Price-Setting and Attainment of Equilibrium: Posted Offers Versus An Administered Price

Collins, Sean M. and James, Duncan and Servátka, Maroš and Woods, Daniel

Fordham University, Fordham University, Macquarie Graduate School of Management, Purdue University

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The operation of the posted offer market with advance production environment (Mestelman and Welland, 1988), appropriately parameterized, differs from that of the market entry game (Selten and Güth, 1982), appropriately presented, only in terms of price-setting. We establish the effect of this difference in price-setting on attainment of the competitive equilibrium allocation while controlling for effects relating to the presentation of the market entry game and to the stationarity or non-stationarity of environment. Free posting of prices promotes convergence to the competitive equilibrium allocation, while the typical market entry game data can be characterized as displaying cycling prices.

How do markets equilibrate? What is responsible when they do not? We generate insight on these questions by setting up a comparison of the market entry game (Selten and Güth, 1982) and a posted offer with advance production environment (Mestelman and Welland, 1988), hereafter denoted as the POAP. We demonstrate that the POAP can be thought of as a non-isomorphic relaxation of the market entry game, where the market entry

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Collins: Fordham University, 113 W 60th St, New York, NY 10023, scollins15@fordham.edu. James: Fordham University, 441 E Fordham Road, Bronx, NY 10458, dujames@fordham.edu. Servátka: Macquarie Graduate School of Management, 99 Talavera Road, Macquarie Park, New South Wales 2113, Sydney, Australia, maros.servatka@mgsm.edu.au. Woods: Purdue University, 403 West State Street, West Lafayette, IN, 47907, woods104@purdue.edu. Funding was provided by University of Canterbury. The Erskine Programme supported this research with a Visiting Erskine Fellowship awarded to Duncan James to visit the University of Canterbury. This study involved human subjects and received IRB approval from Fordham University. The authors are grateful for comments from M. Battaglini, M. Isaac, B. Kőszegi, C. Plott, T. Tassier, an anonymous associate editor, and two anonymous referees.

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game appears conversely as a market with advance production environment restricted to have an administered pricing rule—specifically a uniform price that allows ex post market clearing—instead of freely and individually posted offers. This insight then allows the construction of experiments which isolate the marginal effects of different design features, by means of a sequence of incrementally varying designs. Empirically, we find different out-of-equilibrium dynamics associated with the administered ex post market clearing price rule versus posted offers, and more evidence of convergence to the competitive equilibrium outcome given use of posted offers. Stationarity of environment also aids equilibration.

The above results are demonstrated by data from our study. We generate these data by implementing a sequence of treatments, beginning with the market entry game in its original format. In our experiments, as in the prior empirical literature, the market entry game generates volatile outcomes that are generally inconsistent with complete adoption of pure strategy play, although perhaps tempting to describe as "equilibrium plus noise". From there we alter the exogenous control variable from "capacity" (i.e. a parameter of the demand schedule) to marginal cost. We then build on that by altering the presentation of the game (in previous literature, presented as an algebraic payoff function) to make explicit the (previously implicit) numerical demand schedule and the accompanying administered price rule, i.e. ex post market clearing, both inherent in the market entry game. Each of the experimental treatments listed so far introduces a single change in design only, isolating the marginal effect of each change. Each change in format and/or control variable as just described also preserves isomorphism with the original implementation of the market game.

However, we then break with isomorphism by introducing a further treatment, which introduces a second stage in which each subject nominates his or her own price subsequent to entry. Individual posting of prices thus replaces the uniform ex post market clearing price rule embedded in the immediately prior transformation of the market entry game; our sequence of treatments thus terminates at a particular version of the POAP.

While the market entry game and the POAP are not isomorphic, it is however the case that given pricing "via the demand curve"[1] in the second stage of the POAP (when prices are posted) the payoff function in the first (advance production) stage of the POAP is exactly equivalent to the payoff function in the market entry game. In consequence there are subgame perfect pure strategy equilibria in the POAP that have the same observable outcomes, in quantities and prices, as the pure strategy equilibria in the market entry game, in number of entrants and prices implicit to its administered price rule. (In Appendix A, we demonstrate the preceding and also delineate additional equilibria in the POAP which are not possible in the market entry game; those additional equilibria are not exhibited by our data.)

Does restricting the pricing possibilities, thereby reducing the number of pure strategy equilibria relative to the POAP, allow the market entry game to more quickly attain the competitive equilibrium allocation common to both? Quite the opposite: we find that the POAP converges more rapidly to the competitive equilibrium allocation than does the market entry game. Additionally, outcomes in the market entry game appear not to be evidence of mixed strategy use by the subjects, but rather an out-of-equilibrium phenomenon, *en route* to an equilibrium in pure strategies (consistent on this point with results from Duffy and Hopkins, 2005). We are also able to advance understanding of the market entry game by identifying something

[1] Pricing "via the demand curve" means that each seller nominates a price that is equal to the price coordinate of the point on the demand curve where the quantity coordinate is given by the units produced (i.e., number of sellers who have decided to produce one unit) in that round.

that it would seem *is* going on instead of mixing: cycling.

1. THE GAME, THE MARKET, AND THEIR PREDICTIONS

Introduced by Selten and Güth (1982), the market entry game is an n-player simultaneous game where players decide between two strategies: enter the market (IN) or stay out (OUT). Empirically, the game has been studied with linear payoffs. We consider a specification that nests earlier work, where player i's payoff is

$$\pi_i = \begin{cases} v, & \text{if player } i \text{ chooses OUT,} \\ v + r(c-m) - h, & \text{if player } i \text{ chooses IN.} \end{cases} \tag{1}$$

In this specification, m is the number of entrants, the parameters v, r, and c, are positive integers, and h is a non-negative integer that satisfies $0 < h \leq r(c-1)$. Following the literature, v may be interpreted as an outside option or entry subsidy, c as the capacity of the market to support entrants, and r as a parameter determining the scale of the surplus captured from entry, i.e. $r(c-m)$. The parameter h may be interpreted as a cost incurred to enter the market.

Alternatively, one might present the payoffs in Equation 1 as the consequence of entry or not when demand is $P(m) = r(c-m)$ with an *ex post* market clearing price, P, enforced based on a realized m; entry or not each attract the same subsidy, v; and marginal cost of production is h.

For our discussion of Nash equilibria, we define $\hat{c} \equiv c - h/r$. One might think of $\hat{c}$ as market capacity adjusted for the presence of an entry cost. If $h = 0$, then clearly $\hat{c} = c$.

There are many Nash equilibria for the market entry game (Gary-Bobo, 1990). There is a continuum of equilibria for which $\hat{c} - 1$ players enter, $n - \hat{c}$ stay out, and one player enters with any probability. A pure strategy equilibrium occurs on either end of this continuum, where the profiles of pure strategies are consistent with either $m^* = \hat{c}$ or $m = \hat{c} - 1$ players choosing to enter (and $n - \hat{c}$ or $n - \hat{c} + 1$ players choosing to stay out, respectively).[2]

For $\hat{c} > 1$, there is a symmetric mixed strategy equilibrium for which player i enters with probability

$$(2) \qquad p(\hat{c}) = \frac{\hat{c} - 1}{n - 1} \text{ for } i = \{1, \ldots, n\}.$$

Additionally, there are asymmetric mixed strategy equilibria in which $j < \hat{c} - 1$ players enter with certainty, $k < n - \hat{c}$ players stay out with certainty, and the remaining $n - j - k$ players enter with probability $(\hat{c} - 1 - j)/(n - 1 - j - k)$.

The predicted number of entrants follow from the preceding equilibria. Common to all Nash equilibria for the market entry game is that the expected number of entrants is between $\hat{c}$ and $\hat{c} - 1$, inclusive. The expected number of entrants under pure strategy equilibria occupy each extreme. In the asymmetric mixed strategy equilibrium, the expected number of entrants is $n(\hat{c} - 1)/(n - 1)$. In the symmetric mixed strategy equilibrium, the expected number of entrants is $j + (\hat{c} - 1 - j)(n - j - k)/(n - 1 - j - k)$.

We can convert the market entry game just described into a market with entry: specifically, the POAP.[3] We thus present a market wherein agents must pre-commit to production, but are allowed to nominate their own prices. After making a binary choice — which could be labelled either as

[2]For ease of exposition, we denote only the number of entrants consistent with the competitive equilibrium allocation as m^*.

[3]Mestelman and Welland (1988) present experiments using a differently structured and parameterized posted offer with advance production environment. Among the differences between that study and this one, in Mestelman and Welland: sellers do not know the demand curve; prices are chosen simultaneously to production/entry; and buyers are queued randomly, instead of by value order. Additional differences are delineated in footnote 21. Johnson and Plott (1989) present another, also differently parameterized, version of a posted offer with advance production.

having entered or not, or equivalently, as having incurred the cost of producing one unit or not — each agent is informed of the total number of units for sale and then posts an asking price for his or her unit. The buyer queue consists of robots buying in value order (Levitan and Shubik, 1972). The highest step on the demand curve gets to buy first, buying if resale value is greater than or equal to the lowest asking price, otherwise not at all, and so on down the demand schedule, with ties between units listed at the same asking price broken randomly. The POAP is thus a two-stage game, with a first stage of advance production (with an equivalent space to the entry choice in the market entry game), then a pricing stage. (Note also that the entry/production subsidy and outside option, each equal to v, are still in effect in our implementation of POAP.)

We show in Appendix A that some of the pure strategy equilibria in the POAP feature agents who expect, as of the first stage, that pricing in the second stage will be "via the demand schedule". In such cases the setting for the binary first stage choices in the POAP is identical to the market entry game. The pure strategy equilibria for the market entry game will then have payoff equivalent pure strategy equilibria in the implementation of the POAP that we study. In Appendix A, it is demonstrated that $\hat{c} - 1$ agents producing, then pricing at $r(c - 1 - m)$, or $\hat{c}$ agents producing then pricing at $r(c - m)$ are each pure strategy subgame perfect Nash equilibria. These equilibria yield the same respective payoffs as the $\hat{c}$ and $\hat{c} - 1$ entrant pure strategy equilibria in the market entry game. [4]

How, then, do the outcomes of the POAP compare to the market entry game in actual, real time, play? Does administering the uniform ex post market clearing price or allowing individual posting of prices best facilitate

[4] Additional "collusive pricing" (as opposed to collusive entry/quantity) equilibria exist in the POAP, though obviously not in the market entry game. These equilibria are as characterized in Appendix A, but do not emerge in the data presented in subsection 4.4.

trade? What clues do differences in price (implicit or explicit) and quantity dynamics yield as to cause(s) of any such differences? As the reader will see, our results in section 4 start by first following then recasting the classic work recounted in section 2. From there, observation of dynamics across games ultimately allows a deepened understanding of equilibration and of the role of prices therein.

2. PRIOR EMPIRICAL WORK

Empirical testing of the market entry game took place soon after it was described: Kahneman (1988), Sundali et al. (1995), Rapoport (1995), and Camerer and Lovallo (1999) being four key early contributions. Erev and Rapoport (1998, pg. 150) characterize foundational empirical work on the market entry game as follows.

> The major findings of the previous studies can be briefly summarized. Positive and highly significant correlations between the 10 pairs of c and m values were found on each block.[5] For groups of $n = 20$ subjects, the correlations were around 0.90. When several different groups were combined ($n = 60$), the correlations increased to about 0.98. Rapid convergence to the equilibrium was already achieved on the first block.

Erev and Rapoport also point out individual-level evidence at odds with interpreting the data as having converged to equilibrium on page 150 and in more detail on page 151 (quoted below).

> Although the values of m rapidly converged to c or $c-1$ on the aggregate level (when $v = 1$), no support was found for either the pure-strategy or symmetrical mixed-strategy equilibria on the individual level. In violation of the pure-strategy equilibrium prediction that implies static decision policies, large within-subjects variability was observed. And in violation of the sym-

[5] Erev and Rapoport refer to "blocks" of 10 periods with 10 random orderings of c, and the implied m^*, in each block, resulting in 10 observations of m entrants in each block.

> metrical mixed-strategy equilibrium prediction, the between-subjects standard deviations of number of entries for every value of c were always larger than $(p(c)(1-p(c))n)^{1/2}$, the value predicted at this equilibrium.

Is a high correlation between two variables, or a high R^2 in univariate regression of pooled time series data, sufficient evidence that equilibrium has been attained? As will be detailed later, the results of our study suggest that it is not. Rather the reservations expressed by Erev and Rapoport and others appear to be well-founded. Our experimental design (detailed in section 3 of this paper) implements a multi-block sequence (as in Sundali et al., 1995, and subsequent studies) of alternating sub-blocks of periods with varying $\hat{c}$ (as in Sundali et al.) and sub-blocks of stationary $\hat{c}$ (instead like Erev and Rapoport). This allows us to carry out a variety of analyses, as implemented in these earlier papers, as a calibration exercise.[6]

The other literature with which our experiments connect is the work on the posted offer with advance production (Mestelman and Welland, 1988; Johnson and Plott, 1989). In terms of institution, the POAP is a standard posted offer laboratory market; however, its environment is one in which sellers must incur unrecoverable production costs *prior* to transacting. The environment most commonly used in laboratory markets, production-to-order, instead allows ex post production, which typically would only comprise units profitable to the seller. The advance production environment is generally held to be a difficult setting for equilibration. Indeed prices converge more slowly, and efficiencies (i.e. realized gains from trade) are lower in the advance production environment (Mestelman and Welland, 1988) than

[6]Prior studies find that more information about play in prior rounds aids convergence toward some equilibrium. Duffy and Hopkins (2005) in particular find that their Full Information treatment (where subjects are presented with every payoff of every individual subject in every round) allows attainment of pure strategy equilibrium in some sessions towards the end of a 100 period experiment. We do not provide information from prior rounds, and hence do not vary provision of such information as a treatment.

in a production to order environment.

Does the advance production environment embedded in the market entry game preclude equilibration, or is a change in approach to pricing, holding constant the use of advance production, sufficient to allow the competitive equilibrium to be obtained? As we will show later, the connection between the market entry game and the POAP proves to be useful in understanding the role of price-setting in equilibration of markets.

3. DESIGN

Throughout all experiments, we set $v = 1$, $r = 2$, and have $n = 5$ subjects in each group. In a given treatment, either h is held constant throughout the treatment while c could vary, or vice versa. Regardless of whether h varies or c varies, h and c are chosen such that the cost-of-entry-adjusted capacity of the market, $\hat{c}$, is the same across treatments in each period.[7]

We implement six treatments in total: four versions of the market entry game, and two versions of POAP. The four versions of the market entry game are isomorphic to each other, and implemented as follows.

- MEG:OG-G implements the market entry game in its original form. Subjects choose "IN" or "OUT" by means of radio buttons. The payoff for "OUT" is always 1; the payoff for "IN" is equal to $1+2(c-m)-h$, where c is capacity, varied here as the exogenous control parameter and taking the values $\{1,2,3,4\}$, m is the sum of the "IN" choices, and h is the cost of entry. Cost, h, is held constant at zero for all subjects (but as mentioned earlier, subjects knew only their own h). We have denoted this treatment MEG:OG-G for original game (OG) with a group-level (G) shifter, since payoffs are expressed algebraically and

[7]For example, in period 5, $c = 3$ and $h = 0$ in one treatment (MEG:OG-G) and $c = 5$ and $h = 4$ in another (MEG:OG-I). In either case, $\hat{c} = c - h/r$ equals 3, and the equilibrium predictions are identical.

the commonly known parameter c is varied, as in previous literature.

- MEG:OG-I is the same as MEG:OG-G, except the exogenous control variable is cost instead of capacity. The details remain the same, except that capacity, c, is held constant at 5, and the cost of entry, h, is varied as the exogenous control parameter, taking the values $\{2, 4, 6, 8\}$. We denote this treatment as MEG:OG-I because h is varied rather than c; h is individual (I), and private, information.[8]
- MEG:MF-I is the same as MEG:OG-I, except subjects are presented with a numerical demand schedule and an ex post market clearing price rule replacing the algebraic payoff function in MEG:OG-I (and also MEG:OG-G) in a payoff-preserving manner. As before, subjects choose "IN" or "OUT" by means of radio buttons. The payoff for "OUT" is always 1. The payoff for "IN" is equal to $1+P(m)-h$, where h is the cost of entry, varied here as the exogenous control parameter and taking the values $\{2, 4, 6, 8\}$. The price, $P(m)$, is equal to the resale value coordinate of the demand schedule associated with the number of entrants, m, that period. This demand schedule is presented in Table I. (Note that $r = 2$ is the step between adjacent resale values.) We denote this treatment MEG:MF-I because information is presented to subjects in a market format (MF), and h is varied with c constant.
- MEG:MF-G is the same as MEG:MF-I, except cost of entry does not vary from period to period; rather, the location of the demand curve does. This necessitates a family of demand schedules derived by shift-

[8]The four MEG:OG-I groups are split into two sets of two groups each. One set received an additional line of instruction on the interpretation of $\hat{c}$ as an intersection; one did not. This is done as a procedural check, and ex post statistical checks did not reveal any difference between the two approaches. Instructions are included in sections subsection B.2 and subsection B.3 of the appendix. Groups that received the intersection instructions are denoted MEG:OG-I*, or have session numbers followed by an asterisk (*) in reported MEG:OG-I data.

TABLE I

DEMAND SCHEDULE IN MEG:MF-I AND POAP-I

Unit Number	0	1	2	3	4	5
Resale Value	10	8	6	4	2	0

ing the demand schedule shown in Table I, while holding h constant. These shifts are used to create payoff possibilities in Meg:Mf-g isomorphic to those in Meg:Mf-i, period-by-period.[9] We denote this treatment Meg:Mf-g because a market format is used and there are group-level shifts in demand.

