Nominal Price Shocks in Monopolistically Competitive Markets: An Experimental Analysis*

Douglas Davis
Virginia Commonwealth University
Richmond VA 23284-4000
(804) 828-7140
dddavis@vcu.edu

Oleg Korenok
Virginia Commonwealth University
Richmond VA 23284-4000
(804) 828-3185
okorenok@vcu.edu

June, 2010

Abstract: We report a price-setting market experiment conducted to examine the capacity of price and information frictions to explain real responses to nominal price shocks. As predicted by the standard dynamic models of adjustment in monopolistically competitive markets, we find that both price and information frictions impede the response to a nominal shock. Results deviate from predictions, however, in that the observed adjustment delays far exceed predicted levels. We suggest that another factor - bounded rationality – exerts a predominating effect. A variant of the standard analysis in which a subset of agents price adaptively better organizes our results.

Keywords: Market Experiments, Price Rigidities, Information Rigidities, Bounded Rationality

JEL codes: C9, E42, E47

---

* We thank without implicating Asen Ivanov and Robert Reilly for their helpful comments. Financial assistance from the National Science Foundation (SES 0518829) and the Virginia Commonwealth University Faculty Summer Research Grants Program is gratefully acknowledged. Thanks also to Matthew Nuckols for programming assistance. Experiment instructions, an appendix and the experimental data are available at www.people.vcu.edu/~dddavis

1. Introduction

Explaining the temporary real effects of nominal disturbances engineered by central banks is an important issue in macroeconomics. In a frictionless economy populated by perfectly rational firms, nominal disturbances have no effect on the quantity produced because firms immediately and fully accommodate by adjusting their prices.

To explain real effects, researchers typically introduce frictions. The most popular model introduces a pricing friction by assuming that only a fraction of firms can reset prices at any point in time (e.g., Fischer 1977, Taylor 1980, Calvo, 1983). Other firms, bound by contracts, maintain previous prices and adjust passively their production quantities. An alternative model by Mankiw and Reis (2002) introduces an informational rigidity by assuming that only a fraction of firms update information regarding underlying market conditions at any given time. Other firms adjust production quantities absent information regarding nominal changes.

This paper reports a laboratory experiment conducted to evaluate the relative capacity of these alternative theories to explain a delayed adjustment of prices following a nominal shock. The use of laboratory methods is particularly useful for this sort of examination because these methods allow a control over the environment unprecedented in more conventional empirical macro studies. We avoid the shock identification problem by engineering pure nominal disturbances, we eliminate uncertainty about the true model by specifying precisely the structure of the underlying economy, and we generate real-time data without subsequent revisions or any need for filtering.

Given both the prominence of price and information frictions as explanations for real effects following from nominal shocks and the usefulness of laboratory methods for evaluating the effects of such frictions, we find surprising the relative lack of attention to this question among experimentalists. The only directly related study of which we are aware is Wilson (1998), who investigates the effect of nominal shocks on monopolists. In his experiment, a price setting monopolist optimizes in light of a fixed (menu adjustment) cost. After a nominal shock, the monopolist can either maintain a previous period price or incur the fixed costs and change her price. Wilson's finds that price stickiness in the form of menu costs delays price adjustment.[1]

Our interest in the in the monopolistically competitive structure routinely used in monetary theory as well as in the effects of both 'sticky prices' and 'sticky information' prompts us to deviate from the Wilson monopoly design in two important respects. First, we examine performance in a relatively thick six seller differentiated product environment. Second, we implement price stickiness as staggered contracts rather than as menu adjustment costs. This allows us to introduce comparable price and information frictions. (With staggered contracts a comparable degree of information stickiness can then be introduced as staggered information updates.)

By way of preview, we find that, as predicted, both price and information frictions slow sellers' initial responses to a nominal shock. Comparing across treatments, the price path in the 'sticky information' treatment tends to track below price paths in the other treatments. Most prominently, however, the observed adjustment process in both treatments is far slower than predicted. In fact, we observe long adjustment lags even in a frictionless baseline treatment, suggesting that something other than price or information frictions drives market adjustment delays.

In a subsequent section we examine results in light of bounded rationality (e.g., Haltiwanger and Waldman, 1989). Our observed adjustment lags parallel in some respects experimental results in a related environment by Fehr and Tyran (2001, 2008) in that we observe substantial adjustment lags in response to a nominal shock. Our results differ from Fehr and Tyran, however, in that we observe substantial adjustment lags in response to a *positive* nominal shock. (Fehr and Tyran, 2001 observe long adjustment lags only in response to a negative nominal shock.) We attribute the slow response observed in our markets to a failure of many sellers to best respond to their forecasts. As has been observed previously in the experimental oligopoly literature (e.g., Huck, Norman and Oechssler, 2002), given a rich strategy space, participants often anchor action choices on the expected actions of others rather than on their best responses to

[1] Adam (2007) reports an experiment in a sticky price environment. However, the focus of his study is on expectation formation, and he does not examine directly the effects of price frictions. Fehr and Tyran (2001, 2008), discussed in more detail below, use laboratory methods to examine adaptive expectation and psychological factors such as money illusion as drivers of slow responses to an announced nominal shock.

those actions. This tendency for sellers to anchor price choices on forecasts compounds the inertia induced by adaptive expectations.

The remainder of this paper is organized in as follows. Section 2 addresses theoretical considerations and develops pertinent behavioral conjectures. Section 3 reviews the experiment design and procedures. Results appear in sections 4 and 5. The paper concludes with a short sixth section.

2. Nominal Shocks in Monopolistically Competitive Economies with Rigidities

We implement the monopolistically competitive market structure that predominates in the theoretical discussion regarding effects of nominal disturbances (Blanchard and Kiyotaki, 1987, Romer, 2001, Woodford, 2003). Consider a market with n firms. Each firm i offers a differentiated product at a price of P_i with a common real unit cost, *C*. Defining M as a nominal scale variable we link nominal real prices and unit costs in the usual way, e. g., $c=C/M$ and $p_i = P_i/M$. We posit a linear demand for good i

$$q_i = \alpha - \beta p_i + \theta \overline{p} \; , \tag{1}$$

where $\alpha > 0$, $\beta > \frac{\theta}{n} > 0$, and $\overline{p} = \frac{1}{n}\sum p_i$.[2] Given the demand function, a firm maximizes its profit

$$\pi_i = (p_i - c) q_i(p_i, \overline{p}) .$$

We make the standard monopolistically competitive assumption that "the number of firms is large enough that taking other prices as given is equivalent to taking the price level as given."[3] First order conditions yield the optimal price response in terms of the overall price level and cost

[2] Similar to the demand equation in Blanchard and Kiyotaki (1987), quantity demanded moves directly with own price but inversely with the average price level. We simplify the Blanchard and Kiyotaki analysis slightly by specifying a linear demand function. Consumers' demand is linear when they have quadratic utility over the differentiated products; see, e.g., Vives (1999). A number of differentiated product experiments use linear demand, e.g., Garcia-Gallega (1998), Huck, Normann, Oechssler (2000), and Davis (2002).

[3] Thus, in this development we follow the macro literature (rather than the oligopoly literature) and assume that own price changes do not measurably affect the aggregate price level, e.g,. $\partial \overline{p} / \partial p_i$ =0. We subsequently evaluate these predictions in a design with n=6 sellers. In this case (e.g., with six symmetrical sellers), the difference between 'monopolistically competitive' and static Nash equilibrium predictions is quite small.

$$p_i^{mc} = \alpha_{mc} + c/2 + \phi\overline{p}\,, \qquad (2)$$

where $\alpha_{mc} = \dfrac{\alpha}{2\beta}$ and $\phi = \dfrac{\theta}{2\beta}$. It is useful to observe from the reaction function in (2) that price choices and the aggregate price level are strategic complements: the higher the aggregate price level, the larger the return to seller *i* from increasing its own price.

Invoking symmetry and solving (2) for p^{mc}, yields an optimal price

$$p^{mc} = \frac{1}{1-\phi}\left(\alpha_{mc} + \frac{c}{2}\right). \qquad (3)$$

The organizing power of monopolistically competitive outcomes represents our first conjecture, which we offer primarily for purposes of calibration.

Conjecture 1*: Prices converge to the monopolistically competitive outcomes.*

To help assess the organizing power of the monopolistically competitive prediction, we develop two additional reference outcomes. First, despite product differentiation, sellers may myopically undercut the prices of all rivals. In this case, market prices would collapse on the 'Walrasian' level, $p^w=c$. Second, sellers may collude. The joint profit maximizing price for the whole industry

$$p^{jpm} = \frac{c}{2} + \frac{\alpha_{mc}}{1-2\phi}\,,$$

represents a natural upper limit to collusive prices. We examine prices generated in our markets in light of these alternative predictions.

