of incumbents' ratio of asymmetric equilibrium to symmetric equilibrium across treatments:

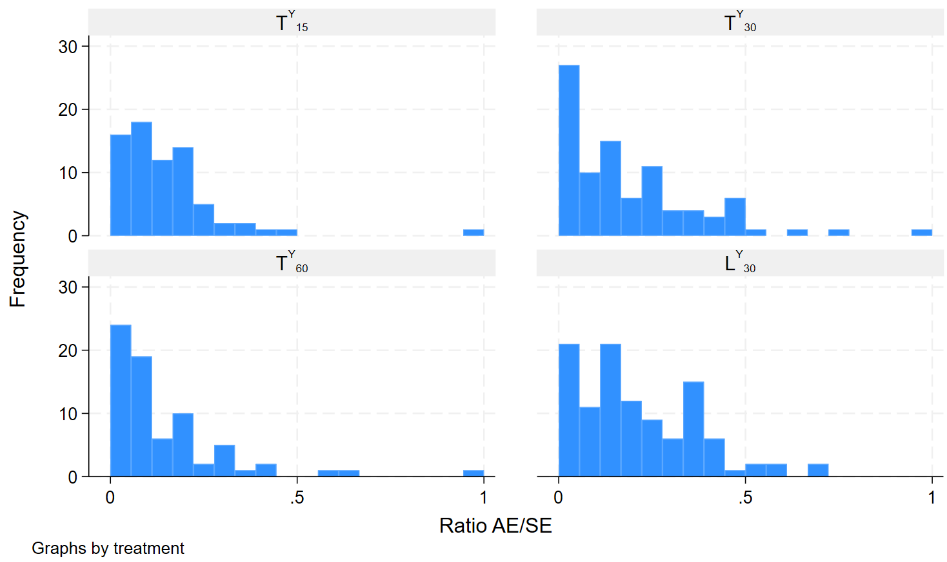

Figure B.6.2 *Frequencies of incumbents' asymmetric to symmetric equilibrium ratio across treatments.*

C Instructions appendix

In this appendix we give some samples of instructions used in the experiments.

C.1 Instructions for treatment T^N_{30}- With simultaneous pricing, 30 uninformed buyers, and 3 sellers

This is an economics experiment, administered by the department of economics at the school.

In economics experiments deception is **never** *used. This means that any information you are provided with in the experiment is* **correct**.

Experiments by other departments at the school may use deception. Whenever they do, you are told so.

Instructions

Welcome! You are participating in an experiment financed by the Department of Economics at BI and the Norwegian Research Council.

It is important that you do not talk to any of the other participants in the room until the experiment is over. Mobile devices are not allowed during the experiment. Please power off any mobile device that you have brought to the lab.

You will earn money in the experiment. How much you earn depends on the decisions you make, as well as on the decisions made by other subjects.
All interactions are anonymous and are performed through a network of computers. The administrators of the experiment will not be able to observe your decisions during the experiment.
All participants in the experiment are present in this room. They have all been recruited in the same way as you and are reading the same instructions as you are for the first time.

In the experiment your payoffs are denominated in experimental currency units (ECUs). At the end of the experiment, you will be paid in Norwegian Kroner (NOK) based on your total earnings in points from all the games of the experiment. The exchange rate from ECU to NOK is:

1 ECU= 0.006 NOK

The more ECUs you earn, the more cash you will receive.

The market

In the experiment you are going to be a seller in a market.
A market consists of three sellers and one hundred buyers.
Each buyer buys one unit. Each seller can serve all buyers who want to buy from him or her.
While all sellers are human subjects present in the lab all buyers are computer programs ("robots").

Sellers

In each market sellers post prices between 0 and 100 ECU with up to three decimal points.
Each seller posts his or her own price *without knowing* the price posted by the other sellers.

Buyers

After all the sellers have posted their prices, the robot buyers make their decisions on whom to buy their unit from.
There are two types of robot buyers: Informed and Uninformed.
In the experiment there are 70 Informed robot buyers and 30 Uninformed robot buyers.
Informed robot buyers *always* buy from the seller with the lowest price.
If one seller has the lowest price he or she gets all the 70 Informed robot buyers.
If two sellers have the lowest price each of them get 35 Informed robot buyers.
If three sellers have the lowest price each of them get 23 Informed robot buyers while the last Informed robot buyer is distributed randomly to one of the three sellers.
Uninformed robot buyers make purchase decisions without regard to the prices posted in the market.
In particular, each seller will get an equal share of the uninformed robot buyers *independently* of the price he or she posts.
That is, each seller gets 10 Uninformed robot buyers independently of the price he or she posts.

Periods and matching

The experiment consists of a series of 60 periods, divided into three sequences of 20 periods each.
In each new period a new market consisting of three sellers is formed randomly from participants present in the lab.
It is therefore highly unlikely that you will be in a market together with the same two participants twice in a row.

Profits

Sellers face no cost when selling an item and each robot buyer has a maximal willingness to pay of 100 ECU.
The profit of the seller in any given period equals his/her posted price times the total number of buyers he/she gets.

Examples

In the tables below we provide three examples of posted prices, purchases by robot buyers, and profits.