The two dimensions along which the original market entry game is transformed are thus: (1) whether individual subject marginal cost or a group-level shifter is the exogenous control variable subject to experimenter variation from period to period and (2) whether the surplus captured from entry, $r(c-m)$ in the original game, is presented by means of an algebraic payoff function or by a numerical step demand function and associated administered price rule. Variation in these two dimensions allows us to assess whether results in the market entry game are or are not dependent on the source of payoff-relevant information (individual or group-level shifter) or the format of that information (algebraic payoff function or verbal description in an economic context). Table II summarizes which of these treatments implements which combination of attributes.

Varying format of information (e.g. between market or game) can impact decision-making (Cox and James, 2012). Any impact on decision-making of whether payoff-relevant changes in parametrization are communicated by

[9] In Meg:Mf-g, the demand schedule specified in Meg:Mf-i (Table I) is shifted, with resale values being $\{8,6,4,2,0\}$, $\{10,8,6,4,2\}$, $\{12,10,8,6,4\}$, or $\{14,12,10,8,6\}$ for units 1 through 5. The cost of entry, h, is held constant at 8. We increased h and simultaneously shifted the curves "up", relative to Meg:Mf-i, in order to avoid the use of negative resale values.

TABLE II

Matrix of Isomorphic Market Entry Game Treatments

	Group-level shifter (capacity, c, or location of demand curve)	Individual-level shifter (cost of entry, h)
Algebraic payoff function	MEG:OG-G	MEG:OG-I
Numerical step demand, and associated pricing rule	MEG:MF-G	MEG:MF-I

either (equivalent) private-and-individual parameter shifts or public-and-global parameter shifts is an empirical question; a difference is a possibility and thus we make provision for its capture, if it exists.[10]

Breaking with isomorphism by allowing subjects to post prices after they have first chosen whether or not to enter, and second, been informed of the number of entrants in that period gives us the two POAP treatments. In these treatments, posting from the set of permitted prices $\{0, 2, 4, 6, 8, 10\}$ is only possible if the player pre-commits and incurs a cost conditional on that pre-commitment (i.e. engages in advance production).

POAP employs robot-buyers queueing in value order (Levitan and Shubik, 1972) on the demand side of the market; value-order queueing helps to shape the theoretical predictions in POAP, as explained in section 1 and detailed in Appendix A. POAP-G employs shifts in the demand schedule in a manner equivalent to MEG:MF-G, while POAP-I employs shifts in the

[10]Note also that market entry experiments typically introduced parameter shifts via changes in capacity, c, a publicly observable and global variable, while many market experiments including those by Mestelman and Welland (1988) have tended to introduce information privately at the individual level. Thus, in order to create a chain of comparable, adjacent experimental parameterizations connecting the market entry game in its usual form and POAP, one needs to effect a transition from using a global variable as a parameter shifter to using an individual variable as a parameter shifter. Our sequence of treatments accomplishes this.

cost of entry equivalent to Meg:Mf-i.[11] Properly translated, a pure strategy equilibrium in, say, period 37 in any of Meg:Og-g, Meg:Og-i, Meg:Mf-g or Meg:Mf-i, has a counterpart with the same payoffs across players, given subgame perfect play, in period 37 of Poap-g and Poap-i. (We provide an example and summary of this in Table VIII of the appendix.)

In all treatments, we disclose the payoff function or demand schedule and accompanying pricing regime at the start of each period. The number of entrants and the individual's own payoff are disclosed as feedback at the end of each period. (Note that in Poap the number of entrants is also disclosed prior to the pricing decision.) Each player's h is private information, throughout all our experiments; h is also identical across all subjects in a given experiment, but not knowing this, subjects can not assess one another's payoffs. In treatments with explicit pricing, whether subject-posted or administered, pricing is also displayed at the end of each period. In Poap, instead of an across-the-board administered price, as in Meg:Mf, different prices across players are possible. However, as players are anonymous (no

[11]The possibility of failure to transact, present in Poap, is not present in Meg:Og or Meg:Mf. Consequently, Poap-g and Poap-i must necessarily differ from each other in at least one of the following: (1) whether or not the loss incurred given failure to sell is identical across otherwise isomorphic (to each other) Poap-g and Poap-i parameterizations and (2) whether or not salvage values for unsold units are employed in Poap-g. If salvage values (of a very specific parameterization) are employed in Poap-g, identical payoffs (including in the case of failure to sell) to those in Poap-i can be established; however this comes at the cost of introducing salvage values which are not present (or rather, are implicitly zero) in Poap-i. Conversely, if no difference is introduced in the form of salvage values for unsold units, then a difference in magnitude of loss, given failure to sell, must necessarily exist. We dealt with this by running half of the Poap-g groups without salvage values and half with salvage values. Instructions may be found in sections subsection B.6 and subsection B.7 of the appendix, respectively. Groups for which no salvage values are used are denoted Poap-g**, or have session numbers followed by a double asterisk (**) in reported Poap-g data.

identifiers are displayed in any treatments) and h is always private information, this conveys no additional payoff information relative to MEG:OG or MEG:MF.[12] Furthermore, note that there is less information available to subjects in our experiments than in Duffy and Hopkins' Aggregate Information treatment, and also their Full Information treatment, *a fortiori*.[13]

There are 96 periods in each experimental session. Each session is divided into 6 blocks of 16 periods. Within each block of 16, during the first 4 periods the exogenous control variable is varied randomly but without replacement through a predicted number of entrants at pure strategy competitive equilibrium, m^*, of $1, 2, 3, 4$. In MEG:OG, this is done by varying $\hat{c} = m^*$; in MEG:MF and POAP, either h or the demand schedule is varied to yield a given m^*. (Recall in cross-section, i.e. across all treatments, m^* is the same in a given period.) During the middle 8 "stationary" periods the exogenous control variable does not change, and $m^* = 3$ remains constant throughout. The final four periods of each block return to varying m^* as during the first four periods but with a new randomized ordering. The orderings of m^* are identical across all sessions. The nonstationary periods implement the environment typical of key early experiments on market entry games, such as those run by Sundali et al. (1995). In keeping m^* constant across the periods in the middle of each block, we implement a feature common in market experiments, including the POAP experiments of Mestelman and Welland (1988), and one used throughout the market entry game experiments of Duffy and Hopkins (2005). The relatively large number of periods is intended to create a chance of capturing long run behavior, as in Duffy

[12]The demand schedule is known prior to all action in a period, in POAP as in MEG:MF (and implicitly MEG:OG, too). Thus knowledge of transactions at particular prices cannot convey any information about demand not already disclosed.

[13]Note also that across the four market entry game treatments (MEG:OG-G, MEG:OG-I, MEG:MF-G and MEG:MF-I), which are isomorphic to each other, there is no variation of economically relevant information whatsoever, only in the format of its presentation.

and Hopkins (2005).

Subjects were given instructions (reproduced in Appendix B) individually and privately for self-paced reading and an additional announcement was made publicly that all subjects had received the same instructions. All questions were addressed individually and privately when subjects raised their hands. Between each block of 16 periods a one minute break was followed by two practice periods and an opportunity to review the instructions if the subjects wished (just as at the start of the experiment).

All subject groups are disjoint, and no subject participated in more than a single session. Each group consists of 5 subjects and is fixed throughout that session; there are two concurrent, unrelated groups per session. All experiments took less than two and a half hours. Payoffs consisted of one period randomly selected after the experiment from each of the six blocks, plus a show-up fee.[14] Subjects were recruited using ORSEE (Greiner, 2015) from the subject pool maintained by the New Zealand Experimental Economics

[14]This payoff procedure is chosen for two reasons. First, we need to avoid incentive problems caused by attained or impending bankruptcy on the part of the subjects. This problem occurs when the subjects can lose money in a single period, and earnings accumulate across periods. The payoff procedures used by Sundali et al. (1995), and that used by Mestelman and Welland (1988), are each not compatible with the rest of our design. Sundali et al. pay for all periods, and avoid the issue of subjects strategizing about trading at or near bankruptcy by withholding feedback; this approach is incompatible with our design. Mestelman and Welland pay for all periods, and give feedback, but also then endow their subjects with working capital, the depletion of which could still (endogenously) change the incentives of the game. With these approaches ruled out, we are left with a choice between paying for a single period (over the entire experiment), or the payoff procedure used by Duffy and Hopkins (2005), who paid one period (randomly selected) from each of their four blocks. In order not to introduce an avoidable difference between our design and that of Duffy and Hopkins, we paid one period (randomly selected) from each of our blocks. We have six blocks, instead of four, but otherwise follow their approach.

Laboratory at the University of Canterbury. Experiments were computerized with z-Tree (Fischbacher, 2007).

4. RESULTS

4.1. *Overview of Results*

Allowing individual posting of prices leads to much more rapid convergence than does a uniform ex post market clearing price. That convergence is to a familiar equilibrium in pure strategies: the competitive market equilibrium. Figure 1 and Figure 2 together encapsulate all group-level (entry/quantity) data for all experiments. (Individual-level price data from POAP are analyzed separately in subsection 4.4).

Notable results from the data are summarized as follows.

- Unlike in MEG:OG-G, in the other treatments data consistent with a pure strategy equilibrium is observed for the entirety of some 8-period segments of the stationary environment.
- Recall the pure strategy equilibrium in the market entry game characterized by *the same players* forming the same split between $\hat{c}$ entrants and $n-\hat{c}$ non-entrants; one could argue that this equilibrium has been "attained" if the preceding characterization holds over all periods in a segment. This condition is indeed fulfilled: thirteen times in POAP, five times in MEG:MF, and twice in MEG:OG (both in MEG:OG-I).[15]
- If the additional standards are imposed on POAP that: (a) all entrants must also successfully transact, and (b) said transactions must take place at the price associated with a single equilibrium, then attainment of pure strategy equilibrium drops to eight instances. Even under the more stringent standard, competitive pure strategy equilibrium is

[15] The "collusive" pure strategy equilibrium consisting of $\hat{c}-1$ entrants and $n-\hat{c}-1$ non-entrants is never observed over the entire length of an eight-period segment, in any treatment.

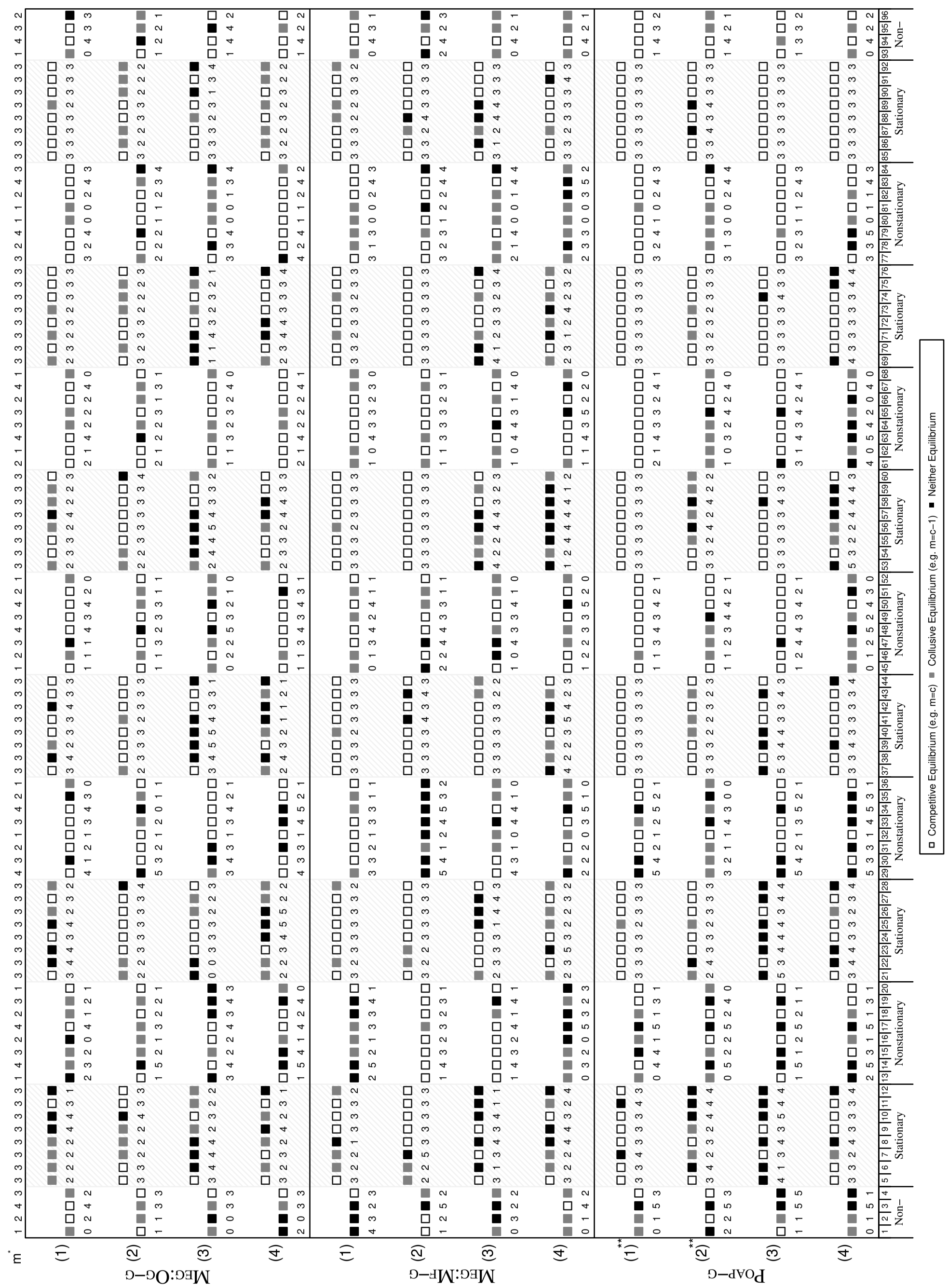

Figure 1: Entry Across Treatments with Group-Level Shifters

The observed number of entrants is listed below the box for each period. The predicted number of entrants, m^* is listed at top. Sessions with $**$ are explained in footnote 11.

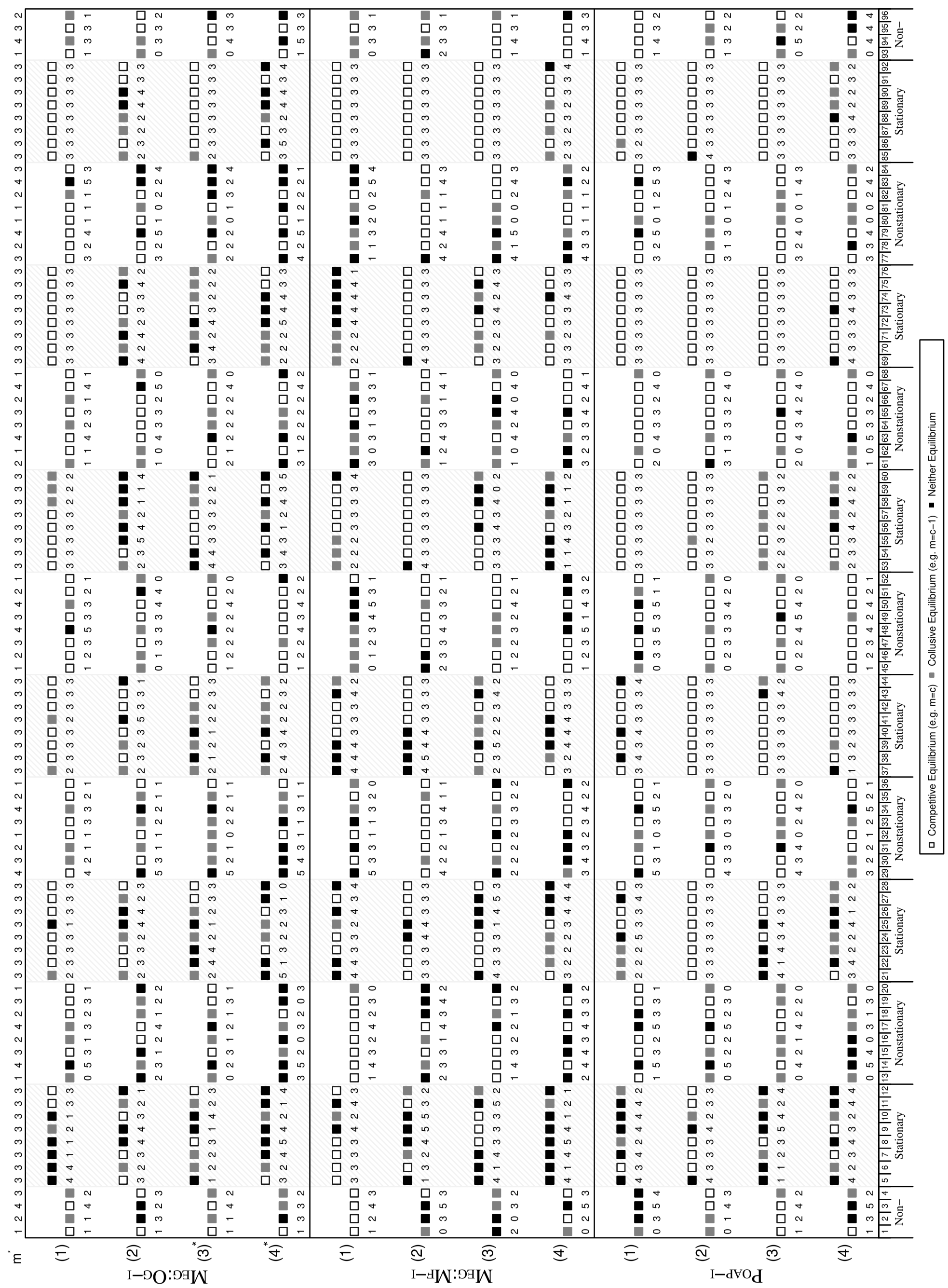

Figure 2: Entry Across Treatments with Individual-Level Shifters

The observed number of entrants is listed below the box for each period. The predicted number of entrants, m^* is listed at top. Sessions with the $*$ are explained in footnote 8.

attained most often, and earliest, in Poap.