*2.1 Price Rigidities. W*e implement a 'sticky price' model, by allowing only one-third of the firms in a market to adjust prices each period. Firms take turns setting prices. When a firm of type *i* is selected to set price, it chooses price, x_{it} equal to the average of desired future prices

$$x_{it}^{sp} = \frac{1}{3}p_{it}^{mc} + \frac{1}{3}E_t\, p_{it+1}^{mc} + +\frac{1}{3}E_t\, p_{it+2}^{mc}\,, \qquad (4)$$

where E_t is the conditional expectation operator given information in period *t*. The staggered price adjustments of each firm type creates a vector of cotemporaneous prices based on the current period price adjustment, an adjustment from the previous period, and an adjustment two periods prior. The average posted price is

$$\overline{p}_t^{sp} = \frac{1}{3} x_t^{sp} + \frac{1}{3} x_{t-1}^{sp} + \frac{1}{3} x_{t-2}^{sp} . \tag{5}$$

Equations (2), (4), and (5) together imply that the current price level is a linear function of past price levels, marginal costs, and expected future price levels.

We adjust prices for sales because low pricing sellers account for a disproportionate sales volume. To find the (quantity weighted) mean transaction price, we generate sales quantities by sequentially inserting { $x_t^{sp}, x_{t-1}^{sp}, x_{t-2}^{sp}$ } along with $\overline{p}_t^{sp}$ into the demand function (1) and then weighting price choices by relative sales.

2.2 Information Rigidities. In a 'sticky information' model all firms may change prices each period. However, we here assume that only one-third of the firms have current information about the state of the economy. Another third of firms have information that is one period old, while the remaining firms have information that is two periods old. A firm that has information that is j periods old sets its price according to

$$x_{j,t}^{si} = E_{t-j} p_t^{mc} . \tag{6}$$

Thus, the average posted price in the economy becomes

$$\overline{p}_t^{si} = \frac{1}{3}\left(\alpha_{mc} + \frac{1}{2} c_t + \phi \overline{p}_t^{si} \right) + \frac{1}{3} E_{t-1}\left(\alpha_{mc} + \frac{1}{2} c_t + \phi \overline{p}_t^{si} \right) + \frac{1}{3} E_{t-2}\left(\alpha_{mc} + \frac{1}{2} c_t + \phi \overline{p}_t^{si} \right). \tag{7}$$

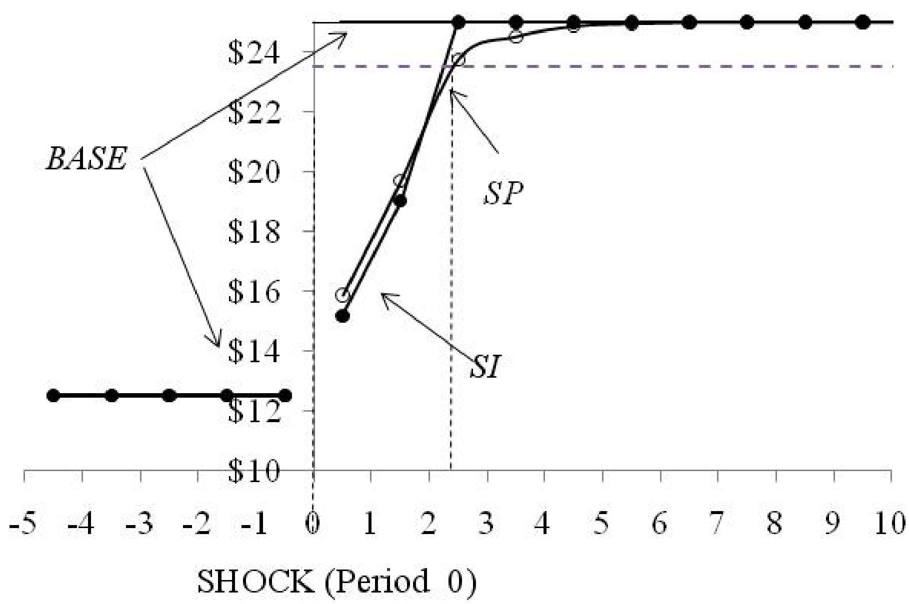
Equation (7) is a variant of the price level equation in Mankiw and Reis (2002): the price level depends on the past expectations of the price level and the past expectations of marginal costs.

As in the sticky price model, the mean transaction price is derived by sequentially inserting elements of the cotemporaneous price vector into the demand function (1) to generate individual and collective sales quantities, and then weighting price choices by relative sales.

2.3 Response of Prices to a Nominal Shock. Absent rigidities, prices adjust immediately to the change in a nominal scale variable: costs and demand shift proportionally with the change in M_t increasing the nominal optimal price P_i^{mc} and unit costs, *C*, without affecting optimal quantity q^{mc} . Either price or informational frictions slow the adjustment process.

To see the magnitude of the adjustment lags caused by price and informational frictions, consider the response of price to a one time permanent doubling of the nominal scale variable M_t. Figure 1 illustrates the price level adjustment under flexible conditions as well as under price and information rigidities using the parameters of our experimental design. (Detailed solutions can be found in Appendix A.1.) In a perfectly flexible *BASE* model, nominal prices rise immediately to a new equilibrium level. Price frictions ('*SP*') and information frictions ('*SI*') delay the adjustment process by two to three periods. We summarize the theoretical predictions about price response to a nominal shock in the form of a second conjecture:

Conjecture 2*: Following a nominal shock the price level rises immediately to a new equilibrium level in a flexible economy. Both information and price frictions slow the adjustment process to a nominal shock by two to three periods.*



*Key***:** The dashed horizontal line demarks a deviation from the post shock P^{mc} that is 5% of the P^{w} to P^{jpm} range. The dashed vertical line highlights when 'large' adjustments are complete for the *SP* and *SI* environments.

Figure 1. Predicted Transaction Price Adjustment to a 100% Increase in a Nominal Scale Variable in a Frictionless Market (*BASE*), a Market with Price Frictions (*SP*) and a Market with Information Frictions (*SI)*

We observe that the predicted effects of price and information frictions here are quite similar. Distinguishing the effects of sticky prices and sticky information requires a somewhat more complicated design.[4] Our relatively simple design provides initial insights necessary for more involved investigation. It also generates distinct predictions regarding the effects of sticky prices and sticky information relative to a perfectly flexible *BASE* condition. Finally, despite the absence of predicted differences between the *SP* and *SI* treatments, we have good reasons to suspect that sellers might behaviorally react differently to the two sorts of frictions. In particular, we anticipate a comparatively slower adjustment in the *SI* treatment. The sharp information restrictions in the *SI* treatment may critically impede learning about the effects of own price changes as well as the market adjustment process in general.

3. Experiment Design and Procedures

3.1. Experiment Design. To evaluate conjectures 1 and 2 we conduct an experiment consisting of 24 markets. In each market a set of six sellers make pricing decisions in a symmetric differentiated product environment. Markets consist of a series of 80 trading periods. At the outset of each period sellers are endowed with symmetrically differentiated products identified by equation (1), with α=9.23, β= 2.538, θ= 2.308. Sellers simultaneously make price decisions under the condition that unit production costs are borne only for units that subsequently sell. Once pricing decisions are complete, the average posted price is displayed publicly and an automated buyer program makes purchases in accordance with the demand condition. Initially the nominal unit cost, *C*=\$10 and the scale factor *M*=1, making p^w =\$10, p^{mc}= \$12.50 and p^{jpm} = \$25.00.

After 30 periods of stable market conditions, we implement a one-time nominal shock between periods 31 and 50, by permanently increasing *M* from 1 to 2. Sellers were told that the shock would occur at some point in this interval, but they were not told in advance in which period the shock would take place. In fact, the shock period was varied across treatments but appeared in periods 35-39, inclusive. The shock is announced on

[4] As a general matter, in a sticky price economy the largest adjustment occurs immediately after the shock, while in a sticky information economy more of the adjustment occurs several periods after the shock. These effects, only marginally visible in Figure 1 can be made more distinctive in an inflationary environment.

sellers' screens at the beginning of the first period when M changes. Post shock, C=\$20 making p^w =\$20, p^{mc}= \$25.00 and p^{jpm} = \$50.00.

The 24 markets are divided into three 8-market treatments. A baseline ('*BASE')* treatment, implements a perfectly flexible economy. Every period sellers both set prices and see market results (the average price and own profits) at the period's end. In a second, sticky price *('SP')* treatment, only two out of the six sellers may adjust prices each period. The sellers take turns, with each seller updating prices every third period. In the third, sticky information ('*SI'*) treatment, only two firms see market results from the immediately preceding period. Two other firms see market results that are one period old, while the remaining two firms see market results that are two periods old. Again, sellers take turns. Each seller sees results of the immediately preceding period every third period.

3.2. Procedures. Data were collected in a series of 12-participant sessions. At the outset of each session a monitor seats participants randomly at visually isolated computers to form two six-seller markets. The monitor then reads aloud instructions as the participants follow along on printed copies of their own. To facilitate understanding, screen displays are also projected to the front of the room as the monitor read instructions. Instructions explain price-posting procedures and the consequences of both a positive and a negative shock. Participants are given as common knowledge full information regarding aggregate supply and demand conditions as well as the terminal period. Sellers have profit calculators that compute their earnings for any choice of their own price and the expected average market price. Prior to beginning subjects answer a quiz about price posting procedures and earnings, and a monitor discusses publicly the correct answer to each question. Finally, to better acquaint subjects with the incidence and indicators of a shock, we administer a pair of 6-period practice sessions for which subjects are not paid. In the first practice session we implement a positive nominal shock in period 5, in the second practice session we implement a negative nominal shock in period 5.