Example 1	Seller	Seller	Seller
Sellers post prices simultaneously	$2,000$ ECU	$97,000$ ECU	$1,999$ ECU
Informed and Uninformed buyers make purchases			
Number of Uninformed buyers	10	10	10
Number of Informed buyers	0	0	70
Profit to each seller	$10 \cdot 2,000 =$ $20,000$ ECU	$10 \cdot 97,000 =$ $970,000$ ECU	$(10 + 70) \cdot 1,999 =$ $159,920$ ECU

Note: The number of uninformed buyers a seller gets is 10 and is not influenced by the prices of the sellers

Example 2	Seller	Seller	Seller
Sellers post prices simultaneously	$8,000$ ECU	$79,000$ ECU	$8,000$ ECU
Informed and Uninformed buyers make purchases			
Number of Uninformed buyers	10	10	10
Number of Informed buyers	35	0	35
Profit to each seller	$(10 + 35) \cdot 8,000 =$ $360,000$ ECU	$10 \cdot 79,000 =$ $790,000$ ECU	$(10 + 35) \cdot 8,000 =$ $360,000$ ECU

Note: Two of the sellers both offer the lowest price. They share the 70 Informed robot buyers equally.

Example 3	Seller	Seller	Seller
Sellers post prices simultaneously	$85,500$ ECU	$4,125$ ECU	$98,000$ ECU
Informed and Uninformed buyers make purchases			
Number of Uninformed buyers	10	10	10
Number of Informed buyers	0	70	0
Profit to each seller	$10 \cdot 85,500 =$ $855,000$ ECU	$(10 + 70) \cdot 4,125 =$ $330,000$ ECU	$10 \cdot 98,000 =$ $980,000$ ECU

Feedback

After each period there is a feedback screen. This screen provides information about the posted prices of all three sellers, your number of sales to Informed and Uninformed robot buyers, your profits in the current period, and your accumulated profits.

Earnings

After the last period is completed, your payoffs in ECU are converted to NOK at the stated exchange rate. Your earnings in NOK will be paid in cash as you exit the lab.

Timely decisions

In the experiment you get an allocated time to make your decisions. If you use more than the allocated time, a blinking red message appears in the upper right hand side of the screen. The message reads "Please make a decision". It is important that participants don't use more than the allocated time, since the experiment will not proceed until everyone in a particular decision stage have made their decisions.

Are there any questions?

C.2 Instructions for treatment T^Y_{30}- With sequential pricing, 30 uninformed buyers, and 3 sellers

> *This is an economics experiment, administered by the department of economics at the school.*
>
> *In economics experiments deception is* **never** *used. This means that any information you are provided with in the experiment is* **correct**.
>
> *Experiments by other departments at the school may use deception. Whenever they do, you are told so.*

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1 ECU= 0.005 NOK

The more ECUs you earn, the more cash you will receive.

The market

In the experiment you are going to be a seller in a market.
A market consists of three sellers and one hundred buyers.
Each buyer buys one unit. Each seller can serve all buyers who want to buy from him or her.
While all sellers are human subjects present in the lab all buyers are computer programs ("robots").

Sellers

Two of the sellers in a market are Incumbents while the third seller is an Entrant.
In each market sellers take decisions as follows:
First the two Incumbent sellers post prices between 0 and 100 ECU with up to three decimal points.
Each Incumbent posts his or her own price *without knowing* the price posted by the other Incumbents.
Then the Entrant observes the prices posted by the two Incumbents and posts his or her own price between 0 and 100 ECU with up to three decimal points.

Buyers

After all the sellers have posted their prices, the robot buyers make their decisions on whom to buy their unit from.
There are two types of robot buyers: Informed and Uninformed.
In the experiment there are 70 Informed robot buyers and 30 Uninformed robot buyers.
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Periods and matching

The experiment consists of a series of 60 periods, divided into three sequences of 20 periods each.
Each subject will be an Incumbent in two of the sequences and an Entrant in one of the sequences.
The sequence in which you are the Entrant is determined randomly.
In each new period a new market consisting of two Incumbents and one Entrant is formed randomly from participants present in the lab.
It is therefore highly unlikely that you will be in a market together with the same two participants twice in a row.

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Sellers face no cost when selling an item and each robot buyer has a maximal willingness to pay of 100 ECU.
The profit of the seller in any given period equals his/her posted price times the total number of buyers he/she gets.

Examples

In the tables below we provide three examples of posted prices, purchases by robot buyers, and profits.

Example 1	Incumbent	Incumbent	Entrant
Incumbents post prices simultaneously	$2,000$ ECU	$97,000$ ECU	
Entrant observe incumbent prices and posts his/her own price			$1,999$ ECU
Informed and Uninformed buyers make purchases			
Number of Uninformed buyers	10	10	10
Number of Informed buyers	0	0	70
Profit to each seller	$10 \cdot 2,000 =$ $20,000$ ECU	$10 \cdot 97,000 =$ $970,000$ ECU	$(10+70) \cdot 1,999 =$ $159,920$ ECU

Note: The number of uninformed buyers a seller gets is 10 and is not influenced by the prices of the sellers

Example 2	Incumbent	Incumbent	Entrant
Incumbents post prices simultaneously	$8,000$ ECU	$79,000$ ECU	
Entrant observe incumbent prices and posts his/her own price			$8,000$ ECU
Informed and Uninformed buyers make purchases			
Number of Uninformed buyers	10	10	10
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Profit to each seller	$(10+35) \cdot 8,000 =$ $360,000$ ECU	$10 \cdot 79,000 =$ $790,000$ ECU	$(10+35) \cdot 8,000 =$ $360,000$ ECU

Note: Two of the sellers both offer the lowest price. They share the 70 Informed robot buyers equally.

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Incumbents post prices simultaneously	$85,500$ ECU	$4,125$ ECU	
Entrant observe incumbent prices and posts his/her own price			$98,000$ ECU
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