Focusing on the subjects' ability to nominate prices in Poap, we see that this feature, despite adding dimensionality to the subjects' respective action sets, is associated with the most rapid convergence to pure strategy equilibrium. That is, despite introducing an extra choice variable with six possible settings (each contingent on the number of entrants), and requiring equilibration across more dimensions, Poap equilibrates fastest as well as most frequently.

As we investigate the data in more detail, we will trace through the successive transformations of the market entry game, starting with an analysis of how our results from Meg:Og-g replicate the key findings on the market entry game in its original form.

4.2. *Establishing a baseline — and comparison with results from Sundali, Rapoport, and Seale (1995)*

The nonstationary periods of Meg:Og-g generate results which are broadly consistent with Experiment 2 of Sundali et al. (1995).[16] Table III presents and summarizes our data in a similar manner to that in Table 4 of Sundali et al.'s study, reporting entry broken down by blocks of the experiment and summary statistics, including correlations between m and c.

Like Sundali et al., we find "high" correlations between m and c, although in our data they are slightly lower (being closer to .80 than .90). One might attribute this difference to greater discreteness in our design.[17]

[16]We consider Sundali et al.'s Experiment 2, rather than Experiment 1, because it more closely matches our design in that subjects receive periodic feedback and that there are more (varying) blocks.

[17]The lower correlations in our data may reflect the fact we have only 5, rather than 20, possible entrants per group, and that we use only 4, rather than 10, exogenous manipulations of c. The number of entrants, m, "missing" c by one entrant in our study represents 20% of the possible variation in m, as opposed to the 5% of possible variation

TABLE III

AVERAGE NUMBER OF ENTRIES BY BLOCK AND MARKET CAPACITY ACROSS GROUPS IN TREATMENT MEG:OG-G

							Observed		Symmetric MSE	
	Block 1	Block 2	Block 3	Block 4	Block 5	Block 6	Mean	SD	Mean	SD
Varying c										
$c = 1$	1.25	1.12	0.75	0.75	0.50	0.62	0.83	0.69	–	–
$c = 2$	0.88	2.25	1.62	1.75	2.00	1.88	1.73	0.79	1.25	0.97
$c = 3$	2.62	2.88	2.62	2.50	2.75	3.00	2.73	0.82	2.50	1.12
$c = 4$	3.75	3.88	3.50	3.25	3.62	3.50	3.58	0.96	3.75	0.97
Mean	2.12	2.53	2.12	2.06	2.22	2.25	2.22	1.32	1.88	1.65
Correlation	0.73	0.78	0.72	0.83	0.88	0.84	0.79	–	–	–
Constant c										
$c = 3$	2.69	2.78	2.84	2.97	2.62	2.59	2.75	0.90	2.50	1.12

Note: "Symmetric MSE" refers to the prediction under the symmetric-mixed strategy Nash equilibrium.

We also replicate another part of Sundali et al.'s analysis (their Table 6) in (our) Table IV. For each of the 4 values of c presented to subjects, we tabulate a 2×2 matrix that summarizes the overlap (or lack thereof) across the ("stay out" or "enter") decisions observed in a given period and those observed in the most immediately prior identically parameterized period.[18] As in Sundali et al. (1995), the off-diagonal cells of these matrices do not contain a count of zero, and are therefore inconsistent with complete adoption of pure strategies.

We however do observe that the proportion of data in the off-diagonal

in Sundali et al.; this phenomenon will then impact the calculated correlations between m and c, for the respective data sets.

[18]Sub-blocks with varying m^* are units of four periods over which c takes the values $\{1, 2, 3, 4\}$ in randomized order. Every other pair of sub-blocks (starting with the first and second, continuing through the third and fourth, and so on), is split by a sequence of 8 periods in which c remains constant (excluded in this analysis). The remaining sub-blocks (starting with the second and third) are directly adjacent — one immediately follows the other. In this way, for each of the 4 values of c presented to subjects, we tabulate a 2×2 matrix that summarizes the overlap (or not) across the "stay out" or "enter" decisions observed in a given period and those observed in the most immediately prior identically parameterized period.

TABLE IV

Transition Matrices Between Adjacent Sub-blocks With Varying c Across all Subjects in Treatment Meg:Og-g

		Sub-Block 2 Out	Sub-Block 2 In
Sub-Block 1	Out	31	19
	In	11	19

IC=0.375

		Sub-Block 3 Out	Sub-Block 3 In
Sub-Block 2	Out	29	13
	In	11	29

IC=0.300

		Sub-Block 4 Out	Sub-Block 4 In
Sub-Block 3	Out	31	9
	In	8	32

IC≈0.213

		Sub-Block 5 Out	Sub-Block 5 In
Sub-Block 4	Out	29	10
	In	15	26

IC=0.313

		Sub-Block 6 Out	Sub-Block 6 In
Sub-Block 5	Out	38	6
	In	10	26

IC=0.200

		Sub-Block 7 Out	Sub-Block 7 In
Sub-Block 6	Out	40	8
	In	6	26

IC=0.175

		Sub-Block 8 Out	Sub-Block 8 In
Sub-Block 7	Out	42	4
	In	6	28

IC=0.125

		Sub-Block 9 Out	Sub-Block 9 In
Sub-Block 8	Out	43	5
	In	3	29

IC=0.100

		Sub-Block 10 Out	Sub-Block 10 In
Sub-Block 9	Out	40	6
	In	3	31

IC≈0.113

		Sub-Block 11 Out	Sub-Block 11 In
Sub-Block 10	Out	39	4
	In	5	32

IC≈0.113

		Sub-Block 12 Out	Sub-Block 12 In
Sub-Block 11	Out	39	5
	In	5	31

IC=0.125

		Sub-Block $j+1$ Out	Sub-Block $j+1$ In
Sub-Block j	Out	401	89
	In	83	307

IC≈0.196

Note: Transition matrices summarize the overlap (or not) across decisions observed in a given period and the most immediately prior identically parameterized period. Sub-blocks are defined in footnote 18. IC is the index of change, or the proportion of observations in the off-diagonal cells.

TABLE V

Number of Entries by Subject and Market Capacity in Treatment Meg:Og-g

Subject	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Varying c																				
$c = 1$	1	0	1	0	4	1	11	0	0	0	2	1	1	4	2	0	2	8	0	2
$c = 2$	0	9	2	0	11	2	11	0	4	0	4	0	5	11	2	2	0	11	0	9
$c = 3$	3	3	12	0	9	11	2	0	6	12	10	7	8	8	4	7	4	12	1	12
$c = 4$	11	12	12	0	12	3	4	6	10	10	12	12	11	5	3	12	11	12	2	12
Total	15	24	27	0	36	17	28	6	20	22	28	20	25	28	11	21	17	43	3	35
Constant c																				
$c = 3$	22	25	41	0	47	45	6	2	28	48	32	38	27	27	10	16	22	48	3	41

cells (i.e. the index of change, denoted IC) tends to fall over the course the experiment, as it does in Sundali et al.'s data.[19] These data thus suggest the possibility of some movement towards (though not attainment of) equilibrium in pure strategies.

4.3. *Evidence concerning whether or not mixing occurs in* Meg:Og-g

We find evidence against mixing similar to Sundali et al. (1995). Sundali et al. (pg. 215) state that "the [symmetric] mixed-strategy equilibrium implies a linear relationship for each subject between the value of c and the corresponding number of entries summed over blocks. Inspection of the individual results does not seem to support the prediction". In Table V, we follow their analysis with our data. The data show that half of the subjects display reductions in the frequency of entry in at least one of their changes in c from 1 to 2, 2 to 3, and 3 to 4. For only four subjects are there always increases in the frequency of entry as c increases.

[19]We find some statistical evidence against the hypothesis that the off-diagonals of the transition matrices in Table IV are equal across sub-blocks. Across the four different values of c, we conduct four McNemar's paired tests over changes in subjects switching strategies; one test rejects that these are the same in the last pair of sub-blocks as in the first pair of sub-blocks; three tests fail to reject. We document these tests in the Table IX of the appendix.

4.4. *The posted offer with advance production — and comparison with results from Mestelman and Welland, 1988*

We will now motivate the statistical analysis to come in subsection 4.6, and aid comparison of the dynamics of the market entry game and POAP, visually, by means of traditional price convergence graphs (for example, Plott and Smith, 1978). In Figure 3 and Figure 4, we do this for stationary periods of both of the Poap treatments (Poap-g and Poap-i, respectively).

Figures 3 and 4 present all information needed to evaluate the functioning of these institutions: asking prices, acceptances or refusals of asking prices, and resultant efficiency numbers. Asking prices are represented by open circles; acceptance of an ask fills in an open circle, creating a black dot; transacted quantity (a count of black dots within a period) is printed above the horizontal axis; efficiency is printed below the horizontal axis. The column of space within which an ask can be recorded within each period maps to a particular subject.[20]

The POAP markets we conduct appear ultimately to converge to equilibrium, with 100% efficiency attained in many periods later in the experiment. The average efficiencies over the entire experiments in our study are around 80%, as excess entry and/or mispricing lead to large efficiency losses on occasion, particularly in early periods. For comparison Mestelman and Welland (1988) find an average efficiency of 80% over all 18 periods, while over the final 8 periods of their 18 periods, average efficiency is 89%.

Restricting attention to just the first 18 stationary periods of Poap (the same number of periods as Mestelman and Welland) we find an average

[20]No ask is printed if no entry takes place, but even then such a blank column still pertains to the particular subject associated with it (and who in that case did not enter in that period). Thus the history of any individual's entry, asks, and outcomes may also be tracked by looking for the column of space allotted that individual, and the overall composition of entrants in a period can be likewise identified.

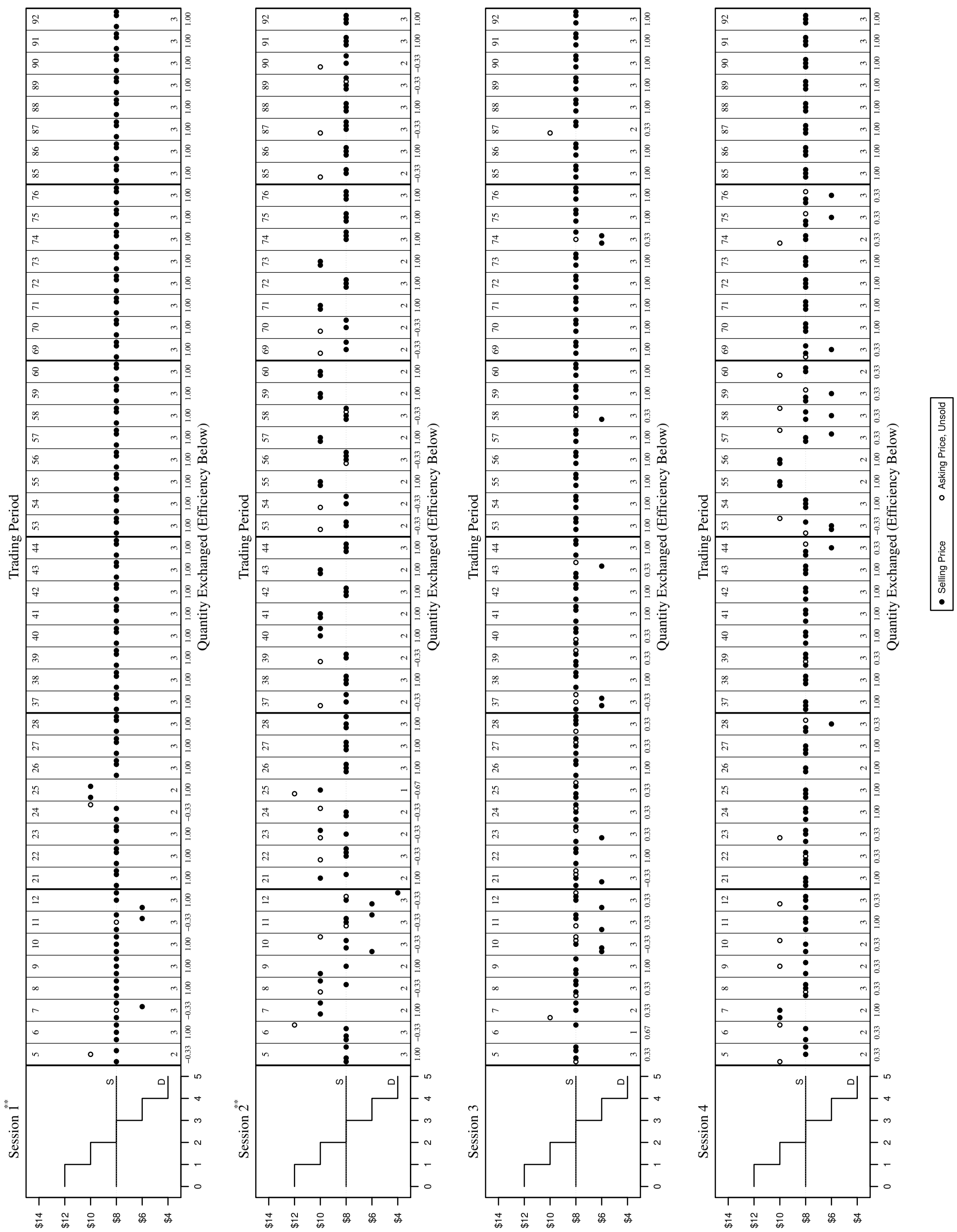

Figure 3: Asks, Prices, and Quantities Exchanged in Stationary Periods of All Sessions of Treatment POAP-G.

Note: Sessions with asterisks (**) are explained in footnote 11.

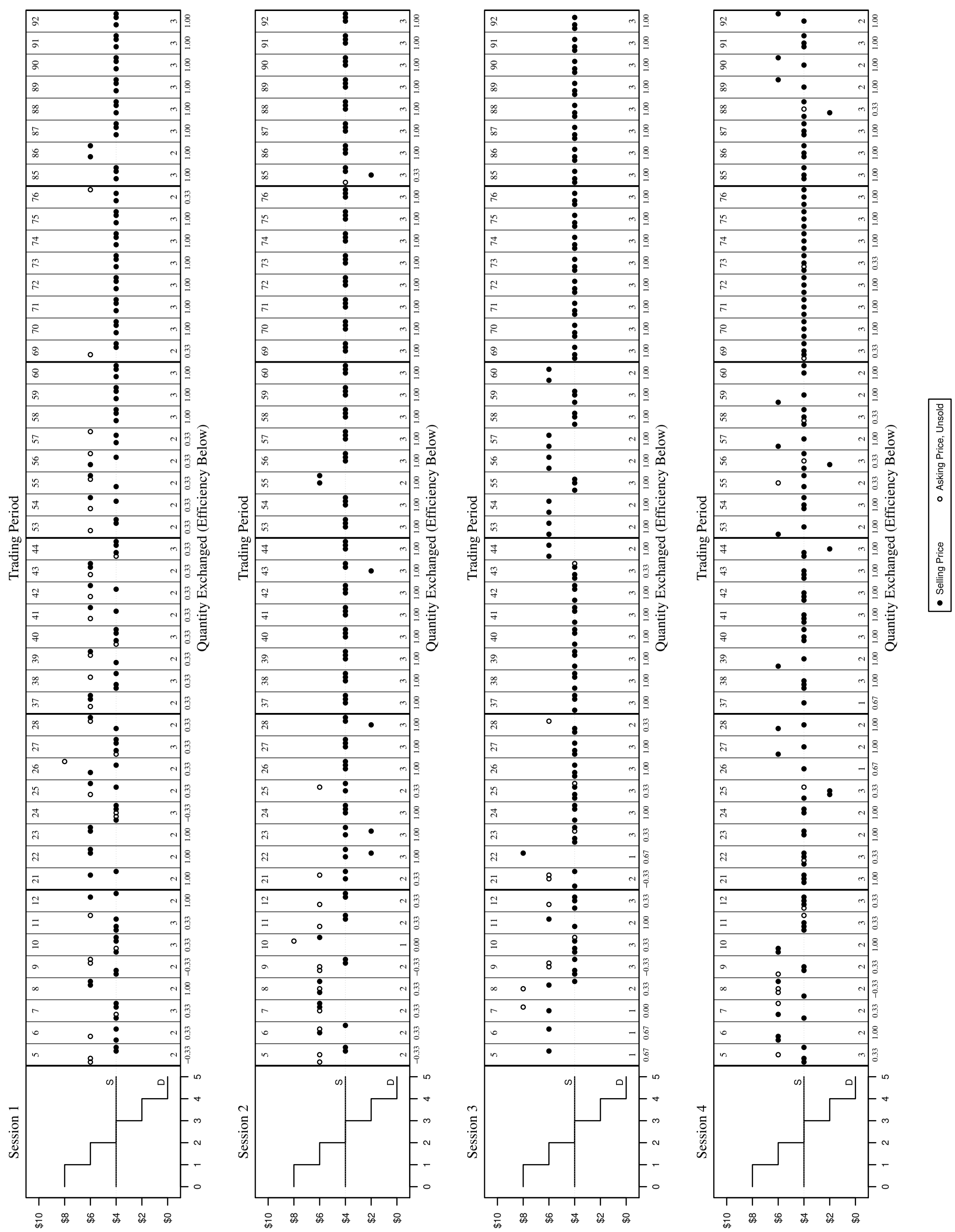

Figure 4: Asks, Prices, and Quantities Exchanged in Stationary Periods of All Sessions of Treatment POAP-I.

efficiency of approximately 51%. For the last 8 of those periods (11 through 18), average efficiency is 65%. In the final 8 period stationary segment of our POAP treatments (periods 85 to 92), average efficiency is 89%. As with comparisons to the market entry game, we should point out that our environment is more discrete than in those previously studied. (In this case, Mestelman and Welland had more units per seller and overall, among other differences.)[21]

Mestelman and Welland report higher-than-equilibrium prices, and we also observe prices converging largely from above during early periods of POAP. Overall, we find that despite parameterization differences, Mestelman and Welland's results fit well with ours—and also that over long horizons it turns out that the POAP converges to the competitive equilibrium.