To facilitate the decision-making process and the interpretation of results, we supplement the numerical display of pricing decisions and earnings with bar graphs. Also, in an effort to identify expectations, we ask sellers to predict the average market price each period. If a seller's forecast lies within 50¢ of the subsequently observed average price, the seller earns a forecast prize of 2 lab dollars. Otherwise the forecast prize is zero. Earnings from the forecasting game supplement period earnings from sales.[5]

At the end of the experiment participants are paid privately the sum of their earnings, converted to U.S. currency at a rate of $100 lab = $1 U.S. before the nominal shock and at a rate of $200 lab = $1 U.S. after the nominal shock plus a $10 appearance fee, and were dismissed one at a time.

In total 144 volunteers participated in the experiment (48 in each treatment). Participants were volunteers recruited from upper level undergraduate business and engineering classes at Virginia Commonwealth University in the spring semester of 2009. No one participated in more than one session. Earnings for the 80-100 minute sessions ranged from $15 to $32 and averaged about $23 (inclusive of the appearance fee).

4. Results

4.1 Market Convergence. To make results regarding the shock comparable across sessions, we standardize market outcomes about the period of the shock, which we label as period 35. This standardization makes period 76 the last common period. The mean transaction prices, shown in Table 1, provide an overview of general convergence tendencies. The upper and lower panels of the Table list deviations of the mean transactions price from P^w, P^{mc} and P^{jpm} for the last ten common pre-shock and post-shock periods, respectively. To facilitate comparisons across regimes we express deviations as percentage of the P^w to P^{jpm} range. As is clear from inspection of the table, monopolistically competitive predictions organize results quite well toward the end of each treatment. Mean transaction prices in all treatments deviate from P^{mc} by no more than 5.4% of the P^w to P^{jpm} range pre-shock, and by no more than 2.4% of the same range post-shock. In all our treatments the data are within one standard deviation of the monopolistically competitive predictions. In contrast, mean transaction prices in each treatment deviate from P^w by at least 16.3% and from P^{jpm} by at least 76.8% of the P^w to

[5] Our forecasting game emulates the expectations elicitation techniques used in some early asset market experiments (e.g., Williams, 1987 and Smith et al., 1988).

P^{jpm} range. The tendency of markets to converge on the monopolistically competitive predictions in each treatment represents a first finding.

***Finding 1**: Monopolistically competitive price predictions organize the outcomes of our six seller differentiated-goods markets reasonably well.*

Table 1. Mean Transaction Prices and Convergence Tendencies.

Treatment	Price	(Std. Dev.)	% Dev from Prediction P^{mc}	P^{w}	P^{jpm}
		Periods 25-34			
BASE	\$13.18	(0.85)	4.5%	21.2%	-78.8%
SP	\$13.27	(1.03)	5.1%	21.8%	-78.2%
SI	\$13.29	(0.88)	5.3%	21.9%	-78.1%
		Periods 67-76			
BASE	\$24.92	(1.55)	-0.3%	16.4%	-83.6%
SP	\$25.72	(1.17)	2.4%	19.1%	-80.9%
SI	\$24.88	(1.42)	-0.4%	16.3%	-83.7%

This result parallels findings regarding convergence to static Nash predictions in a number of differentiated product oligopoly experiments (e.g, Garcia-Gallego, 1998, Huck, Normann, and Oechssler, 2000, Garcia-Gallego and Georgantzis, 2001, Davis 2002 and Davis and Wilson, 2005).[6] Nevertheless, Finding 1 is a useful calibration result, for two reasons. First, to the best of our knowledge, no one has previously examined convergence properties of markets with price or information frictions. Second and perhaps more importantly, tacit collusion does not importantly affect outcomes.[7] The absence of tacit collusion as an important driver of behavior in our markets enhances the appeal of our design for a laboratory examination of price adjustment processes in monopolistically competitive markets.

4.2. Response of Prices to the Nominal Shock. The mean transaction price paths shown in Figure 2 provide an overview of market responses to the nominal shock. The

[6] Given our parameters, the static Nash equilibrium price predictions are \$12.90 pre- shock and \$25.80 post shock, quite close to the comparable pre- and post-shock monopolistically competitive predictions.

[7] As will be seen in the next subsection, tacit collusion also does not affect the adjustment process in response to the shock. An efficient tacitly collusive response to an upward nominal shock would be a very rapid elevation of prices to the post-shock P^{jpm}. More generally, evidence of tacit collusion would be a faster than predicted adjustment to prices above the post- shock P^{mc}. We observe just the opposite behavior.

figure suggests three primary results. First, comparing the *SP* and *SI* transaction price paths with that for the *BASE* treatment, observe that both price and information frictions elicit the predicted depressed prices in the periods immediately following the shock. Second, notice that after the first three post-shock periods, the *SP* price path jumps up and tracks *BASE* price path quite closely, while the *SI* price path remains comparatively depressed. This observation suggests that, 'sticky information' behaviorally exerts an effect on the adjustment process beyond that predicted by the theory.

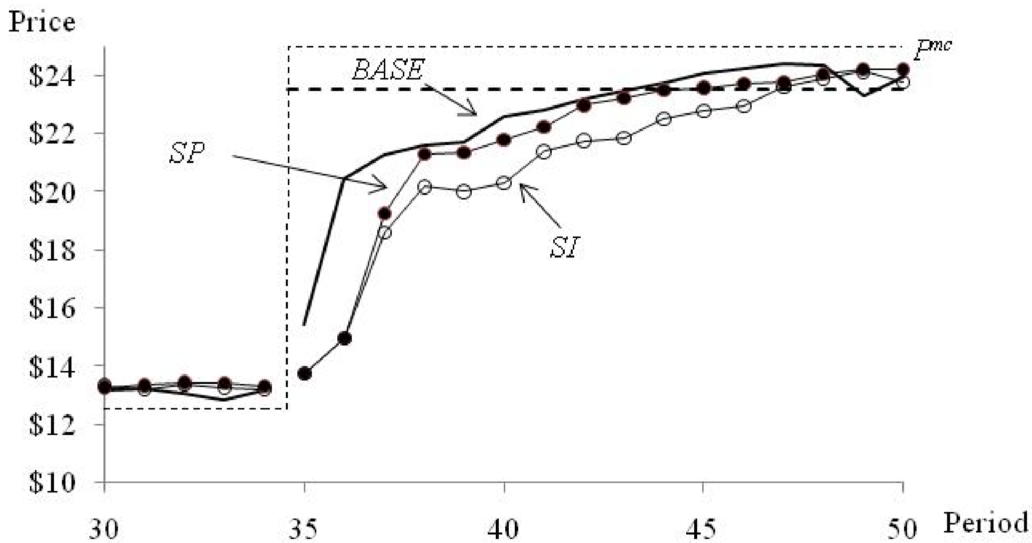


Figure 2: Response of Aggregate Prices to the Pure Nominal Shock. *Key:* The dotted line tracks the P^{mc} prediction. The dashed line demarks a deviation from P^{mc} post-shock that is 5% of the P^{w} to P^{jpm} range.

Third, and most prominent, observe that in all treatments the adjustment to the post-shock equilibrium is far slower than predicted. Even in the *BASE* treatment sizable deviations (e.g., of at least $1.50 or 5% of the P^{w} to P^{jpm} range) persist for nine post-shock periods.[8] In the *SP* and *SI* treatments, similarly defined 'sizable' deviations persist for the first 10 and first 12 post-shock periods, respectively.

We now develop more formal results regarding treatment effects, and the overall convergence process.

[8] As suggested by the very low aggregate price in period 35 of the *BASE* treatment, some sellers failed to immediately recognize the shock and posted prices below costs in period 36. The propensity for a subset of sellers to miss the incidence of a shock (despite our best efforts to alert them that it was coming) has obvious parallels to natural contexts. Rather more interesting is the extended delay in adjustment induced by this initial failure.

4.2.1. Prices across Treatments. Consider first across-treatment differences in the price adjustment process, the subject of conjecture 2. Table 2 reports differences in mean transaction prices between treatment pairs for the 12 periods following the shock.[9] Looking first at the comparisons for periods 35 to 37 shown at the top of the Table observe that immediately following the shock mean transaction prices in the *SP* and *SI* treatments are much lower than in the *BASE* treatment. The *BASE- SP* difference, in column (1) grows from $1.68 in period 35 to $5.46 in period 36 prior to falling to $2.04 in period 37. The period 36 comparison is significant at p<.05 using a Mann-Whitney test. Initial post shock differences between the *BASE* and *SI* treatments, summarized in column (2) are very similar: the *BASE-SI* difference of $1.68 in period 35 grows to $5.44 in period 36 prior to shrinking somewhat to $2.71 in period 37. The period 35 and 37 *BASE-SI* differences are significant at p<.10, while the period 36 comparison is significant at p<.05. These differences are as predicted.

Table 2: Post- Shock Price Differences Across Treatments

Periods	Treatment Differences		
	(1) *BASE- SP*	(2) *BASE – SI*	(3) *SP – SI*
35	1.68	1.68*	0.00
36	5.46**	5.44**	-0.01
37	2.04	2.71*	0.68
38	0.27	1.41	1.14
39	0.37	1.69	1.32*
40	0.78	2.27**	1.49
41	0.57	1.41	0.84
42	0.19	1.41	1.22
43	0.22	1.60**	1.38**
44	0.26	1.26**	1.00*
45	0.52	1.31*	0.78
46	0.53	1.33*	0.80

Notes: Asterisks indicate periods prices differ significantly across compare treatments using a Mann-Whitney test *p< 10%, **p< 05% (two tailed tests).

Following period 37 however, the *BASE-SP* and *BASE-SI* series diverge. The *BASE-SP* difference falls to 27¢ in period 38, and remains less than 60¢ in all subsequent periods 39-46 except one (a 78¢ difference in period 40). None of these differences are

[9] The first 12 post-shock periods include all treatment differences significant at p<.10.

significant at *p*<.10. In contrast, the *BASE–SI* difference is \$1.41 in period 38 and differences in the eight subsequent periods 39-46 all exceed \$1.25. These differences are significant at *p*<.05 in three instances (periods 40, 43 and 44) and at *p*<.10 in two other instance (periods 45 and 46).

The *SP – SI* comparisons in column (3) provide some evidence that 'sticky information' also slows adjustment relative to a comparable 'sticky price' friction. Initial post-shock *SP –SI* differences of 0, -1¢ and 68¢ in periods 35, 36 and 37 suggest that sticky price and sticky information elicit similar effects immediately following the shock. However, in period 38 the *SP –SI* difference increases to \$1.14 and remains \$1.00 or more for periods 39-44. Outcome variability renders these differences less persistently significant: differences are significant at *p*<0.10 twice (in periods 39 and 44) and at *p*<.05 only once (in period 43). Nevertheless, these results at least tentatively indicate that as a behavioral matter 'sticky information' not only retards convergence relative to a frictionless baseline by a more than predicted amount, but it also retards market adjustment more than a comparable 'sticky price' friction. Findings 2(a) and 2(b) summarize our comparison of prices across treatments.

Finding 2(a)*: Consistent with predictions, deviations in both the SP and SI treatments exceed those in the BASE treatment in the periods immediately following the shock.*

Finding 2(b)*: Prices in the SI treatment adjust more slowly than in the BASE and SP treatments.*

As mentioned in the introduction, increased inertia in the *SI* treatment was not entirely unexpected. Sellers in the *SI* treatment get a view of current market conditions only every third period, and as a result neither receive immediate feedback regarding the consequences of their own price choices on profits, nor a consistent view of the way that other sellers are adjusting prices. The average standard deviations of forecasts shown as Figure 3 illustrate how the *SI* treatment undermines the formation of homogenous price expectations among sellers. Disagreement about expected market prices is several times higher in the *SI* treatment than in *BASE* and *SP* treatments. As indicated by the '×' and '+' symbols shown at the bottom of Figure 3, using a Mann-Whitney test the differences in standard deviations across both the *SI/BASE* and the *SI/SP* treatments are significant at $p<.05$ in 13 of the 14 periods 37-50. Higher degrees of price disagreement in the *SI* treatment imply sales volume increases for the low pricing sellers, which in turn exerts downward pressure on transaction prices.

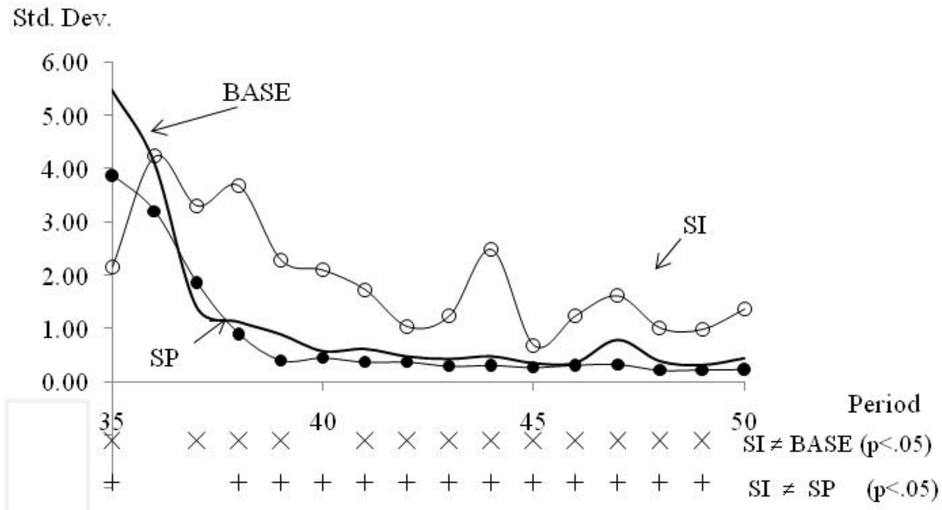


Figure 3. Average Standard Deviations of Forecasts by Treatment, Post-Shock.

4.2.2. Predicted versus Observed Responses to the Nominal Shock. While we observe some differences in the adjustment process across treatments, undoubtedly our most prominent finding is that markets in all treatments respond to the nominal shock far more slowly than predicted. The deviations from the predicted adjustment paths for periods 35-55 of the *BASE*, *SP* and *SI* treatments shown in Table 3 document quantitatively the differences between predicted and observed responses to the nominal shock.[10]

Looking over deviations for the *BASE*, *SP* and *SI* treatments, notice that other than the small deviations from the predicted adjustment path in the immediate post-shock periods of *SP* and *SI* treatments (where the price and information frictions generate predicted delays), the adjustment patterns in the three treatments are far more similar than different. Following period 37, deviations in all treatments uniformly differ significantly from zero at $p<.05$ at least until period 45, and exceed \$1.50 (5% of the P^w to P^{jpm} range) at least until period 43. The observed lags exceed the predicted effects of price and

[10] The listed periods 35-55 include all deviations significant at $p<.10$.

information frictions, which are at most two to three periods.[11] Finding 3 summarizes our comparison of post-shock prices to the monopolistically competitive predictions.

Finding 3*: In all three treatments, prices adjust to a nominal shock far more slowly than predicted by the monopolistically competitive models with fully rational sellers*

Table 3. Deviations of Mean Transaction Prices from the Predicted Adjustment Path

Period	(1) $\overline{P}_B^T - \overline{P}_B^{mc}$	(2) $\overline{P}_{SP}^T - \overline{P}_{SP}^{mc}$	(3) $\overline{P}_{SI}^T - \overline{P}_{SI}^{mc}$
35	**-9.58****	1.24**	1.00**
36	**-4.60****	0.02	-0.23
37	**-3.72****	**-4.37****	**-6.43****
38	**-3.44****	**-3.19****	**-4.85****
39	**-3.31****	**-3.54****	**-5.00****
40	**-2.43****	**-3.16****	**-4.70****
41	**-2.22****	**-2.77****	**-3.63****
42	**-1.84****	**-2.03****	**-3.26****
43	**-1.56****	**-1.78****	**-3.17****
44	-1.26**	**-1.52****	**-2.52****
45	-0.91**	-1.44**	**-2.22****
46	-0.75	-1.28**	**-2.08****
47	-0.63	-1.22**	-1.40**
48	-0.67	-0.97**	-1.12*
49	**-1.73****	-0.81	-0.87
50	-1.03**	-0.80*	-1.22*
51	-0.94**	-0.68	-0.86
52	-0.90**	-0.65	-0.78
53	-0.86**	-0.39	-0.70
54	-0.71**	-0.28	-0.62
55	-0.62*	-0.18	-0.72

Notes: Asterisks denote rejection of $H_o: \overline{P}_i^T - \overline{P}_i^{mc}\ i = \{B, SP, SI\}$, ** p<.05, * p<.10 (two tailed Wilcoxon tests). Bolded entries highlight periods where the deviation exceeds 5% of the P^w to P^{jpm} range.

5. Delayed Price Adjustment and Bounded Rationality.

We turn attention now to possible reasons for the generically slower-than-predicted responses to the nominal shock in our markets. Given that the delay is common to all three treatments, we focus here on *BASE* treatment results, where the data are best

[11] The re-emergence of significant deviations in periods 49-55 of the *BASE* treatment after falling below 75¢ in periods 46-48 is reminiscent of the long adjustment swings observed in markets where actions are strategic complements observed e.g., by Heemeijer et al. (2009). The absence of similar cycles in the *SP* and *SI* treatments lead us to speculate that while price and information frictions impede the adjustment process, sellers' incapacity to respond immediately to their rivals may perhaps help somewhat with market stability. At this point, however, we emphasize that this conjecture is purely speculative.

suited to examining the link between expectations and prices because sellers can both reset prices each period and examine immediately the impact of their actions.