4.5. *Price and quantities within and across periods: administered prices versus individually posted offers*

Juxtaposition of MEG:OG and POAP allows us to assess outcomes of the market entry game in a new light—as out-of-equilibrium price dynamics. In particular, when viewed in this way, volatile outcomes in the market entry game might be characterized as cycling in prices.

One can plot the quantities and prices generated via the administered

[21] As mentioned in footnote 3, Mestelman and Welland (1988) implement the POAP environment with different design parameters than those in the present study: markets run for 18 periods (rather than 96 periods in the present study); sellers do not know the market demand curve, and make production and posted price decisions simultaneously without knowledge of market production prior to posting prices (rather than these being known, with production preceding pricing); human buyers purchase in a randomized order (rather than value-order robots); pricing varies down to the penny (rather than a minimum price increment of $2.00); different and entirely stationary supply and demand parameters (rather than only 48 of 96 periods being stationary); and no outside option or entry subsidy (rather than there being one, i.e. $v = 1$).

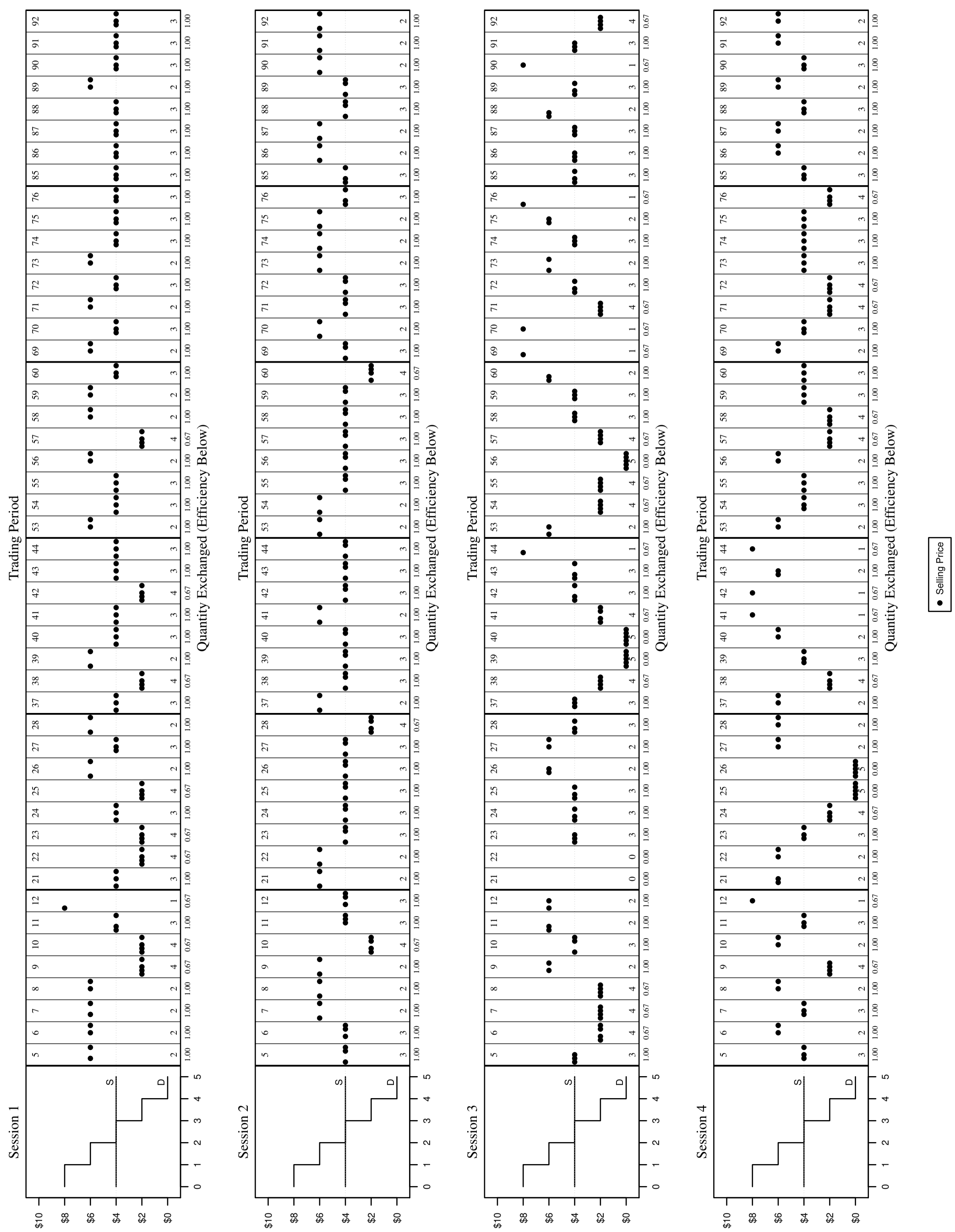

Figure 5: Implied Prices and Quantities Exchanged in Stationary Periods of All Sessions of Treatment Meg:Og-g.

price rule embedded in the original market entry game (MEG:OG-G) in the same manner as one might visualize the POAP markets. We present such results for MEG:OG-G in Figure 5.[22]

As will be further demonstrated in the statistical analysis to come in subsection 4.6, POAP converges to the competitive equilibrium. By the same criteria, the original market entry game (MEG:OG-G) may not do so, except over a much longer time horizon. Rather, over shorter time horizons, prices in MEG:OG-G oscillate to either side of the competitive equilibrium price. In between failing to converge to the competitive equilibrium in stationary segments, MEG:OG-G generates metrics in non-stationary segments similar to the Sundali et al. (1995) market entry game when analyzed using their methods. We thus suspect that a similar cycling dynamic is embedded in typical market entry game data, and contributes to the characteristic patterns therein.

In turn we believe that cycling is enabled by the pricing rule implicit to the market entry game, which forces all strategy and adaptation on the part of the subjects into a single dimension, quantity.[23] Thus, price dispersion under the administered uniform ex post market clearing price can

[22]We present similar graphs for MEG:OG-I, MEG:MF-G, and MEG:MF-I in Figure 6, Figure 7, and Figure 8 of the appendix.

[23]Relative to to POAP, the market entry game exhibits high efficiencies. This results from the forced clearing of all produced units (i.e. all entrants necessarily record a sale). For example, excess entry such that there are 4 entrants in a period where $\hat{c} = 3$ necessarily maps to efficiency of 67% in the market entry game, but could potentially result in a negative efficiency number in the POAP if some entrants post high enough prices and unsold units result.

In effect, the market entry game forces a cross-subsidization of losses induced by excess entry. While this may allow for higher efficiencies in the market entry game than the POAP before convergence, it also distorts the feedback that sellers in the market entry game might otherwise receive about their entry decisions, and may thus slow the attainment of convergence.

only occur across periods. Consider the following comparison of variation of prices in cross-section versus that in time series. The standard deviation of prices *within* periods in MEG:OG-G is \$0 (by construction). The standard deviation of prices *across* all periods of MEG:OG-G is \$2.32. In POAP by contrast, the average of within-period standard deviation of prices is \$1.85. But the standard deviation of the average price *across* all periods of POAP is only \$0.80. Allowing variability in prices at a point in time may allow for (naturally evolving) lower variability in prices across time. Our findings complement the findings of Johnson and Plott (1989), who implemented in the laboratory a POAP environment, but never used an institution with an ex post market clearing price, or other uniform price institution. Johnson and Plott did not find price cycling of the kind which might be expected under textbook-model uniform pricing, and conjectured that this might be due to the posted offer and double auction institutions—which they did use–suppressing price cycling. We can now claim more directly that this indeed seems to be the case: in the presence of advance production, replacing the posted offer institution with an institution imposing an ex post market clearing price can lead to cycling.

4.6. *Comparative convergence properties of the market entry game and posted offer with advance production*

To quantify the impact of our treatments on convergence to equilibrium, we regress an indicator for the achievement of competitive equilibrium entry in each period ($m_t = m_t^*$), on a set of treatment and control variables, the marginal effects of which are reported in Table VI. In addition to allowing for a random effect at the group level, the specification includes a time trend, binaries for treatment attributes and interactions between treatment attributes and time, and a variable tracking whether or not the period in

TABLE VI

Marginal Effects of Random Effects Probit on Competitive Equilibrium Number of Entrants

	Marginal Effect on the Prob. of Competitive Equilibrium Entry, $Pr(m = m^*)$	
	Marginal Effect	Std. Error
Individual-level Shifter	−0.0404	(0.0656)
Numerical Step Demand	0.0781	(0.0800)
Market (Poap)	−0.0614	(0.0803)
Stationary c and h	−0.0468	(0.0432)
Period	0.0012	(0.0009)
Period × Individual-level Shifter	0.0004	(0.0008)
Period × Numerical Step Demand	−0.0011	(0.0009)
Period × Market (Poap)	0.0039***	(0.0010)
Period × Stationary c and h	0.0028***	(0.0008)
Observations	2,304	
Random Effect St. Dev.	0.3038	

Note: Random effect is at the group level, with 4 groups per each of the 6 treatments, and 96 periods per group. Standard errors are in parentheses. Meg:Mf and Poap were coded as having Numerical Step Demand. All treatments with "-i" designations had Individual-level Shifters.

*** Significant at the 1 percent level.

question is part of a stationary segment.[24]

We report a variety of tests, including both those for individual and for joint significance. Table VI reports the estimated marginal effects and (individual) significance of each of the control and treatment variables. While none of the intercept estimates on the treatment variables are significant, the coefficients on the interaction between Period and Market (Poap), and Period and Stationary c and h, are significant at the 1% level. Joint tests,

[24]We report a probit with robust standard errors clustered on groups in Table X of the appendix.

with the null hypothesis being that both the intercept and slope coefficients for a single treatment are zero, are appropriate. We find that the coefficients on Individual-level Shifter and Numerical Step Demand are not significant in joint tests (with p-values greater than 0.8035 and 0.4820, respectively), and that the joint coefficients on Market and Stationary c and h are significant at the 1% level (with a p-value less than 0.0001).[25]

The estimated coefficients suggest that convergence to the competitive pure strategy equilibrium is promoted by a stationary environment (as conjectured by Duffy and Hopkins (2005)), and by individual posting of prices rather than a single administered price. Any effect of system-wide versus individual level variables (e.g. demand versus marginal costs) being used to shift the parameterization across periods is ambiguous, and small. Verbal, rather than algebraic presentation is signed so as to aid convergence, but is not statistically significant. The estimate of the time trend variable *without* interactions (i.e. for the original market entry game), is positive, but insignificant.

The estimated coefficients can be used to calculate fitted probabilities of observing competitive equilibrium, and thus expected time of a particular likelihood of competitive equilibrium play under different combinations of treatments and environments. For instance, in expectation, an average group in treatment Poap-i, featuring verbal description, individually posted prices, and marginal cost as shifter, would if implemented in a stationary environment reach 95% competitive equilibrium play at 120 periods under the fitted model.[26] Individual posting of prices aids convergence, because by

[25]Tests for joint significance are chi-squared tests over the likelihood ratios of the reported unrestricted model and unreported (nested) restricted models. This involves separate estimates (not reported, but available upon request) from those in Table VI. This is also responsible for different p-values for the joint tests and for the tests on individual coefficients — each is calculated with respect to different estimates.

[26]Group-level heterogeneity permitted by the model also makes a difference in time

contrast, the original market entry game (MEG:OG-G) also implemented in a stationary environment would have an expected time to 95% convergence equal to 210 periods under the fitted model.

Typical results for the market entry game can now be understood more deeply. Under the fitted model, an average group in the original market entry game (MEG:OG-G) implemented in a nonstationary (varying c) environment would be expected to reach 95% competitive equilibrium play on the 648th period. When contrasted to 210 periods to 95% competitive equilibrium play in a stationary environment, the fitted model demonstrates the importance of the stationary environment in equilibration. The fitted model also thus sheds light on the widespread failure to observe pure strategy play in the original market entry game; 648 periods is far longer than most single session human subjects experiments last.[27] Binmore and Swierzbinski (2007) have pointed out the possibility of cases — particular learning dynamics in particular games — where convergence cannot be observed within the time spans feasible for human subjects experiments. The original market entry game in a nonstationary environment appears to be such a case, albeit a mild version. (Binmore and Swierzbinski include examples requiring thousands of iterations for convergence).

The analysis reported in Table VI takes the group decision each period as

to convergence. For instance, for POAP-I, the impact of one standard deviation in the random effect amounts to ±17 periods to 95% convergence. Notably, the fitted model also predicts that the impact of group heterogeneity is greater, the greater the expected number of periods to some level of convergence. (This, in addition to the stochastic disturbance term, accommodates both later and earlier convergence than the average.)

[27]While the fitted model predicts convergence for MEG:OG-G in a non-stationary environment, it does so by means of estimated coefficients—primarily the time trend without interactions—which are not significant. Thus, the possibility should be kept in mind that MEG:OG-G, when implemented in a non-stationary environment, might not ever converge.

TABLE VII

OLS on Mean Squared Deviation (MSD) from Equilibrium Entrants by Treatment

Treatment	MSD from:	Constant	Std. Error	P-value	1/Block	Std. Error	P-value	R^2
Meg:Og	Pure	0.0204	(0.0048)	< 0.0001	0.0236	(0.0158)	0.0015	0.0242
	Sym. Mixed	0.0332	(0.0023)	< 0.0001	-0.0197	(0.0045)	< 0.0001	0.0736
Meg:Mf	Pure	0.0104	(0.0051)	0.0429	0.0402	(0.0102)	0.0001	0.0613
	Sym. Mixed	0.0394	(0.0022)	< 0.0001	-0.0257	(0.0044)	< 0.0001	0.1262
Poap	Pure	0.0016	(0.0050)	0.7413	0.0474	(0.0100)	< 0.0001	0.0864
	Sym. Mixed	0.0477	(0.002)	< 0.0001	-0.0264	(0.0039)	< 0.0001	0.1590

the level of observation. While theory makes specific predictions about the proportion of entrants for a given group in a given period, these predictions are necessary, but not sufficient, to say equilibration has been achieved. (For instance, there are off-equilibrium strategies that could yield, in a single period, the same proportion of entrants as the symmetric mixed-strategy equilibrium.) For a deeper analysis, we must look at individual decision-making that underlies the proportion of entry in groups.

To do so we employ, with our data, a modification of the approach to individual level data used by Duffy and Hopkins (2005). Table VII reports the results of three OLS regressions (for each of the Meg:Og, Meg:Mf, and Poap pairs of treatments, pooled) of mean squared deviation from pure or symmetric mixed strategy equilibrium versus a time trend. In our implementation, the time series is measured the reciprocal of multi-period "Block" of the experiment.[28]

The dependent variable, $(\hat{y} - y)^2$, is the mean squared deviation from the prediction, with y being the proportion of entry in for subject i in the eight-period constant segment of block t. The prediction, $\hat{y}$, is $\hat{y} = (c-1)/(n-1)$ for the mixed strategy symmetric equilibrium. For the pure strategy equilibrium, we follow Duffy and Hopkins (2005) by assigning pure strategy

[28]The specification employed by Duffy and Hopkins (2005) is linear in "Block". To aid comparison, we report a model with "Block" as the independent variable, rather than its reciprocal, in Table XIII of the appendix.

predictions based on subjects' proportion of entry during the final block of the experiment.[29] Thus, we assign $\hat{y} = 1$ to the three subjects who enter the most during the final block and $\hat{y} = 0$ to those who enter the least.[30] Thus, the unit of observation is individual proportion of decisions aggregated across non-overlapping eight-period blocks.[31] The independent variable is 1/block, the reciprocal of number of blocks elapsed. The specification allows the estimated constant to be interpreted as the asymptotic mean squared deviation.

We find movement towards lower mean squared deviation from the pure strategy equilibrium in all treatments (as illustrated by the positive and significant estimates on the 1/block coefficients for the pure strategy regressions), and movement away from the symmetric mixed strategy equilibrium in all treatments (as illustrated by the negative and significant estimates on the 1/block coefficients for the symmetric mixed strategy regressions). We also find no evidence contra the hypothesis that POAP converges asymptotically to pure strategy equilibrium (as illustrated by the estimate of the constant being not significantly different from zero in this case). The model predicts that the two market entry game treatments, MEG:OG and MEG:MF, do not converge asymptotically to pure strategy equilibrium (as illustrated by significant estimates of the constant), although both slowly close toward low levels of mean squared error from the pure strategy equilibrium.

[29] We identify *ex post* the players who are predicted *ex ante* to be the entrants in the first and subsequent periods in an attempt to track the adjustment process that leads to the outcome observed at the end of the session.

[30] For most groups, assignment of pure strategy predictions is unambiguous. For one group, MEG:OG-I (4)*, there is a tie between the number of times certain subjects entered the most in the final block. Assignment of subjects to the pure strategy equilibrium is resolved by recursively examining prior blocks, until one is found for which the criteria above are satisfied.