A rival to the more standard 'frictions' models of real responses to nominal shocks analyzed above in section 2 is the approach taken by Haltiwanger and Waldman (1989), who posit that a subset of agents are boundedly rational in the sense that they have (adaptive) backward looking rather than forward looking expectations. Even in an economy with no frictions, backward looking agents ignore the nominal shock and thus delay price adjustment. Moreover, Haltiwanger and Waldman show that when actions are strategic complements, as is the case in our price-setting markets, boundedly rational agents slow the adjustment process to a much larger degree than would follow from their own failure to adjust prices, because rational agents optimize by mimicking the actions of the adaptive players.[12]

5.1. Adaptive Expectations. Previous experimental research suggests that a subset of agents do in fact form expectations adaptively, and these backward looking agents can importantly hinder the convergence process when action choices are strategic complements (Fehr and Tyran, 2001, 2008, Adam 2007, Heemeijer et al. 2009). Thus, bounded rationality in the form of adaptive expectations seems a likely candidate explanation for the slow observed adjustment responses in our markets.

Making the relatively weak working assumption that the expectation formation process can be characterized as a linear function we can identify roughly one fifth of *BASE* treatment participants as forming expectations adaptively.[13] We begin with an 'encompassing' model of sellers' forecasts which includes shift in mean in period 35 and three lags of aggregate and own prices:

$$f_{it} = c_{1i} + c_{2i}d_{35} + \beta_{1i}\overline{p}_{t-1} + \beta_{2i}\overline{p}_{t-2} + \beta_{3i}\overline{p}_{t-3} + \beta_{4i}p_{it-1} + \beta_{5i}p_{it-2} + \beta_{6i}p_{it-3} + \epsilon_i ,$$

where f_{it} denotes seller i's forecast in period t, d_{35} is a dummy variable that equals 0 up to period 35 and 1 from period 35 on, p_{it} and $\overline{p}_t$ denote individual and average market

[12] Haltiwanger and Waldman further argue that the strategic nature of actions importantly affects the response to nominal shocks. When actions are strategic substitutes, as would be the case, for example, in a Cournot quantity-setting context, rational players optimize by counteracting the choices of boundedly rational players, thus hastening the convergence process. Fehr and Tyran (2008) report some experimental evidence that supports this prediction.

[13] Our use of this assumption is not novel. See Heemeijer et al. (2009).

price respectively, and ϵ_t is the i.i.d. error term. This encompassing model fits 1-step-ahead forecasts of the sellers quite well. For 44 sellers (92% of subjects) R^2 is above 90%, and for 34 sellers (71%) it is above 95%. Also, for 31 sellers (65%) we cannot reject the hypothesis that residuals are white noise (using a Q-test), which implies that no other variable is necessary to explain sellers' forecast. Finally, for 8 sellers (17%) we cannot reject the hypothesis that the model with only lagged aggregate price

$$f_{it} = c_{1i} + \beta_{1i}\overline{p}_{t-1} + \beta_{2i}\overline{p}_{t-2} + \beta_{3i}\overline{p}_{t-3} + \epsilon_i$$

fits the data as well as the encompassing model with a white noise residual.[14] We classify these eight sellers as having adaptive expectations.

5.2. Imitative Behavior vs. Best Responses. Although previous experimental research does suggest that adaptive expectations impede the market convergence process, the existing evidence provides incomplete support for our results in that the previous research suggests that markets respond quite fluidly to an announced *positive* nominal shock. Most pertinent is Fehr and Tyran (2001), who report an experiment in a price setting context where action choices are strategic complements. These authors find an adjustment lag of some eight periods to a negative nominal shock. However, in response to an announced positive shock, the markets adjusted quite quickly, within three periods.

Fehr and Tyran attribute the far more fluid response to the positive shock to the asymmetric effects of money illusion: in the case of negative nominal shock sellers must overcome a psychological desire to maintain high nominal prices, which retards adjustment. In contrast, the case of a positive nominal shock, money illusions does not impede the response to a positive shock, since it allows sellers to make psychologically appealing rapid nominal price increases.

A number of differences distinguish our *BASE* markets from the stylized price setting game in Fehr and Tyran.[15] However, perhaps most important are differences in

---

[14] Appendix Tables B1 and B2 report the results of individual forecast regressions.

[15] In addition to differences in the strategy space mentioned in the text, other possibly pertinent differences between our design and the Fehr and Tyran designs include the number of sellers (6 rather than 4), the amount of repetition (80 vs. 30 periods), the game structure (a symmetric structure with standard cost and demand conditions presented in a market context vs. an asymmetric structure presented in a normal form game with a Pareto dominant Nash equilibrium), and the way the shock was implemented (as simultaneously presented private information or as common knowledge). These many differences make comparisons with the Fehr and Tyran experiments necessarily speculative

the strategy space. In contrast to the 30-choice price space in the Fehr and Tyran design, sellers in our markets faced an essentially continuous price grid. We conjecture that this change in the strategy space affects the propensity for sellers to choose best responses to their forecasts. Given the coarse strategy action space in Fehr and Tyran, sellers may find playing best responses to be a natural strategy choice. In a related experiment using a design very similar to their earlier paper, Fehr and Tyran (2008) analyze the relationship between price choices and best responses and find that sellers tend to select prices that are very close to the best responses to their expectations. This finding allows Fehr and Tyran to isolate adaptive expectations as the reason for their observed adjustment lags.

In our markets, however, the link between forecast and price choice differs markedly, in that sellers exhibit a pronounced propensity to anchor price choices on their forecasts of the expected price level rather than on the best response to those actions. The histogram of price choices, forecasts and best responses shown as Figure 4 illustrates. Consistent with results of the previous subsection, the node at $13 (the $1 interval that includes the initial equilibrium price) reflects the effects of a minority of sellers forming expectations adaptively in our markets.[16] More impressive, however, is the proximity between prices and forecasts when viewed in light of the distance between prices and best responses.[17] For the first five periods post-shock 69% of sellers priced within $1.50 of their forecast, compared to only 41% of sellers pricing within $1.50 of their best response, a difference of 28%.[18] The propensity for sellers to base pricing decisions on forecast is our fourth finding.

Finding 4*: Many sellers set prices close to their forecasts rather than to the best response to those forecasts.*

Basing pricing decisions on forecasts rather than best responses is, for many sellers, a natural rule of thumb. Indeed, when products are perfect substitutes such a rule is

---

[16] The 7-8% of price choices in the interval including the pre-shock P^{MC} price for the first five post shock is not inconsistent our conclusion that 17% of sellers in the *BASE* treatment have adaptive expectations. Most forecasts at the pre-shock price occurred in period 35. In the following periods mean prices increased, which imply raised forecasts.

[17] The interested reader should compare our Figure 4 with Figure 3a in Fehr and Tyran (2008).

[18] The difference between price choices close to forecasts and best responses diminish as aggregate prices increase. For example, periods 40-44, difference in the percentage of sellers' prices close to forecasts and best responses falls to 13% (74% of price choices are with $1.50 of forecasts and 62% within $1.50 of best responses). For periods 45-49 this difference falls to zero.

perfectly appropriate. However, it fails in a monopolistically competitive structure, where sellers have some market power due to produce differentiation. As suggested by Figure 4, given product differentiation the best response to even a purely adaptive expectation is to raise price substantially.

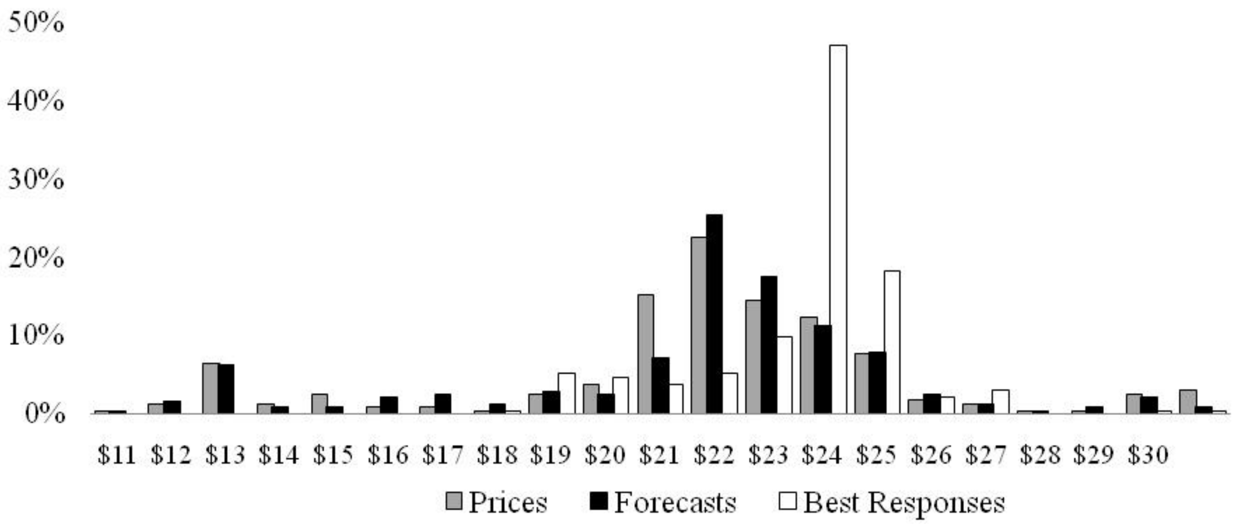


Figure 4. Prices, Forecasts and Best Responses in the First Five Post-Shock Periods. (*Note*: Increments on the horizontal axis demark the center of $1 price ranges)

The tendency of sellers to imitate their expectation of the average choice rather than to best respond to that expectation has been observed previously in the behavioral oligopoly literature (e.g., Huck, Norman and Oechssler, 2002).[19] In the present context it represents a sort of additional strategic complementarity that retards the market response to an upward nominal shock parallels to the effects of money illusion and incentives to tacitly collude in response to a negative nominal shock. Effectively, the propensity of sellers to anchor price choices on their expectations of the price level amplifies the effects of agents who are boundedly rational in the narrow sense that they form expectations adaptively, and suggests why slow adjustments to positive as well as negative nominal shocks might be observed.

[19] On the basis of experiments in a quantity-setting Cournot environment Huck, Norman and Oechssler (2002) conclude that the tendency for sellers to engage in 'imitative' behavior rather than playing a best response drives behavioral stability of Cournot markets that are unstable to a best response dynamic. We find it interesting that in the present case, where choices are strategic complements rather than strategic substitutes, this same tendency retards convergence.

5.3. Adaptive Price-Setting. The propensity of sellers to key pricing decisions on forecasts allows us to estimate 'adaptive price-setting' behavior.[20,21] Adapting the estimation procedure for forecasting behavior in section 5.1 to prices, we here identify roughly one quarter of *BASE* treatment sellers as 'adaptive price-setters' – that is as sellers who base pricing decisions on the previous period aggregate price. We begin with an encompassing model of sellers' price choices, which includes a shift in mean prices in period 35 and three lags of own price choices in addition to three lags of the aggregate price level:

$$p_{it} = c_{1i} + c_{2i} d_{35} + \beta_{1i} \overline{p}_{t-1} + \beta_{2i} \overline{p}_{t-2} + \beta_{3i} \overline{p}_{t-3} + \\ + \beta_{4i} p_{it-1} + \beta_{5i} p_{it-2} + \beta_{6i} p_{it-3} + \epsilon_i ,$$

(we use the same notation as for the encompassing estimate of forecast decisions). This encompassing model fits sellers' price choices quite well. For 33 sellers (69%), R^2 is above 90%, and for 27 sellers (56%), it is above 95%. For 36 sellers (75%) we cannot reject the hypothesis that residuals are white noise (Q-test). Finally, for 11 sellers (23%) we cannot reject the hypothesis that the model with only lagged aggregate price:

$$p_{it} = c_{1i} + \beta_{1i} \overline{p}_{t-1} + \beta_{2i} \overline{p}_{t-2} + \beta_{3i} \overline{p}_{t-3} + \epsilon_i$$

fits the data as well as the encompassing model with white noise residual. We classify these sellers as adaptive price setters.[22]

5.4. Monopolistically Competitive Predictions with Adaptive Price-Setters. Assuming that subset of sellers are adaptive price-setters allows a parsimonious modification of the standard dynamic analysis of a monopolistically competitive economy that reflects the combined effects of adaptive expectations and keying pricing decisions off of forecasts because the assumption of adaptive price-setting allows us to express the adjustment

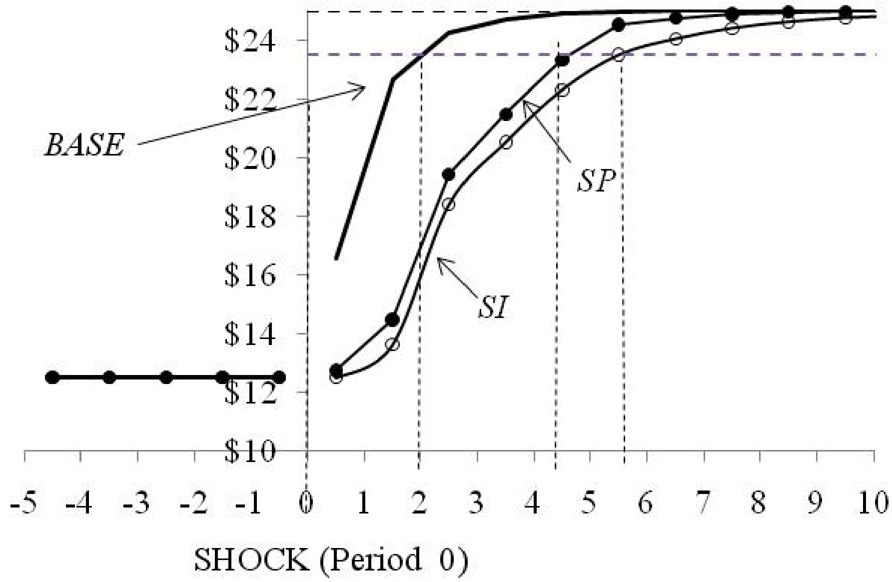
---

[20] Adaptive expectations imply that $f_t = \overline{p}_{t-1}$. If sellers key price choices off of forecasts then $p_t = f_t$. Combining, $p_t = \overline{p}_{t-1}$.

[21] Our assumption that some sellers key pricing decisions on the past price level is hardly unique in this literature. For example, to account for observed inflation persistence Gali and Gertler (1999) append an assumed fraction of firms that use a simple rule of thumb based on the recent history of aggregate price behavior to an otherwise standard Calvo sticky price model. This modification became quite popular in the empirically literature evaluating sticky prices, e.g., Christiano *et al*. (2005), Smets and Wouters (2003).

[22] The increase in the number of 'adaptive price setting' sellers over the number of sellers with adaptive expectations (11 vs. 8) is curious. Possibly the difference is attributable to the increased salience of the pricing game. In the forecasting game, a few sellers occasionally experimented with their forecasts, exhibiting what appear to be erratic expectations. These sellers made more consistent price choices.

process purely in terms of prices.[23] Analytically, assuming a fraction of adaptive price-setting agents is similar to assuming a fraction of agents with sticky prices. (Appendices A2 and A3 provide details of the model modifications and price path predictions.)



Key: The dashed horizontal line demarks a deviation from the post shock P^{mc} that is 5% of the P^{w} to P^{jpm} range. The dashed vertical lines highlight when 'large' adjustments are complete for the *BASE*, *SP* and *SI* environments respectively (moving rightward).

Figure 5. Predicted Adjustment of Mean Transaction Prices to a 100% Increase in a Nominal Scale Variable in Frictionless ('*BASE*'), Sticky Price ('*SP*') and Sticky Information ('*SI*') markets assuming that 25% of sellers set prices adaptively.

Figure 5 illustrates a series of predicted transaction price adjustments to a permanent doubling of the nominal scale variable that parallels predicted adjustments shown in Figure 1, but under the condition that 1/4 of firms set prices adaptively. Notice in the figure that even in the frictionless *BASE* environment the presence of adaptive price setters creates an adjustment delay (of 2-3 periods). Similarly, adaptive price setters increase the predicted adjustment delays given price and information frictions from 2-3 periods to 5-6 periods. The intuition underlying the predicted delay in the frictionless *BASE* treatment parallels that for price and information frictions. Adaptive price-setting firms ignore the nominal shock and set price close to the previous period aggregate price. Buyers flock to the lowest price sellers, keeping the mean transaction

[23] Our approach is similar to Haltiwanger and Waldman (1989) except that we assume a fraction of adaptive price setting firms rather than a fraction of firms with adaptive expectations,

price low. Profit-maximizing rational firms then further amplify the delay by mimicking the price postings of the adaptive firms.

The adjustment path deviations shown in Table 4 (formatted as Table 3), illustrate quantitatively the improvement in explanatory power associated with incorporating adaptive price-setting sellers into the otherwise standard monopolistically competitive model. Two aspects of Table 4 merit comment. First, comparing Table 4 with Table 3, notice the sizable reduction in the observed deviations. In the *BASE* treatment the largest deviation decreases by two-thirds (from \$9.58 to \$3.21). Similarly, in the *SP* and *SI* treatments the maximum observed deviations fall by one half (from \$4.37 to \$1.86) and by one third (from \$6.43 to \$4.22), respectively. For the three treatments pooled, the number of 'large' deviations that exceed \$1.50 (5% of the P^w to P^{jpm} range) drops from by a third (from 28 to 19).