[31] We report a table of pure strategy $\hat{y}$ and mean squared deviations by block for every subject in Table XI and Table XII of the appendix.

Thus, we see that individual-level results support the inferences drawn from our earlier consideration of the aggregate results. We also see that the posted offer treatments (POAP-G and POAP-I) show greater evidence of convergence toward competitive, pure-strategy equilibrium than do MEG:OG and MEG:MF.

5. CONCLUSION

In comparing two different games, the market entry game and the POAP, we find an intriguing and perhaps paradoxical result. For while the market entry game has both fewer actions available to players and a smaller set of pure strategy equilibria than does the POAP, the POAP converges much more rapidly to the competitive equilibrium—obtainable under pure strategy Nash equilibrium in market entry game and POAP alike—than does the market entry game.

Whether prices are set centrally and formulaically, or individually and freely, makes a dramatic difference to whether or not the competitive equilibrium allocation is attained. Replacing posted offer pricing with a formulaic, ex post market clearing price is associated with the emergence of endogenous fluctuations in prices/quantities. Insofar as such cycling may be attributed to the use of a particular pricing approach in an advance production environment, such cycling might also be described as self-inflicted, and avoidable.

The traditional characterization of behavior in the market entry game as attaining equilibrium is also worth revisiting. The basis for such statements has generally been a correspondence between the central tendency of pooled data on entry decisions, m^*, and the number of entrants under the competitive outcome. In typical market entry game data there is variation around this central tendency, but in the absence of counterfactual cases, under which unvarying equilibrium play is observed in similar environments, over similar time horizons, it would be tempting to dismiss discrepancies as noise. However, in our experiments we have just such counterfactual cases, employing similar environments and number of rounds, albeit implementing a perturbation in pricing method. These counterfactual cases show that equilibrium in empirical reality can look exactly as it is supposed to theoretically—the exact m^* number of entrants, of unchanging identity, unvaryingly, repeatedly playing in a manner consistent with pure strategy equilibrium at the competitive outcome. Changing the pricing rule to allow freely posted individual offers, holding environment the same, curtails fluctuation in prices and promotes attainment of the competitive equilibrium. This pinpoints the key role of the uniform, ex post market clearing, price implicit in the market entry game in shaping the data typical of the market entry game.

Conversely, pooled data that center near the competitive outcome might be produced by decidedly dis-equilibrium phenomena. For instance, in the stationary segments (where $\hat{c}$ and m^* equal 3) of the market entry game (MEG:OG-G) data, m has a mean of 2.75; the median of those data is 3.[32] Is this evidence of equilibrium, or of something close enough thereto? A rank-sum test leads us to reject the hypothesis that the central tendency is 3 (with $p < 0.0003$), but would not tell us whether the observed dispersion around the median matters in terms of economics, not just statistics, or why it might occur. However, when the data are plotted as (implicit) price series in Figure 5, they show pronounced cycling in prices (and necessarily also in quantities). No one would claim that these data exhibit converged competitive equilibrium pricing.

[32]Note also that in subsection 4.2 and subsection 4.3, the interspersed non-stationary segments of these same MEG:OG-G experiments produce just the kind of patterns typically found in market entry game studies — the kind of patterns that might conceivably be held to be evidence of some correspondence with equilibrium.

By first identifying the presence of an implicit pricing rule in the market entry game, then taking steps to relax that rule, in this present study we have been able to generate new insight into the role of price-setting in the equilibration of markets. Allowing individual posting of prices (rather than an ex post, market clearing administered price) leads to widespread and early convergence to the competitive equilibrium allocation, net of presentational effects, and net of (non-)stationarity of demand or supply—even when production decisions are irrevocable.

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APPENDIX A: EQUILIBRIUM IN THE POSTED OFFER WITH ADVANCE PRODUCTION (FOR ONLINE PUBLICATION)

Our implementation of the POAP has two stages: the first, which for ease of exposition we shall call the entry stage, and the second, the pricing stage. We refer to the first stage as the entry stage, rather than the advance production stage, because each agent can only produce zero or one units, so that like the entry stage in the market entry game the decision in the first stage of the POAP is binary. We do wish to emphasize this overlap between the market entry game and the POAP, and we do not wish to unnecessarily introduce new nomenclature.

During the first stage, the entry stage, agents choose either to enter the market (IN) or stay out (OUT). As in the market entry game described in section 1, agents choosing OUT receive a payoff of v. Agents choosing IN become entrants and proceed to the second stage of the game, the pricing stage. In the pricing stage, entrants are informed of the number of entrants, m, and then nominate an asking price for their units.

Below we characterize equilibrium strategies in the pricing stage. For the parameters used in the experiment, we also demonstrate that (1) Nash equilibrium play in the pricing stage can yield expected payoffs for price-posting decisions that are equivalent to the payoffs attained by nominating price as a function of number of entrants, via the demand curve and given this, (2) subgame perfect play in the POAP yields payoffs in subgame perfect equilibrium which are the same as in the pure strategy equilibria of the market entry game.

A.1. *Specification of Posted Offer with Advance Production*

The demand curve faced by entrants can be expressed algebraically as $P(m) = r(c - m)$. The variable c, interpreted as capacity in the market entry game, is here a parameter that determines the intercept of the demand curve, i.e. rc.[33] The demand curve is a step function with an interval between prices of r and (as a consequence of value-order queuing) buyers purchase at most x units at price $P(x)$. As detailed in section 1, the variable h is interpreted as the cost of advance production and we define adjusted capacity as $\hat{c} \equiv c - h/r$.

If an entrant i sells at her asking price, P_i, her profit is $\pi(P_i) = v + P_i - h$. If she fails to sell, her profit is $\pi(P_i) = v - h$. Whether or not entrant i sells is determined by the implications of value-order queueing as applied to the price that she nominates, P_i, and the prices other entrants nominate. An

[33] The demand curve may be written as $P(m) = rc - rm$. Note that for $m = 0$ demand is $P(0) = rc$ and for $m = 1$, $P(1) = r(c - 1)$.

entrant that prices "via the demand curve", nominating a price of $P_i = P_m \equiv P(m)$ always sells and receives the payoff $\pi_i = v + r(c - m) - h$, equivalent to that of the market entry game.

A.1.1. *Pricing Below P_m is a Dominated Strategy*

Asking a price below P_m does not affect whether or not the entrant will sell and can only lower the price at which the entrant does sell, which will reduce the entrant's payoff relative to pricing at P_m.

The demand curve has m units available for purchase at price P_m. Let P_{-k} be any price strictly less than P_m. An entrant that nominates a price P_{-k} always sells and receives $\pi_i(P_{-k}) = v + P_{-k} - h$. Had the entrant priced at P_m, the unit would have sold and earned $\pi_i(P_m) = v + P_m - h$, which is greater than $\pi_i(P_{m-k})$.

A.1.2. *Pricing at P_m is an Equilibrium Strategy*

Unilaterally asking at a price above P_m when all other entrants price at P_m guarantees that the entrant will not sell, and can at best reduce the entrant's payoff relative to pricing at P_m.

Suppose that $j = 1$ entrant posts at $P_k > P_m$ (with $k > 1$) and $m - 1$ other entrants post at P_m. Then demand curve has at most $m - k$ units available for purchase at P_k. The $m - 1$ asks at lower prices are filled first (if possible), meaning that there are at most $j - 1 = 0$ units to be assigned to the ask at P_k and the entrant will not sell. Provided that $P_m > 0$, the entrant pricing at P_k would be better off pricing at P_m and selling (and if $P_m = 0$, the entrant would be indifferent).

A.1.3. *Pricing Above P_m is an Equilibrium Strategy Under Some Conditions*

While there is a competitive equilibrium in which entrants price via the demand curve at $P_i = P_m$, there may also be "collusive pricing" equilibria under which entrants price above P_m. Below we characterize the conditions under which such equilibria occur.

The demand curve has at most $m-k$ units available for purchase at any price $P_k > P(m)$, where k is the number of intervals (of r) by which that P_k is strictly greater than P_m. In this nomenclature, $P_k = P_m + rk$.

Suppose that $1 \leq j \leq m$ entrants each post the same asking price $P_k > P_m$. Suppose also that $m-j$ entrants have posted at prices below P_k (possibly but not necessarily including P_m).

For the j entrants pricing at P_k, the demand curve has at most $m-k$ units available for purchase. The $m-j$ asks at lower prices are filled first (if possible), meaning that there are at most $j-k$ units to be assigned to the j asks at P_k. Because ties are broken randomly, the probability that an entrant sells is $\frac{(j-k)}{j}$ and the probability that an entrant does not sell is $\frac{k}{j}$.

The expected payoff received by the j entrants pricing at P_k is $\mathrm{E}\left(\pi_i(P_k)\right) = v + \left(\frac{j-k}{j}\right) P_k - h$. Note that this payoff is strictly increasing in j and neither the number of entrants pricing below P_k nor the prices they post affect the payoff of entrants posting at P_k (nor vice versa). It follows that pricing in equilibrium will be symmetric and uniform; we therefore impose $j = m$.[34]

Then, in expectation, the entrants' payoffs are higher posting at P_k (with

[34] A symmetry argument explains why asking prices cannot differ in equilibrium. If there were different asking prices and an entrant were better off pricing at P_k, entrant(s) pricing at a lower price would also be better off pricing at P_k (or vice versa). In the case that an entrant asking P_k is indifferent between this and asking some lower price, an entrant asking a lower price that instead asks P_k will increase the expected payoff of pricing at P_k (since $\mathrm{E}\left(\pi_i(P_k)\right)$ is increasing in j).

$m-1$ other entrants) than unilaterally deviating to a lower price P_{k-1} (with guaranteed sale) if $\frac{m-k}{m}P_k > P_{k-1}$ (for $P_k > P_{k-1} \geq P_m$). The interval between price P_k and P_{k-1} is r, so these entrants are better off posting at P_k than P_{k-1} if $P_k < \frac{r}{k}m$. (Since unilaterally pricing at P_{k+1} guarantees an entrant no sale, pricing at P_{k-1} may be be an equilibrium for m entrants, even when no entrant would unilaterally deviate to P_{k-1} from P_k.) The expected payoff of posting at P_k is $\mathrm{E}\left(\pi_i(P_k)\right) = v + \frac{m-k}{m}P_k - h$.

Note that when $P_k = \frac{r}{k}m$, entrants pricing at P_{k+1} are indifferent between pricing at P_k and P_{k-1}. Such an equality is not robust to trembles (Selten, 1975), since a tremble implies a non-zero probability of one or more of the m entrants posting a lower asking price.

A.1.4. *Predictions for the* Poap *Treatments via Subgame Perfection*

In subgame perfect equilibrium, agents only enter (and proceed to the pricing stage) if the expected payoff of entering is at least as great than the outside option, v. This is true when $\mathrm{E}(P_i) \geq h$. For entrants pricing at P_m, this is true when $P_m > h$; for m entrants pricing at $P_k > P_m$, this is true when $\frac{m-k}{m}P_k > h$. (Agents are indifferent between entering and staying out at equality.)

A.2. *Subgame Perfection in the* Poap *Treatments*

Now let us consider the parameterization of the Poap-i treatment. (Solutions to the Poap-g treatment follow trivially.) In Poap-i, c=5 and $h = \{2, 4, 6, 8\}$. As in all treatments, $v = 1$, $r = 2$, and there are $n = 5$ agents.

A.2.1. *The Pricing Stage*

Pricing along the demand curve is always supported in equilibrium. For some number of entrants (i.e. $m = \{3, 4, 5\}$) other equilibria also exist.

For $m = 1$ and $m = 2$, it is trivial to verify that in equilibrium entrants will price along the demand curve at $P_m = 8$ and $P_m = 6$.

For $m = 3$, both all entrants pricing along the demand schedule at $P_1 = 4$ and all entrants pricing at $P_1 = 6$ are equilibria. However, all entrants pricing at $P_1 = 6$ is not robust to trembles.

For $m = 4$, all entrants posting at $P_m = 2$ and all entrants posting at $P_1 = 4$ are each equilibrium strategy profiles in the pricing stage.

For $m = 5$, all entrants posting at $P_m = 0$, all entrants posting at $P_1 = 2$, and all entrants posting at $P_2 = 4$ are each equilibrium strategy profiles in the pricing stage.

A.2.2. *The Entry Stage and Subgame Perfection*

Pricing along the demand curve in the pricing stage results in a subgame perfect equilibrium with payoff equivalence with the market entry game for any h. For $h = \{2, 4\}$ other equilibria also exist.

If $h = 8$, then entry is profitable, i.e. $\mathrm{E}(P_i) \geq h$ only when $P(m) = 8$, which occurs when $m = 1$. The entrant is indifferent between entering and staying out.

If $h = 6$, then entry is profitable only when $P(m) \geq 6$, which occurs when $m \leq 2$. When $m = 1$, the second entrant is indifferent between entering and staying out.

If $h = 4$, then entry is profitable only when $P(m) \geq 4$ or $\frac{m-k}{m} P_k \geq 4$. Both occur when $m \leq 3$. Regardless of whether all entrants price at $P_m = 4$ or $P_1 = 6$, the third entrant is indifferent between entering and staying out.

If $h = 2$, then entry is profitable only when $P(m) \geq 2$ or $\frac{m-k}{m} P_k \geq 2$. There is an equilibrium whem $m \leq 4$ and all entrants price at $P_m = 2$, with the fourth entrant being indifferent between entering and staying out. There is also an equilibrium when $m \leq 5$; for both four and five entrants, posting at $P_k = 4$ is an equilibrium in the pricing stage, so the fifth entrant in this case has a strictly positive incentive to enter.

TABLE VIII

SUMMARY OF PARAMETERS BY TREATMENT FOR THE FIRST BLOCK

Panel A. Demand Schedule A: $c = 5$

Unit Number	0	1	2	3	4	5
Resale Value	10	8	6	4	2	0

Panel B. Demand Schedule B: $c = 6$

Unit Number	0	1	2	3	4	5
Resale Value	12	10	8	6	4	2

Panel C. Demand Schedule C: $c = 7$

Unit Number	0	1	2	3	4	5
Resale Value	14	12	10	8	6	4

Panel D. Demand Schedule D: $c = 8$

Unit Number	0	1	2	3	4	5
Resale Value	16	14	12	10	8	6

Panel E. Summary of Parameters for First Block, Periods 1 through 16

	Varying				Constant								Varying			
Period	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
m^*	1	2	4	3	3	3	3	3	3	3	3	3	1	4	3	2
MEG:OG-G																
c	1	2	4	3	3	3	3	3	3	3	3	3	1	4	3	2
h	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MEG:OG-I																
c	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
h	8	6	2	4	4	4	4	4	4	4	4	4	8	2	4	6
MEG:MF-G																
Demand	A	B	D	C	C	C	C	C	C	C	C	C	A	D	C	B
h	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
MEG:MF-I																
Demand	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
h	8	6	2	4	4	4	4	4	4	4	4	4	8	2	4	6
POAP-G																
Demand	A	B	D	C	C	C	C	C	C	C	C	C	A	D	C	B
h	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
POAP-I																
Demand	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
h	8	6	2	4	4	4	4	4	4	4	4	4	8	2	4	6

Note: Demand is given by $P(m) = r(c - m)$ where $r = 2$ throughout; varying c produces demand schedules A, B, C, and D. The predicted number of entrants is $m^* = \hat{c}$ where $\hat{c} = c - h/r$.

TABLE IX

McNemar's Paired Tests on Contingency Tables of Transitions in First and Last Pairs of Sub-Blocks for $c = \{1, 2, 3, 4\}$ in Meg:Og-g

Panel A. Contingency Table of Transitions and McNemar's Test for $c = 1$

$\chi^2 = 5.1429$, $p \approx 0.0233$		Sub-Blocks 11 and 12	
		Transition	No Transition
Sub-Blocks 1 and 2	Transition	1	7
	No Transition	0	12

Panel B. Contingency Table of Transitions and McNemar's Test for $c = 2$

$\chi^2 = 0.9000$, $p \approx 0.3428$		Sub-Blocks 11 and 12	
		Transition	No Transition
Sub-Blocks 1 and 2	Transition	0	7
	No Transition	3	10

Panel C. Contingency Table of Transitions and McNemar's Test for $c = 3$

$\chi^2 = 2.3442$, $p \approx 0.1258$		Sub-Blocks 11 and 12	
		Transition	No Transition
Sub-Blocks 1 and 2	Transition	2	7
	No Transition	2	9

Panel D. Contingency Table of Transitions and McNemar's Test for $c = 4$

$\chi^2 = 1.7778$, $p \approx 0.1824$		Sub-Blocks 11 and 12	
		Transition	No Transition
Sub-Blocks 1 and 2	Transition	0	6
	No Transition	2	12

Note: Each panel, A through D, reports the contingent frequencies of 20 subjects transitioning or not in the first and last pair of sub-blocks, for $c = \{1, 2, 3, 4\}$ respectively. For each, the results of a McNemar test are reported, with the null hypothesis being equality of the marginal probabilities of each outcome.

TABLE X

MARGINAL EFFECTS OF PROBIT ON COMPETITIVE EQUILIBRIUM NUMBER OF ENTRANTS WITH ROBUST STANDARD ERRORS CLUSTERED ON GROUPS

	Prob. of Competitive Equilibrium Entry, $Pr(m = m^*)$
Individual-level Shifter	−0.0391
	(0.0574)
Numerical Step Demand	0.0764
	(0.0709)
Market (POAP)	−0.0576
	(0.0737)
Stationary c and h	−0.0457
	(0.0544)
Period	0.0012
	(0.0010)
Period × Individual-level Shifter	0.0005
	(0.0011)
Period × Numerical Step Demand	−0.0010
	(0.0013)
Period × Market (POAP)	0.0036**
	(0.0015)
Period × Stationary c and h	0.0027***
	(0.0009)
Observations	2,304

Note: Robust standard errors are clustered at the group level, with 4 groups per each of the 6 treatments, and 96 periods per group. Standard errors are in parentheses. MEG:MF and POAP were coded as having Numerical Step Demand. Treatments with "-I" designations had Individual-level Shifters.

*** Significant at the 1 percent level.
** Significant at the 5 percent level.

TABLE XI

Mean Squared Deviation from Pure and Symmetric Mixed Strategy Equilibria Entry Across Treatments with Group-Level Shifters

Treat.	Group	Subject	P.S. $\hat{y}$	Pure Strategy $(\hat{y}-y)^2$, in Block 1	2	3	4	5	6	Symm. Mixed Strategy $(\hat{y}-y)^2$ in Block 1	2	3	4	5	6
Meg:Og-g	1	1	0	.050	.153	.200	.028	.000	.000	.000	.028	.050	.003	.050	.050
Meg:Og-g	1	2	1	.028	.050	.112	.112	.028	.003	.003	.000	.012	.012	.003	.028
Meg:Og-g	1	3	1	.050	.012	.003	.000	.000	.000	.000	.012	.028	.050	.050	.050
Meg:Og-g	1	4	0	.000	.000	.000	.000	.000	.000	.050	.050	.050	.050	.050	.050
Meg:Og-g	1	5	1	.003	.000	.000	.000	.000	.000	.028	.050	.050	.050	.050	.050
Meg:Og-g	2	1	1	.028	.000	.000	.000	.000	.000	.003	.050	.050	.050	.050	.050
Meg:Og-g	2	2	0	.028	.003	.000	.000	.003	.003	.003	.028	.050	.050	.028	.028
Meg:Og-g	2	3	0	.003	.000	.000	.003	.000	.000	.028	.050	.050	.028	.050	.050
Meg:Og-g	2	4	1	.028	.012	.012	.012	.078	.112	.003	.012	.012	.012	.003	.012
Meg:Og-g	2	5	1	.000	.000	.000	.000	.000	.000	.050	.050	.050	.050	.050	.050
Meg:Og-g	3	1	1	.003	.050	.012	.028	.050	.012	.028	.000	.012	.003	.000	.012
Meg:Og-g	3	2	1	.012	.028	.000	.003	.028	.003	.012	.003	.050	.028	.003	.028
Meg:Og-g	3	3	1	.050	.078	.050	.003	.050	.028	.000	.003	.000	.028	.000	.003
Meg:Og-g	3	4	0	.078	.028	.078	.112	.050	.050	.003	.003	.003	.012	.000	.000
Meg:Og-g	3	5	0	.012	.003	.078	.012	.000	.000	.012	.028	.003	.012	.050	.050
Meg:Og-g	4	1	0	.003	.028	.003	.078	.112	.000	.028	.003	.028	.003	.012	.050
Meg:Og-g	4	2	1	.050	.028	.078	.078	.050	.078	.000	.003	.003	.003	.000	.003
Meg:Og-g	4	3	1	.000	.000	.000	.000	.000	.000	.050	.050	.050	.050	.050	.050
Meg:Og-g	4	4	0	.003	.012	.000	.000	.000	.000	.028	.012	.050	.050	.050	.050
Meg:Og-g	4	5	1	.012	.003	.050	.000	.000	.000	.012	.028	.000	.050	.050	.050
Meg:Mf-g	1	1	0	.028	.000	.000	.000	.000	.000	.003	.050	.050	.050	.050	.050
Meg:Mf-g	1	2	1	.003	.012	.003	.003	.012	.028	.028	.012	.028	.028	.012	.003
Meg:Mf-g	1	3	1	.153	.000	.000	.000	.000	.000	.028	.050	.050	.050	.050	.050
Meg:Mf-g	1	4	1	.000	.000	.000	.000	.000	.000	.050	.050	.050	.050	.050	.050
Meg:Mf-g	1	5	0	.000	.000	.000	.000	.000	.000	.050	.050	.050	.050	.050	.050
Meg:Mf-g	2	1	1	.153	.028	.000	.000	.000	.000	.028	.003	.050	.050	.050	.050
Meg:Mf-g	2	2	1	.000	.000	.000	.000	.000	.000	.050	.050	.050	.050	.050	.050
Meg:Mf-g	2	3	0	.078	.200	.012	.200	.200	.003	.003	.050	.012	.050	.050	.028
Meg:Mf-g	2	4	0	.012	.000	.000	.000	.000	.000	.012	.050	.050	.050	.050	.050
Meg:Mf-g	2	5	1	.000	.153	.000	.200	.200	.003	.050	.028	.050	.050	.050	.028
Meg:Mf-g	3	1	1	.028	.000	.000	.000	.000	.000	.003	.050	.050	.050	.050	.050
Meg:Mf-g	3	2	0	.050	.050	.028	.050	.003	.028	.000	.000	.003	.000	.028	.003
Meg:Mf-g	3	3	1	.028	.012	.012	.003	.012	.012	.003	.012	.012	.028	.012	.012
Meg:Mf-g	3	4	1	.050	.050	.028	.028	.012	.012	.000	.000	.003	.003	.012	.012
Meg:Mf-g	3	5	0	.012	.003	.000	.000	.003	.000	.012	.028	.050	.050	.028	.050
Meg:Mf-g	4	1	1	.050	.078	.078	.050	.078	.012	.000	.003	.003	.000	.003	.012
Meg:Mf-g	4	2	0	.078	.050	.050	.050	.000	.000	.003	.000	.000	.000	.050	.050
Meg:Mf-g	4	3	1	.028	.003	.000	.003	.003	.000	.003	.028	.050	.028	.028	.050
Meg:Mf-g	4	4	1	.028	.003	.000	.003	.000	.000	.003	.028	.050	.028	.050	.050
Meg:Mf-g	4	5	0	.078	.003	.012	.000	.003	.012	.003	.028	.012	.050	.028	.012
Poap-g	1	1	1	.000	.000	.000	.000	.000	.000	.050	.050	.050	.050	.050	.050
Poap-g	1	2	0	.000	.000	.000	.000	.000	.000	.050	.050	.050	.050	.050	.050
Poap-g	1	3	0	.200	.000	.000	.000	.000	.000	.050	.050	.050	.050	.050	.050
Poap-g	1	4	1	.078	.000	.000	.000	.000	.000	.003	.050	.050	.050	.050	.050
Poap-g	1	5	1	.003	.003	.000	.000	.000	.000	.028	.028	.050	.050	.050	.050
Poap-g	2	1	0	.050	.000	.000	.000	.000	.000	.000	.050	.050	.050	.050	.050
Poap-g	2	2	1	.003	.003	.003	.000	.003	.000	.028	.028	.028	.050	.028	.050
Poap-g	2	3	1	.078	.000	.000	.000	.000	.000	.003	.050	.050	.050	.050	.050
Poap-g	2	4	1	.028	.012	.050	.078	.050	.003	.003	.012	.000	.003	.000	.028
Poap-g	2	5	0	.153	.012	.012	.028	.028	.028	.028	.012	.012	.003	.003	.003
Poap-g	3	1	0	.153	.200	.200	.000	.000	.000	.028	.050	.050	.050	.050	.050
Poap-g	3	2	1	.028	.078	.050	.000	.000	.000	.003	.003	.000	.050	.050	.050
Poap-g	3	3	0	.028	.050	.003	.003	.003	.000	.003	.000	.028	.028	.028	.050
Poap-g	3	4	1	.028	.000	.000	.000	.000	.000	.003	.050	.050	.050	.050	.050
Poap-g	3	5	1	.000	.000	.000	.000	.000	.000	.050	.050	.050	.050	.050	.050
Poap-g	4	1	0	.200	.153	.112	.012	.028	.000	.050	.028	.012	.012	.003	.050
Poap-g	4	2	1	.112	.003	.028	.000	.000	.000	.012	.028	.003	.050	.050	.050
Poap-g	4	3	1	.003	.000	.000	.000	.000	.000	.028	.050	.050	.050	.050	.050
Poap-g	4	4	1	.012	.050	.003	.012	.000	.000	.012	.000	.028	.012	.050	.050
Poap-g	4	5	0	.012	.000	.000	.028	.000	.000	.012	.050	.050	.003	.050	.050

TABLE XII

Mean Squared Deviation from Pure and Symmetric Mixed Strategy Equilibria Entry Across Treatments with Individual-Level Shifters

Treat.	Group	Subject	P.S. $\hat{y}$	Pure Strategy $(\hat{y}-y)^2$, in Block						Symm. Mixed Strategy $(\hat{y}-y)^2$ in Block					
				1	2	3	4	5	6	1	2	3	4	5	6
Meg:Og-i	1	1	1	.028	.003	.000	.028	.000	.000	.003	.028	.050	.003	.050	.050
Meg:Og-i	1	2	0	.000	.000	.000	.000	.000	.000	.050	.050	.050	.050	.050	.050
Meg:Og-i	1	3	0	.050	.000	.000	.000	.000	.000	.000	.050	.050	.050	.050	.050
Meg:Og-i	1	4	1	.050	.012	.012	.000	.000	.000	.000	.012	.012	.050	.050	.050
Meg:Og-i	1	5	1	.012	.000	.000	.000	.000	.000	.012	.050	.050	.050	.050	.050
Meg:Og-i	2	1	0	.028	.012	.028	.012	.012	.012	.003	.012	.003	.012	.012	.012
Meg:Og-i	2	2	0	.112	.112	.078	.078	.078	.012	.012	.012	.003	.003	.003	.012
Meg:Og-i	2	3	1	.078	.153	.078	.050	.078	.028	.003	.028	.003	.000	.003	.003
Meg:Og-i	2	4	1	.050	.003	.050	.028	.012	.012	.000	.028	.000	.003	.012	.012
Meg:Og-i	2	5	1	.012	.003	.003	.012	.000	.000	.012	.028	.028	.012	.050	.050
Meg:Og-i	3	1	0	.078	.078	.012	.078	.000	.000	.003	.003	.012	.003	.050	.050
Meg:Og-i	3	2	1	.112	.050	.153	.003	.012	.000	.012	.000	.028	.028	.012	.050
Meg:Og-i	3	3	1	.028	.003	.000	.012	.028	.003	.003	.028	.050	.012	.003	.028
Meg:Og-i	3	4	1	.200	.200	.200	.200	.003	.000	.050	.050	.050	.050	.028	.050
Meg:Og-i	3	5	0	.112	.078	.078	.050	.050	.000	.012	.003	.003	.000	.000	.050
Meg:Og-i	4	1	0	.078	.050	.050	.050	.003	.028	.003	.000	.000	.000	.028	.003
Meg:Og-i	4	2	0	.050	.003	.012	.028	.078	.153	.000	.028	.012	.003	.003	.028
Meg:Og-i	4	3	1	.028	.050	.028	.012	.028	.028	.003	.000	.003	.012	.003	.003
Meg:Og-i	4	4	1	.050	.153	.078	.050	.012	.028	.000	.028	.003	.000	.012	.003
Meg:Og-i	4	5	1	.003	.003	.000	.000	.000	.000	.028	.028	.050	.050	.050	.050
Meg:Mf-i	1	1	0	.200	.200	.050	.078	.078	.000	.050	.050	.000	.003	.003	.050
Meg:Mf-i	1	2	1	.153	.028	.000	.003	.028	.000	.028	.003	.050	.028	.003	.050
Meg:Mf-i	1	3	1	.012	.012	.050	.078	.078	.000	.012	.012	.000	.003	.003	.050
Meg:Mf-i	1	4	0	.050	.028	.153	.000	.050	.000	.000	.003	.028	.050	.000	.050
Meg:Mf-i	1	5	1	.012	.028	.050	.003	.012	.000	.012	.003	.000	.028	.012	.050
Meg:Mf-i	2	1	1	.050	.112	.000	.000	.000	.000	.000	.012	.050	.050	.050	.050
Meg:Mf-i	2	2	0	.112	.000	.003	.000	.000	.000	.012	.050	.028	.050	.050	.050
Meg:Mf-i	2	3	0	.078	.200	.050	.003	.003	.000	.003	.050	.000	.028	.028	.050
Meg:Mf-i	2	4	1	.078	.000	.000	.000	.000	.000	.003	.050	.050	.050	.050	.050
Meg:Mf-i	2	5	1	.003	.000	.000	.000	.000	.000	.028	.050	.050	.050	.050	.050
Meg:Mf-i	3	1	1	.050	.012	.012	.012	.003	.000	.000	.012	.012	.012	.028	.050
Meg:Mf-i	3	2	1	.003	.000	.000	.003	.000	.000	.028	.050	.050	.028	.050	.050
Meg:Mf-i	3	3	1	.003	.028	.050	.012	.050	.000	.028	.003	.000	.012	.000	.050
Meg:Mf-i	3	4	0	.050	.078	.050	.012	.028	.000	.000	.003	.000	.012	.003	.050
Meg:Mf-i	3	5	0	.028	.012	.003	.003	.003	.000	.003	.012	.028	.028	.028	.050
Meg:Mf-i	4	1	0	.028	.112	.200	.003	.028	.028	.003	.012	.050	.028	.003	.003
Meg:Mf-i	4	2	1	.028	.028	.000	.028	.000	.000	.003	.003	.050	.003	.050	.050
Meg:Mf-i	4	3	1	.012	.012	.003	.012	.000	.003	.012	.012	.028	.012	.050	.028
Meg:Mf-i	4	4	1	.028	.003	.078	.078	.028	.050	.003	.028	.003	.003	.003	.000
Meg:Mf-i	4	5	0	.028	.000	.000	.000	.000	.000	.003	.050	.050	.050	.050	.050
Poap-i	1	1	0	.112	.012	.028	.000	.000	.000	.012	.012	.003	.050	.050	.050
Poap-i	1	2	1	.012	.028	.000	.000	.000	.000	.012	.003	.050	.050	.050	.050
Poap-i	1	3	0	.000	.003	.000	.000	.000	.000	.050	.028	.050	.050	.050	.050
Poap-i	1	4	1	.000	.000	.000	.000	.000	.003	.050	.050	.050	.050	.050	.028
Poap-i	1	5	1	.003	.000	.000	.000	.000	.000	.028	.050	.050	.050	.050	.050
Poap-i	2	1	0	.003	.000	.000	.000	.000	.003	.028	.050	.050	.050	.050	.028
Poap-i	2	2	0	.050	.000	.000	.000	.000	.000	.000	.050	.050	.050	.050	.050
Poap-i	2	3	1	.028	.000	.000	.000	.000	.000	.003	.050	.050	.050	.050	.050
Poap-i	2	4	1	.003	.000	.000	.003	.000	.000	.028	.050	.050	.028	.050	.050
Poap-i	2	5	1	.000	.000	.000	.000	.000	.000	.050	.050	.050	.050	.050	.050
Poap-i	3	1	1	.078	.003	.000	.000	.000	.000	.003	.028	.050	.050	.050	.050
Poap-i	3	2	1	.050	.028	.153	.200	.000	.000	.000	.003	.028	.050	.050	.050
Poap-i	3	3	0	.050	.003	.000	.028	.000	.000	.000	.028	.050	.003	.050	.050
Poap-i	3	4	1	.000	.000	.000	.000	.000	.000	.050	.050	.050	.050	.050	.050
Poap-i	3	5	0	.028	.050	.153	.000	.000	.000	.003	.000	.028	.050	.050	.050
Poap-i	4	1	0	.200	.028	.112	.078	.200	.003	.050	.003	.012	.003	.050	.028
Poap-i	4	2	1	.000	.050	.012	.050	.112	.028	.050	.000	.012	.000	.012	.003
Poap-i	4	3	1	.028	.000	.000	.000	.000	.000	.003	.050	.050	.050	.050	.050
Poap-i	4	4	0	.003	.078	.000	.000	.000	.000	.028	.003	.050	.050	.050	.050
Poap-i	4	5	1	.050	.200	.153	.028	.000	.000	.000	.050	.028	.003	.050	.050

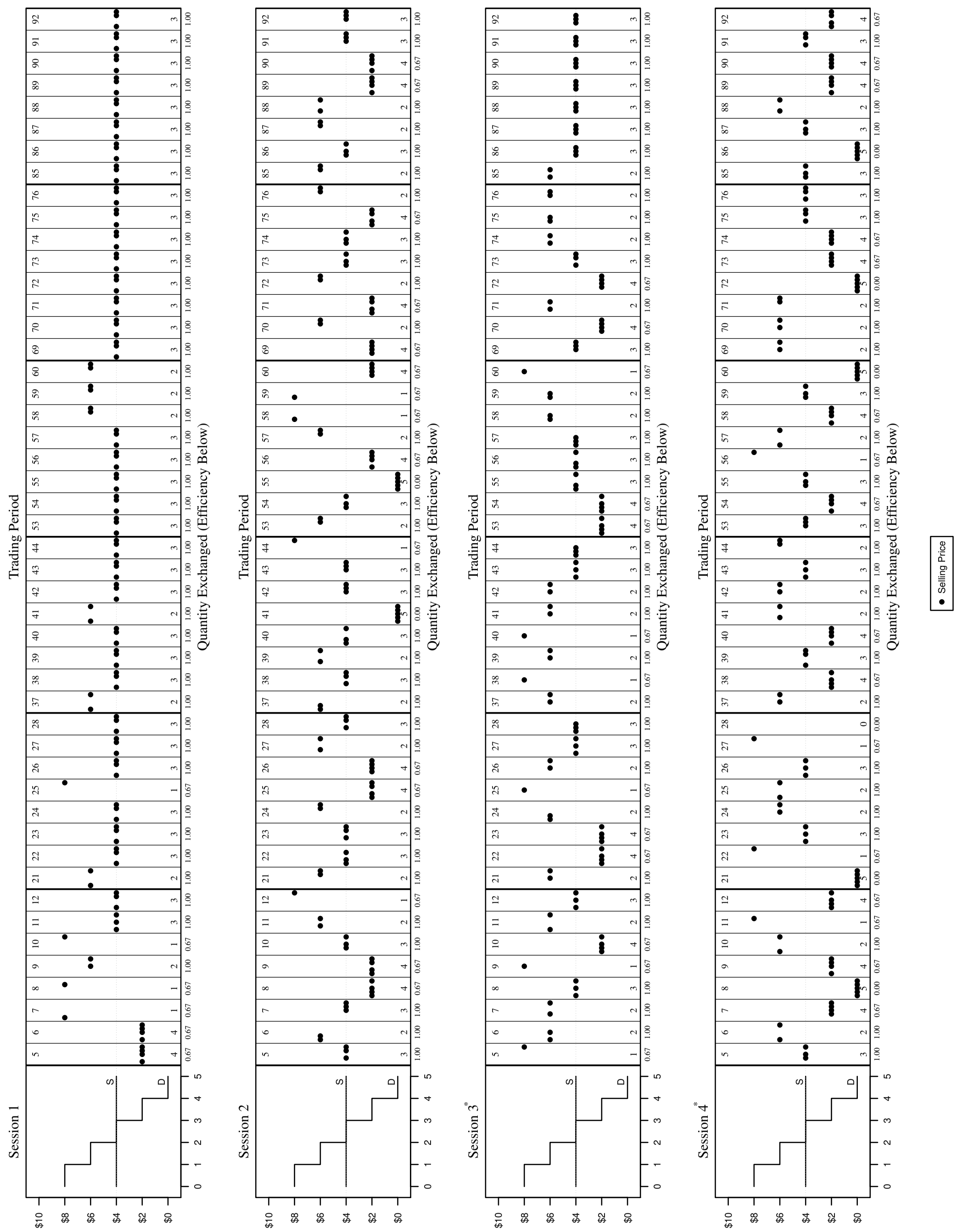

Figure 6: Implied Prices and Quantities Exchanged in Stationary Periods of All Sessions of Treatment MEG:OG-I.