Table 4. Deviations of Mean Transaction Prices from Predicted Adjustment Path with 1/4 of Adaptive Price Setters

Period	(1) $\overline{P}_B^T - \overline{P}_B^{mcA}$	(2) $\overline{P}_{SP}^T - \overline{P}_{SP}^{mcA}$	(3) $\overline{P}_{SI}^T - \overline{P}_{SI}^{mcA}$
35	-1.15	1.24**	1.01**
36	**-2.24****	1.33*	0.48
37	**-2.96****	0.86	-0.87
38	**-3.17****	0.76	-1.33
39	**-3.21****	-0.99**	**-3.33****
40	**-2.39****	**-1.70****	**-4.22****
41	**-2.21****	**-1.83****	**-3.37****
42	**-1.84****	-1.44**	**-3.14****
43	**-1.56****	-1.41**	**-3.12****
44	-1.26**	-1.28**	**-2.49****
45	-0.91*	-1.28*	**-2.21****
46	-0.75	-1.18*	**-2.07****
47	-0.63	-1.16**	-1.40**
48	-0.67	-0.93*	-1.12
49	**-1.73****	-0.78	-0.87
50	-1.03*	-0.78	-1.22*
51	-0.94**	-0.67	-0.86
52	-0.90**	-0.65	-0.78
53	-0.86*	-0.39	-0.70
54	-0.71*	-0.27	-0.62
55	-0.62	-0.18	-0.72

Notes: Asterisks denote rejection of $\overline{P}_i^T - \overline{P}_i^{mcA}$ $i = \{B, SP, SI\}$, ** $p<.05$, * $p<.10$ (two tailed Wilcoxon tests). Bolded entries highlight periods where the deviation exceeds 5% of the P^W to P^{JPM} range.

Observe second, however, that the improvement in fit is incomplete. Across the three treatments nearly two thirds of the listed deviations (39 of 63) still differ significantly from zero at $p<.10$, and 30 of those deviations are significant at $p<.05$. These remaining deviations are driven by the propensity of many sellers with forward looking expectations to key prices off of their forecasts.[24] A predicted adjustment path that paralleled the observed process would have to assume a much higher percentage of adaptive price setting sellers that the 23% we identified in our *BASE* treatment.

We summarize these observations as the following comment.

***Comment**: Incorporating adaptive price setting behavior into the standard dynamic models of monopolistically competitive markets improves the models' predictive powers. Further, the propensity of many forward-looking sellers to key pricing decisions off of their forecasts very considerably amplifies the effects of sellers who can be identified as adaptive price setters.*

6. Discussion.

This paper reports an experiment conducted to evaluate the role of information and price frictions as drivers of real effects resulting from a nominal shock. We find that both price and information frictions impede price adjustment by several periods, as predicted by the standard dynamic models of monopolistically competitive markets. However, and more importantly, we observe much longer than predicted adjustment lags not only in 'sticky price' and 'sticky information' treatments, but in a frictionless baseline environment as well. We conclude that a variant of the bounded rationality argument by Haltiwanger and Waldman (1989) plays a much more profound role in explaining the slow response to a nominal shock in our experiment than do either price or information frictions.

Our results differ from implications of Haltiwanger and Waldman (1989) in that we observe not only evidence of some sellers who are boundedly rational in the sense of having adaptive expectations, but also evidence of a pronounced tendency for sellers to anchor pricing decisions on their expectations of the price level rather than on their best

[24] Recall in the first five post shock periods 69% of sellers priced 'close' to their forecasts, while only 41% priced similarly close to their best responses. This vastly exceeds the 23% of *BASE* sellers we identified as adaptive price setters.

responses to those expectations. In a simple model where one fourth of subjects are 'adaptive price setters' in the sense that they both have adaptive expectations and set prices equal to the previous period average price, we show that a relatively small percentage of adaptive price setting sellers can explain adjustment delays in a frictionless baseline environment, as well as increased adjustment delays in sticky price and sticky information environments. We further show that this simple model substantially improves predictive power of the otherwise standard monopolistically competitive models, although the improvement is imperfect due to the widespread tendency of many forward looking sellers to also key prices off of forecasts, a tendency which further amplifies adjustment delays.

In closing, we wish to emphasize the usefulness of the differentiated product monopolistically competitive market structure for examining price inertia, a critical element of most monetary policy models. Laboratory methods offer the distinct advantages of allowing the investigator to control cost, demand and market structure conditions, to specify the nature of strategic interactions between agents, and to explicitly engineer shocks in a manner that is not even approachable in natural contexts. Further, even in the relatively thin six seller markets examined here monopolistically competitive predictions organize outcomes quite well. Most notably, repeated game effects, particularly coordinated behavior such as tacit collusion, do not importantly affect either final prices or the market convergence process. Our results, combined with previous related experimental research suggest that alterations in the structure conditions interact with rules of thumb and other psychological factors to importantly affect market outcomes. The use of laboratory methods provides a unique and parsimonious way to examine the effects of these interactions on market dynamics.

Appendix A. Details of Solutions

A.1. Response of Prices to a 100% Increase of the Nominal Scale Variable.

The nominal scale variable equals $M_t = 1$ for $t < 0$ and it equals $M_t = 2$ for $t \geq 0$. We derive the path of nominal prices as a function of the nominal scale variable. The solution of output follows from the demand equation (3).

For the sticky price model we begin by inserting the best response equation (2) into the optimal price equation (4)

$$x_t^{sp} = \frac{1}{3}\left(\alpha_{mc} + c_t / 2 + \phi \overline{p}_t\right) + \frac{1}{3} E_t\left(\alpha_{mc} + c_{t+1} / 2 + \phi \overline{p}_{t+1}\right) + \frac{1}{3} E_t\left(\alpha_{mc} + c_{t+2} / 2 + \phi \overline{p}_{t+2}\right)$$

Then, inserting the average price expression (5) in for each of the average prices yields

$$\begin{aligned} x_t^{sp} &= \frac{1}{3}\left(\alpha_{mc} + c_t / 2 + \phi\left(\frac{1}{3}x_t^{sp} + \frac{1}{3}x_{t-1}^{sp} + \frac{1}{3}x_{t-2}^{sp}\right)\right) \\ &+ \frac{1}{3}E_t\left(\alpha_{mc} + c_{t+1} / 2 + \phi\left(\frac{1}{3}x_{t+1}^{sp} + \frac{1}{3}x_t^{sp} + \frac{1}{3}x_{t-1}^{sp}\right)\right) \\ &+ \frac{1}{3}E_t\left(\alpha_{mc} + c_{t+2} / 2 + \phi\left(\frac{1}{3}x_{t+2}^{sp} + \frac{1}{3}x_{t+1}^{sp} + \frac{1}{3}x_t^{sp}\right)\right) \end{aligned}$$

Solving for x_t^{sp} and defining $A = \dfrac{\phi}{3(3-\phi)}$ yields,

$$x_t = \frac{1}{6(3-\phi)}\left(18\alpha_{mc} + 3c_t + 3E_t c_{t+1} + 3E_t c_{t+2} + 2\phi x_{t-2} + 4\phi x_{t-1} + 4\phi E_t x_{t+1} + 2\phi E_t x_{t+2}\right). \quad \text{(A1)}$$

Expressing (A1) in nominal terms,

$$X_t - 2AX_{t-1} - AX_{t-2} - 2AE_t X_{t+1} - AE_t X_{t+2} = \frac{1+3A}{3}\left(\alpha_{mc} + \frac{c}{2}\right)\left(M_t + E_t M_{t+1} + E_t M_{t+2}\right), \text{(A2)}$$

where for the right most term we use our assumption that marginal costs are constant, apart from the nominal term.

We solve this expectational difference equation using the standard methodology (e.g. Sargent (1987), Romer (2001)). Using lag operator $LE_t\overline{P}_t = E_t\overline{P}_{t-1}$ and its inverse we re-write equation (A2) as

$$\left(1 - 2AL - AL^2 - 2AL^{-1} - AL^{-2}\right)X_t = \frac{1+3A}{3}\left(\alpha_{mc} + \frac{c}{2}\right)\left(1 + L^{-1} + L^{-2}\right)M_t. \quad \text{(A3)}$$

By factoring the lag-polynomial equation we re-write (A2) as

$$(1-\lambda_1^{-1}L^{-1})(1-\lambda_2^{-1}L^{-1})(1-\lambda_3 L)(1-\lambda_4 L)X_t = -\frac{1+3A}{3A\lambda_1\lambda_2}\left(\alpha_{mc} + \frac{c}{2}\right)\left(1 + L^{-1} + L^{-2}\right)M_t, \quad \text{(A4)}$$

where λ_i are the roots of lag-polynomial equation. When $|\lambda_i| > 1$ inverse of $(1-\lambda_i^{-1}L^{-1})$ is well defined. Dividing both sides of equation (A4) by $(1-\lambda_1^{-1}L^{-1})$ and $\left(1-\lambda_2^{-1}L^{-1}\right)$, using definition of lag operators, and the fact that shock is permanent ($E_t M_{t+i} = M_t$ before and after the shock) results in

$$X_t = (\lambda_3 + \lambda_4) X_{t-1} - \lambda_3 \lambda_4 X_{t-2} - \frac{1+3A}{A(1+\lambda_1)(1+\lambda_2)} \left(\alpha_{mc} + \frac{c}{2} \right) M_t . \quad \text{(A5)}$$

We obtain the firm's optimal price by recursion of equation (A5) with initial conditions $X_{-2} = X_{-1} = \frac{M_{-1}}{1-\phi} \left(\alpha_{mc} + \frac{c}{2} \right)$. Given the firm's optimal price, the nominal price level in economy can be obtained from equation (5) in the text.