Note: Sessions with asterisks (*) are explained in footnote 8.

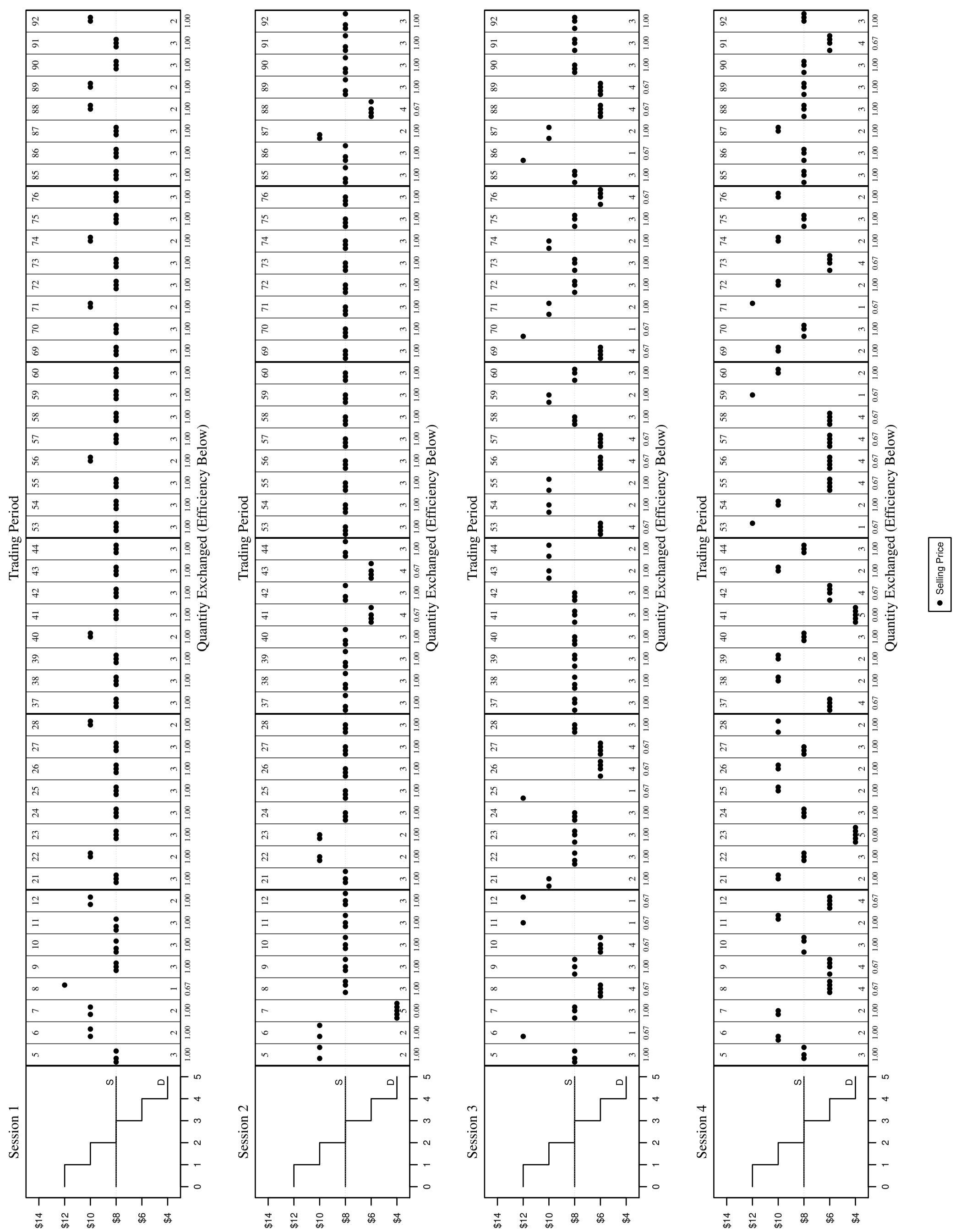

Figure 7: Implied Prices and Quantities Exchanged in Stationary Periods of All Sessions of Treatment Meg:Mf-g.

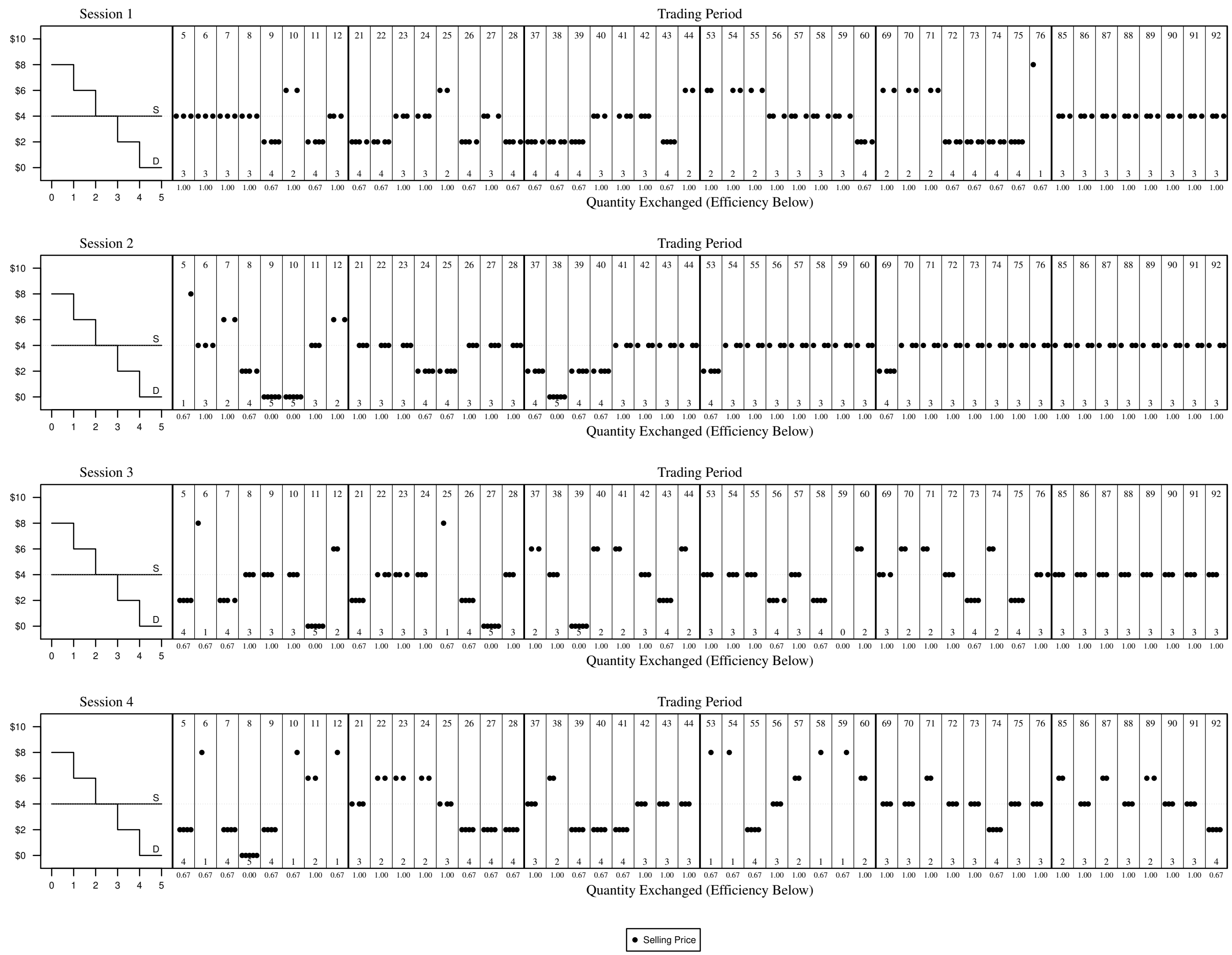

Figure 8: Implied Prices and Quantities Exchanged in Stationary Periods of All Sessions of Treatment MEG:MF-I.

TABLE XIII

OLS on Mean Squared Deviation (MSD) from Equilibrium Entrants by Treatment

Treatment	MSD from:	Constant	Std. Error	P-value	Block	Std. Error	P-value	R^2
Meg:Og	Pure	0.0482	(0.0063)	< 0.001	-0.0052	(0.0016)	0.0015	0.0417
	Sym. Mixed	0.0138	(0.0030)	< 0.001	0.0033	(0.0008)	< 0.001	0.0717
Meg:Mf	Pure	0.0525	(0.0066)	< 0.001	-0.0074	(0.0017)	< 0.001	0.0732
	Sym. Mixed	0.0142	(0.0029)	< 0.001	0.0042	(0.0007)	< 0.001	0.1186
Poap	Pure	0.0495	(0.0065)	< 0.001	-0.0082	(0.0017)	< 0.001	0.0911
	Sym. Mixed	0.0218	(0.0026)	< 0.001	0.0043	(0.0007)	< 0.001	0.1519

APPENDIX B: INSTRUCTIONS (FOR ONLINE PUBLICATION)

B.1. *Instructions for Treatment* Meg:Og-g

B.1.1. *This Segment*

In the rounds about to begin, and which will continue until further notice, there are 5 participants. In each round, you will have the opportunity to make a decision between one of two possible actions. Once all participants have made their decisions, a second screen will appear which will report to you your payoff resulting from that round's events, and also the determinants of that payoff — namely your decision, and the decisions of others also participating. (More on this below.) There will be multiple rounds. Throughout these rounds you will stay in the same group of 5 participants.

B.1.2. *The Sequence of Play in a Round*

The first computer screen you see in each round asks you to make a decision between two actions: IN or OUT. You enter your decision by using the mouse to fill in the radio-button next to the action you wish to take. If you want to choose action IN, fill in the circle next to IN by clicking on it with the mouse. If you want to choose action OUT, fill in the circle next to OUT by clicking on it with the mouse. Once all participants have entered their decisions, a second screen will appear. This second screen reminds you of your decision for the round, informs you of your payoff for the round, and informs you of other determinants of your payoff (e.g. the decisions taken by other participants). Your payoff represents an amount in ECU that could be paid to you in cash (if the given round is randomly selected for payoff) as will be explained below.

B.1.3. *How payoffs are Determined*

Payoffs are determined as follows:

- If you choose OUT your payoff for the round is equal to 1 (this is true in each round).
- If you choose IN, your payoff depends on the total number of participants, including yourself, who choose action IN. Suppose that $m = 1$, 2, 3, 4, or 5 represents the number of participants who choose IN. If you are one of these m participants, your payoff for the round is given by:

$$\text{Payoff} = 1 + 2 \cdot (c - m) - h_i$$

where
$c =$ "capacity" of the market (may vary by round)
$m =$ determined as the total number of participants choosing IN in a given round
$h_i =$ your individual cost of choosing IN (may vary by round)

For example, if you are one of 3 participants who chooses IN, and $c = 4$ and $h_i = 0$, then your payoff from choosing IN would be: $1 + 2 \cdot (4 - 3) - 0$, which equals 3.

As another example, suppose all of the numbers in the first example stayed the same, except c, which was instead $c = 2$. Then your payoff from choosing IN would be: $1 + 2 \cdot (2 - 3) - 0$, which equals -1.

As another example, suppose all of the numbers in the first example stayed the same, except m, which was instead $m = 2$. Then your payoff from choosing IN would be: $1 + 2 \cdot (4 - 2) - 0$, which equals 5.

Are there any questions before we begin?

B.2. *Instructions for Treatment* MEG:OG-I

B.2.1. *This Segment*

In the rounds about to begin, and which will continue until further notice, there are 5 participants. In each round, you will have the opportunity to make a decision between one of two possible actions. Once all participants have made their decisions, a second screen will appear which will report to you your payoff resulting from that round's events, and also the determinants of that payoff — namely your decision, and the decisions of others also participating. (More on this below.) There will be multiple rounds. Throughout these rounds you will stay in the same group of 5 participants.

B.2.2. *The Sequence of Play in a Round*

The first computer screen you see in each round asks you to make a decision between two actions: IN or OUT. You enter your decision by using the mouse to fill in the radio-button next to the action you wish to take. If you want to choose action IN, fill in the circle next to IN by clicking on it with the mouse. If you want to choose action OUT, fill in the circle next to OUT by clicking on it with the mouse. Once all participants have entered their decisions, a second screen will appear. This second screen reminds you of your decision for the round, informs you of your payoff for the round, and informs you of other determinants of your payoff (e.g. the decisions taken by other participants). Your payoff represents an amount in ECU that could be paid to you in cash (if the given round is randomly selected for payoff) as will be explained below.

B.2.3. *How payoffs are Determined*

Payoffs are determined as follows:

- If you choose OUT your payoff for the round is equal to 1 (this is true in each round).
- If you choose IN, your payoff depends on the total number of participants, including yourself, who choose action IN. Suppose that $m = 1$, 2, 3, 4, or 5 represents the number of participants who choose IN. If you are one of these m participants, your payoff for the round is given by:

  $$\text{Payoff} = 1 + 2 \cdot (c - m) - h_i$$

  where

  $c =$ "capacity" of the market (may vary by round)

  $m =$ determined as the total number of participants choosing IN in a given round

  $h_i =$ your individual cost of choosing IN (may vary by round)

For example, if you are one of 3 participants who chooses IN, and $c = 4$ and $h_i = 0$, then your payoff from choosing IN would be: $1 + 2 \cdot (4 - 3) - 0$, which equals 3.

As another example, suppose all of the numbers in the first example stayed the same, except h_i, which was instead $h_i = 4$. Then your payoff from choosing IN would be: $1 + 2 \cdot (4 - 3) - 4$, which equals -1.

As another example, suppose all of the numbers in the first example stayed the same, except m, which was instead $m = 2$. Then your payoff from choosing IN would be: $1 + 2 \cdot (4 - 2) - 0$, which equals 5.

Are there any questions before we begin?

B.3. *Instructions for Treatment* Meg:Og-i*

B.3.1. *This Segment*

In the rounds about to begin, and which will continue until further notice, there are 5 participants. In each round, you will have the opportunity to make a decision between one of two possible actions. Once all participants have made their decisions, a second screen will appear which will report to you your payoff resulting from that round's events, and also the determinants of that payoff — namely your decision, and the decisions of others also participating. (More on this below.) There will be multiple rounds. Throughout these rounds you will stay in the same group of 5 participants.

B.3.2. *The Sequence of Play in a Round*

The first computer screen you see in each round asks you to make a decision between two actions: IN or OUT. You enter your decision by using the mouse to fill in the radio-button next to the action you wish to take. If you want to choose action IN, fill in the circle next to IN by clicking on it with the mouse. If you want to choose action OUT, fill in the circle next to OUT by clicking on it with the mouse. Once all participants have entered their decisions, a second screen will appear. This second screen reminds you of your decision for the round, informs you of your payoff for the round, and informs you of other determinants of your payoff (e.g. the decisions taken by other participants). Your payoff represents an amount in ECU that could be paid to you in cash (if the given round is randomly selected for payoff) as will be explained below.

B.3.3. *How payoffs are Determined*

Payoffs are determined as follows:

- If you choose OUT your payoff for the round is equal to 1 (this is true in each round).
- If you choose IN, your payoff depends on the total number of participants, including yourself, who choose action IN. Suppose that $m = 1$, 2, 3, 4, or 5 represents the number of participants who choose IN. If you are one of these m participants, your payoff for the round is given

by:

$$\text{Payoff} = 1 + 2 \cdot (c - m) - h_i$$

where
$c =$ "capacity" of the market (may vary by round)
$m =$ determined as the total number of participants choosing IN in a given round
$h_i =$ your individual cost of choosing IN (may vary by round)

(Note also that at the beginning of each round, you will be informed of the number of units at which the payoff to "IN" and the payoff to "OUT" intersect in that round.)

For example, if you are one of 3 participants who chooses IN, and $c = 4$ and $h_i = 0$, then your payoff from choosing IN would be: $1 + 2 \cdot (4 - 3) - 0$, which equals 3.

As another example, suppose all of the numbers in the first example stayed the same, except h_i, which was instead $h_i = 4$. Then your payoff from choosing IN would be: $1 + 2 \cdot (4 - 3) - 4$, which equals -1.

As another example, suppose all of the numbers in the first example stayed the same, except m, which was instead $m = 2$. Then your payoff from choosing IN would be: $1 + 2 \cdot (4 - 2) - 0$, which equals 5.

Are there any questions before we begin?

B.4. *Instructions for Treatment* Meg:Mf-g

B.4.1. *This Segment*

In the rounds about to begin, and which will continue until further notice, there are 5 participants. In each round, you will have the opportunity to make a decision between one of two possible actions. Once all participants have made their decisions, a second screen will appear which will report to you your payoff resulting from that round's events, and also the determinants of that payoff — namely your decision, and the decisions of others also participating. (More on this below.) There will be multiple rounds. Throughout these rounds you will stay in the same group of 5 participants.

B.4.2. *The Sequence of Play in a Round*

The first computer screen you see in each round asks you to make a decision between two actions: IN or OUT. You enter your decision by using the mouse to fill in the radio-button next to the action you wish to take. If you want to choose action IN, fill in the circle next to IN by clicking on it with the mouse. If you want to choose action OUT, fill in the circle next to OUT by clicking on it with the mouse. Once all participants have entered their decisions, a second screen will appear. This second screen reminds you of your decision for the round, informs you of your payoff for the round, and informs you of other determinants of your payoff (e.g. the decisions taken by other participants). Your payoff represents an amount in ECU that could be paid to you in cash (if the given round is randomly selected for payoff) as will be explained below.

B.4.3. *How payoffs are Determined*

Payoffs are determined as follows:

- If you choose OUT your payoff for the round is equal to 1 (this is true in each round).
- If you choose IN, your payoff will be equal to $1 + \text{Price} - \text{MC}_i$. The components of this payoff are given by the following:
  - Price will be determined by the computer (a) adding up the number of people choosing IN (and who are thus attempting to sell 1 unit of a good) and (b) calculating the price which will allow all units to be sold at a single price. In a given round, the computer

does this (b) by referencing a given one of the following four demand schedules (which demand schedule is in effect in a given round is disclosed to you at the start of that round):

Demand Schedule A

Unit	Resale Value
First	8
Second	6
Third	4
Fourth	2
Fifth	0

Demand Schedule B

Unit	Resale Value
First	10
Second	8
Third	6
Fourth	4
Fifth	2

Demand Schedule C

Unit	Resale Value
First	12
Second	10
Third	8
Fourth	6
Fifth	4

Demand Schedule D

Unit	Resale Value
First	14
Second	12
Third	10
Fourth	8
Fifth	6

If one person chooses IN, then 1 unit is sold at the first unit price; if two people choose IN, then 2 units are sold at the second unit price, and so on. (Note also that at the beginning of each round, you will be informed of the number of units at which the demand schedule and the supply schedule intersect in that round.)

– You have an individual marginal cost of supplying a unit, MC_i.

For example, if you are one of 3 people who chooses IN, and $MC_i = 8$ and demand schedule D is in effect, then your payoff from choosing IN would be: $1 + 10 - 8$, which equals 3.

As another example, suppose all of the numbers in the first example stayed the same, except demand schedule B was in effect. Then your payoff from choosing IN would be: $1 + 6 - 8$, which equals -1.

As another example, suppose all of the numbers in the first example stayed the same, except the number of people choosing IN, which was instead 2. Then your payoff from choosing IN would be: $1 + 12 - 8$, which equals 5.

Are there any questions before we begin?

B.5. *Instructions for Treatment* MEG:MF-I

B.5.1. *This Segment*

In the rounds about to begin, and which will continue until further notice, there are 5 participants. In each round, you will have the opportunity to make a decision between one of two possible actions. Once all participants have made their decisions, a second screen will appear which will report to you your payoff resulting from that round's events, and also the determinants of that payoff — namely your decision, and the decisions of others also participating. (More on this below.) There will be multiple rounds. Throughout these rounds you will stay in the same group of 5 participants.

B.5.2. *The Sequence of Play in a Round*

The first computer screen you see in each round asks you to make a decision between two actions: IN or OUT. You enter your decision by using the mouse to fill in the radio-button next to the action you wish to take. If you want to choose action IN, fill in the circle next to IN by clicking on it with the mouse. If you want to choose action OUT, fill in the circle next to OUT by clicking on it with the mouse. Once all participants have entered their decisions, a second screen will appear. This second screen reminds you of your decision for the round, informs you of your payoff for the round, and informs you of other determinants of your payoff (e.g. the decisions taken by other participants). Your payoff represents an amount in ECU that could be paid to you in cash (if the given round is randomly selected for payoff) as will be explained below.

B.5.3. *How payoffs are Determined*

Payoffs are determined as follows:

- If you choose OUT your payoff for the round is equal to 1 (this is true in each round).
- If you choose IN, your payoff will be equal to $1 + \text{Price} - \text{MC}_i$. The components of this payoff are given by the following:
  - Price will be determined by the computer (a) adding up the number of people choosing IN (and who are thus attempting to sell 1 unit of a good) and (b) calculating the price which will allow all units to be sold at a single price. In a given round, the computer does this (b) by referencing the following demand schedule:

Unit	Resale Value
First	8
Second	6
Third	4
Fourth	2
Fifth	0

    If one person chooses IN, then 1 unit is sold at a price equal to 8; if two people choose IN, then 2 units are sold at a price of 6, and so on. (Note also that at the beginning of each round, you will be informed of the number of units at which the demand schedule and the supply schedule intersect in that round.)
  - You have an individual marginal cost of supplying a unit, MC_i

(may vary by round).

For example, if you are one of 3 people who chooses IN, and $MC_i = 2$, then your payoff from choosing IN would be: $1 + 4 - 2$, which equals 3.

As another example, suppose all of the numbers in the first example stayed the same, except MC_i, which was instead $MC_i = 6$. Then your payoff from choosing IN would be: $1 + 4 - 6$, which equals -1.

As another example, suppose all of the numbers in the first example stayed the same, except the number of people choosing IN, which was instead 2. Then your payoff from choosing IN would be: $1+6-2$, which equals 5.

Are there any questions before we begin?

B.6. *Instructions for Treatment* Poap-g

B.6.1. *This Segment*

In the rounds about to begin, and which will continue until further notice, there are 5 human participants acting as sellers and 5 robots acting as buyers. In each round, you will have the opportunity to make a decision between one of two possible actions. Once all participants have made their decisions, a second screen will appear which will report to you your payoff resulting from that round's events, and also the determinants of that payoff - namely your decision, and the decisions of others also participating. (More on this below.) There will be multiple rounds. Throughout these rounds you will stay in the same group of 5 human participants as sellers (with 5 robots as buyers).

B.6.2. *The Sequence of Play in a Round*

The first computer screen you see in each round asks you to make a decision between two actions: IN or OUT. You enter your decision by using the mouse to fill in the radio-button next to the action you wish to take. If you want to choose action IN, fill in the circle next to IN by clicking on it with the mouse; If you want to choose action OUT, fill in the circle next to OUT by clicking on it with the mouse. Once all participants have entered their decisions, a second screen will appear. This second screen reminds you of your decision for the round, informs you of your payoff for the round, and informs you of other determinants of your payoff (e.g. the decisions taken by other participants). Your payoff represents an amount in ECU that could be paid to you in cash (if the given round is randomly selected for payoff) as will be explained below.

B.6.3. *How payoffs are Determined*

Payoffs are determined as follows:

- If you choose OUT your payoff for the round is equal to 1 (this is true in each round).
- If you choose IN, your payoff will be equal to $1 + \text{Price} - \text{MC}_i$. The components of this payoff are given by the following:
  - Price will be determined by (a) what you nominate as a price (which must be an even number) and (b) whether a robot buyer chooses to purchase from you at the price you nominate. There are 5 robot buyers, each of whom can re-sell a purchased unit to the experimenter. The amount for which each robot buyer can re-sell a purchased unit to the experimenter is given by the demand schedule in effect in that round. In a given round, one of the following four demand schedules will be in effect (which demand schedule is in effect in a given round is disclosed to you at the start of the round):

Demand Schedule A

Unit	Resale Value
First	8
Second	6
Third	4
Fourth	2
Fifth	0

Demand Schedule B

Unit	Resale Value
First	10
Second	8
Third	6
Fourth	4
Fifth	2

Demand Schedule C

Unit	Resale Value
First	12
Second	10
Third	8
Fourth	6
Fifth	4

Demand Schedule D

Unit	Resale Value
First	14
Second	12
Third	10
Fourth	8
Fifth	6

(Note also that at the beginning of each round, you will be informed of the number of units at which the demand schedule and the supply schedule intersect in that round.)

– The robot buyers are programmed to choose (among units listed for sale) in descending order of resale value — that is, the robot buyer with the highest resale value chooses first, the buyer with the second highest resale value chooses second, and so on. A robot buyer chooses the lowest priced unit available, provided that resale value is greater than or equal to the price (otherwise it will not purchase at all).

– If no robot buyer purchases from you (in a round in which you have chosen IN), then the price will equal the "scrap price" for your purposes of determining your payoff in that round. The scrap price will always equal the lowest resale value on the demand schedule.

– If multiple units are listed at a given price, then the robot buyers may purchase all, none, or one or some but not all units. In the last case (in which only one or some but not all units are purchased) a random tie-breaker is employed to determine which of the units are purchased or not.

– You have an individual marginal cost of supplying a unit, MC_i.

For example, if demand schedule D is in effect, and you choose IN, and $\mathrm{MC}_i = 8$, and you nominate a price of 10, and a buyer purchases your unit, then your payoff from choosing IN would be: $1 + 10 - 8$, which equals 3.

As another example, suppose all of the numbers in the first example stayed the same, except no robot buyer bought your unit. Because you couldnt sell to a robot buyer, you would receive the scrap price, 6. Then your payoff from choosing IN would be: $1 + 6 - 8$, which equals -1.

As another example, suppose all of the numbers in the first example stayed the same, except the price you nominated was 12. Then your payoff from choosing IN would be: $1 + 12 - 8$, which equals 5.

Are there any questions before we begin?

B.7. *Instructions for Treatment* Poap-g**

B.7.1. *This Segment*

In the rounds about to begin, and which will continue until further notice, there are 5 human participants acting as sellers and 5 robots acting as buyers. In each round, you will have the opportunity to make a decision between one of two possible actions. Once all participants have made their decisions, a second screen will appear which will report to you your payoff resulting from that round's events, and also the determinants of that payoff - namely your decision, and the decisions of others also participating. (More on this below.) There will be multiple rounds. Throughout these rounds you will stay in the same group of 5 human participants as sellers (with 5 robots as buyers).

B.7.2. *The Sequence of Play in a Round*

The first computer screen you see in each round asks you to make a decision between two actions: IN or OUT. You enter your decision by using the mouse to fill in the radio-button next to the action you wish to take. If you want to choose action IN, fill in the circle next to IN by clicking on it with the mouse; If you want to choose action OUT, fill in the circle next to OUT by clicking on it with the mouse. Once all participants have entered their decisions, a second screen will appear. This second screen reminds you of your decision for the round, informs you of your payoff for the round, and informs you of other determinants of your payoff (e.g. the decisions taken by other participants). Your payoff represents an amount in ECU that could be paid to you in cash (if the given round is randomly selected for payoff) as will be explained below.

B.7.3. *How payoffs are Determined*

Payoffs are determined as follows:

- If you choose OUT your payoff for the round is equal to 1 (this is true in each round).
- If you choose IN, your payoff will be equal to $1 + \text{Price} - \text{MC}_i$. The components of this payoff are given by the following:
  - Price will be determined by (a) what you nominate as a price (which must be an even number) and (b) whether a robot buyer chooses to purchase from you at the price you nominate. There are 5 robot buyers, each of whom can re-sell a purchased unit to the experimenter. The amount for which each robot buyer can re-sell a purchased unit to the experimenter is given by the de-

mand schedule in effect in that round. In a given round, one of the following four demand schedules will be in effect (which demand schedule is in effect in a given round is disclosed to you at the start of the round):

Demand Schedule A

Unit	Resale Value
First	8
Second	6
Third	4
Fourth	2
Fifth	0

Demand Schedule B

Unit	Resale Value
First	10
Second	8
Third	6
Fourth	4
Fifth	2

Demand Schedule C

Unit	Resale Value
First	12
Second	10
Third	8
Fourth	6
Fifth	4

Demand Schedule D

Unit	Resale Value
First	14
Second	12
Third	10
Fourth	8
Fifth	6

(Note also that at the beginning of each round, you will be informed of the number of units at which the demand schedule and the supply schedule intersect in that round.)

– The robot buyers are programmed to choose (among units listed for sale) in descending order of resale value — that is, the robot buyer with the highest resale value chooses first, the buyer with the second highest resale value chooses second, and so on. A robot buyer chooses the lowest priced unit available, provided that resale value is greater than or equal to the price (otherwise it will not purchase at all).

– If no robot buyer purchases from you (in a round in which you have chosen IN), price will equal 0 for purposes of determining your payoff in that round.

– If multiple units are listed at a given price, then the robot buyers may purchase all, none, or one or some but not all units. In the last case (in which only one or some but not all units are purchased) a random tie-breaker is employed to determine which of the units are purchased or not.

– You have an individual marginal cost of supplying a unit, MC_i.

For example, if demand schedule D is in effect, and you choose IN, and $MC_i = 8$, and you nominate a price of 10, and a buyer purchases your unit, then your payoff from choosing IN would be: $1 + 10 - 8$, which equals 3.

As another example, suppose all of the numbers in the first example stayed the same, except demand schedule A was in effect. Then your payoff from choosing IN would be: $1 + 0 - 8$, which equals -7.

As another example, suppose all of the numbers in the first example stayed the same, except the price you nominated was 12. Then your payoff from choosing IN would be: $1 + 12 - 8$, which equals 5.

Are there any questions before we begin?

B.8. *Instructions for Treatment* POAP-I

B.8.1. *This Segment*

In the rounds about to begin, and which will continue until further notice, there are 5 human participants acting as sellers and 5 robots acting as buyers. In each round, you will have the opportunity to make a decision between one of two possible actions. Once all participants have made their decisions, a second screen will appear which will report to you your payoff resulting from that round's events, and also the determinants of that payoff

- namely your decision, and the decisions of others also participating. (More on this below.) There will be multiple rounds. Throughout these rounds you will stay in the same group of 5 human participants as sellers (with 5 robots as buyers).

B.8.2. *The Sequence of Play in a Round*

The first computer screen you see in each round asks you to make a decision between two actions: IN or OUT. You enter your decision by using the mouse to fill in the radio-button next to the action you wish to take. If you want to choose action IN, fill in the circle next to IN by clicking on it with the mouse; If you want to choose action OUT, fill in the circle next to OUT by clicking on it with the mouse. Once all participants have entered their decisions, a second screen will appear. This second screen reminds you of your decision for the round, informs you of your payoff for the round, and informs you of other determinants of your payoff (e.g. the decisions taken by other participants). Your payoff represents an amount in ECU that could be paid to you in cash (if the given round is randomly selected for payoff) as will be explained below.

B.8.3. *How payoffs are Determined*

Payoffs are determined as follows:

- If you choose OUT your payoff for the round is equal to 1 (this is true in each round).
- If you choose IN, your payoff will be equal to $1 + \text{Price} - \text{MC}_i$. The components of this payoff are given by the following:
  - Price will be determined by (a) what you nominate as a price (which must be an even number) and (b) whether a robot buyer chooses to purchase from you at the price you nominate. There are 5 robot buyers, each of whom can re-sell a purchased unit to

the experimenter, such that:
One buyer has a resale value of 8.
One buyer has a resale value of 6.
One buyer has a resale value of 4.
One buyer has a resale value of 2.
One buyer has a resale value of 0.
(Note also that at the beginning of each round, you will be informed of the number of units at which the demand schedule and the supply schedule intersect in that round.)

– The robot buyers are programmed to choose (among units listed for sale) in descending order of resale value — that is, the robot buyer with the highest resale value chooses first, the buyer with the second highest resale value chooses second, and so on. A robot buyer chooses the lowest priced unit available, provided that resale value is greater than or equal to the price (otherwise it will not purchase at all).

– If no robot buyer purchases from you (in a round in which you have chosen IN), price will equal 0 for purposes of determining your payoff in that round.

– If multiple units are listed at a given price, then the robot buyers may purchase all, none, or one or some but not all units. In the last case (in which only one or some but not all units are purchased) a random tie-breaker is employed to determine which of the units are purchased or not.

– You have an individual marginal cost of supplying a unit, MC_i (which may vary by round).

For example, if you choose IN, and $MC_i = 2$, and you nominate a price equal to 4, and a buyer purchases your unit, then your payoff from choosing

IN would be: $1 + 4 - 2$, which equals 3.

As another example, suppose all of the numbers in the first example stayed the same, except MC_i which was instead equal to 6. Then your payoff from choosing IN would be: $1 + 4 - 6$, which equals -1.

As another example, suppose all of the numbers in the first example stayed the same, except the price you nominated was 6. Then your payoff from choosing IN would be: $1 + 6 - 2$, which equals 5.

Are there any questions before we begin?