For the sticky information model, the price level equation (7) in nominal form becomes

$$\begin{aligned} \overline{P}_t = & \frac{1}{3} \left(\left(\alpha_{mc} + \frac{c}{2} \right) M_t + \phi \overline{P}_t \right) + \frac{1}{3} E_{t-1} \left(\left(\alpha_{mc} + \frac{c}{2} \right) M_t + \phi \overline{P}_t \right) \\ & + \frac{1}{3} E_{t-2} \left(\left(\alpha_{mc} + \frac{c}{2} \right) M_t + \phi \overline{P}_t \right) \end{aligned} . \quad \text{(A6)}$$

Taking expectations of equation (A6) as of $t-2$ we can solve for $E_{t-2} \overline{P}_t$

$$E_{t-2} \overline{P}_t = \frac{1}{1-\phi} \left(\alpha_{mc} + \frac{c}{2} \right) E_{t-2} M_t . \quad \text{(A7)}$$

Taking expectations of equation (A7) as of $t-1$ and using the solution (A6) we can solve for $E_{t-1} \overline{P}_t$

$$E_{t-1} \overline{P}_t = \frac{2}{3-2\phi} \left(\alpha_{mc} + \frac{c}{2} \right) E_{t-1} M_t + \frac{1}{(3-2\phi)(1-\phi)} \left(\alpha_{mc} + \frac{c}{2} \right) E_{t-2} M_t . \quad \text{(A8)}$$

Finally, plugging in the solutions for $E_{t-2} \overline{P}_t$ and $E_{t-1} \overline{P}_t$ into equation (A5) we get the solution for the nominal price level

$$\begin{aligned} \overline{P}_t = & \frac{1}{3-\phi} \left(\alpha_{mc} + \frac{c}{2} \right) M_t + \frac{3}{(3-2\phi)(1-\phi)} \left(\alpha_{mc} + \frac{c}{2} \right) E_{t-1} M_t \\ & + \frac{1}{(3-2\phi)(1-\phi)} \left(\alpha_{mc} + \frac{c}{2} \right) E_{t-2} M_t \end{aligned} , \quad \text{(A9)}$$

using the fact that $E_t M_{t+i} = M_t$ before and after the shock.

A.2. Aggregate Prices in Monopolistically Competitive Economies with Adaptive Price Setters.

Assume that, a fraction of firms ω set price equal to the previous period aggregate price. Then, in a perfectly flexible economy, the average price with adaptive price-setting firms becomes

$$\bar{p}_t^{mc,a} = (1-\omega)\, p_t^{mc} + \omega \bar{p}_{t-1}^{mc,a} \,. \tag{A10}$$

Given sticky prices, the average price level will still be set according to equation (5). However the presence of adaptive price-setting sellers implies that the firms who may change price will adjust them according to

$$x_t^{sp,a} = (1-\omega)\left(\frac{1}{3} p_t^{mc} + \frac{1}{3} E_t p_{t+1}^{mc} + \frac{1}{3} E_t p_{t+2}^{mc}\right) + \omega \bar{p}_{t-1}^{sp,a} \,, \tag{A11}$$

Similarly, given the backward looking firms in the sticky information economy, the nominal price becomes

$$\begin{aligned}\bar{p}_t^{si,a} = (1-\omega)&\left(\frac{1}{3}\left(\alpha_{mc} + \frac{1}{2} c_t + \phi \bar{p}_t^{si,b}\right) + \frac{1}{3} E_{t-1}\left(\alpha_{mc} + \frac{1}{2} c_t + \phi \bar{p}_t^{si,a}\right) + \frac{1}{3} E_{t-2}\left(\alpha_{mc} + \frac{1}{2} c_t + \phi \bar{p}_t^{si,a}\right)\right) \\ &+ \omega\left(\frac{1}{3} \bar{p}_{t-1}^{si,b} + \frac{1}{3} \bar{p}_{t-2}^{si,b} + \frac{1}{3} \bar{p}_{t-3}^{si,b}\right).\end{aligned} \tag{A12}$$

A.3. Response of Prices to a 100% Increase of the Nominal Scale Variable in Economy with one-third Adaptive Price Setters.

For the flexible economy model we insert the optimal price expression in equation (3) into equation (A10). Expressing the result in nominal form yields

$$\bar{P}_t = \frac{3}{4-3\phi}\left(\alpha_{mc} + \frac{c}{2}\right) M_t + \frac{1}{4-3\phi} \bar{P}_{t-1} \,. \tag{A13}$$

For the sticky price model we insert the best response expression (2) and the optimal price expressions (5) into equation (A11) to obtain an expression for the optimal price adjustment. In nominal form this reduces to

$$\begin{aligned}&\left(9 - \frac{9}{4}\phi\right) X_t - \left(\frac{3}{2}\phi + \frac{3}{4}\right) X_{t-1} - \left(\frac{3}{4}\phi + \frac{3}{4}\right) X_{t-2} - \frac{3}{4} X_{t-3} - \frac{3}{2}\phi E_t X_{t+1} - \frac{3}{4}\phi E_t X_{t+2} = \\ &= \frac{9}{4}\left(\alpha_{mc} + \frac{c}{2}\right)\left(M_t + E_t M_{t+1} + E_t M_{t+2}\right)\end{aligned} \,, \tag{A14}$$

where in (A14) we used our assumption that marginal costs are constant apart from the nominal scale variable. As in part A.1 we use lag operators. Factoring the lag-polynomial equation we re-write (A14) as

$$\begin{aligned}&(1-\lambda_1^{-1}L^{-1})(1-\lambda_2^{-1}L^{-1})(1-\lambda_3 L)(1-\lambda_4 L)(1-\lambda_5 L)X_t = \\ &= -\frac{3}{\lambda_1\lambda_2\phi}\left(\alpha_{mc}+\frac{c}{2}\right)\left(1+L^{-1}+L^{-2}\right)M_t\end{aligned}, \qquad \text{(A15)}$$

where λ_i are the roots of lag-polynomial equation. When $|\lambda_i|>1$ inverse of $(1-\lambda_i^{-1}L^{-1})$ is well defined. Dividing both sides of equation (A15) by $(1-\lambda_1^{-1}L^{-1})$ and $\left(1-\lambda_2^{-1}L^{-1}\right)$, using the definition of lag operators, and the fact that shock is permanent ($E_t M_{t+i} = M_t$ before and after the shock) results in

$$\begin{aligned}X_t &= (\lambda_3+\lambda_4+\lambda_5)X_{t-1} - \left((\lambda_3+\lambda_4)\lambda_5+\lambda_3\lambda_4\right)X_{t-2} + \lambda_3\lambda_4\lambda_5 X_{t-3} \\ &-\frac{9}{\phi(\lambda_1-1)(\lambda_2-1)}\left(\alpha_{mc}+\frac{c}{2}\right)M_t\end{aligned}. \qquad \text{(A16)}$$

We obtain the adjusting firm price by recursion of equation (A16) with the initial condition $X_{-2} = X_{-1} = \frac{M_{-1}}{1-\phi}\left(\alpha_{mc}+\frac{1}{2}c\right)$. Given the adjusting firm's price at each *t*, the nominal price level in economy can be obtained from equation (5).

For the sticky information model, we first re-express the price level equation (A12) in nominal form:

$$\begin{aligned}\overline{P}_t &= \frac{1}{4}\left(\left(\alpha_{mc}+\frac{c}{2}\right)M_t+\phi\overline{P}_t\right)+\frac{1}{4}E_{t-1}\left(\left(\alpha_{mc}+\frac{c}{2}\right)M_t+\phi\overline{P}_t\right) \\ &+\frac{1}{4}E_{t-2}\left(\left(\alpha_{mc}+\frac{c}{2}\right)M_t+\phi\overline{P}_t\right)+\frac{1}{12}\left(\overline{P}_{t-1}+\overline{P}_{t-2}+\overline{P}_{t-3}\right)\end{aligned}. \qquad \text{(A17)}$$

Taking expectations of equation (A17) as of $t-2$ we can solve for $E_{t-2}\overline{P}_t$

$$E_{t-2}\overline{P}_t = \frac{3}{4-3\phi}\left(\alpha_{mc}+\frac{c}{2}\right)E_{t-2}M_t + \frac{1}{3(4-3\phi)}\left(E_{t-2}\overline{P}_{t-1}+\overline{P}_{t-2}+\overline{P}_{t-3}\right). \qquad \text{(A18)}$$

Taking expectations of equation (A17) as of $t-1$ and using (A18) we can solve for $E_{t-1}\overline{P}_t$

$$E_{t-1}\overline{P}_t = \frac{1}{3(2-\phi)}\left(\alpha_{mc} + \frac{c}{2}\right)\left(2E_{t-1}M_t + E_{t-2}M_t + \phi E_{t-2}\overline{P}_t\right) - \frac{1}{6(2-\phi)}\left(\overline{P}_{t-1} + \overline{P}_{t-2} + \overline{P}_{t-3}\right) . \quad \text{(A19)}$$

Beginning recursion from $E_{-2}P_{-1} = \frac{M_{-1}}{1-\phi}\left(\alpha_{mc} + \frac{c}{2}\right)$, iterating on equations (A17), (A18), and using the fact that $E_t M_{t+i} = M_t$ before and after the shock, allows calculation of the economy's nominal price in equation (A14).

Appendix B. Estimates of Individual Forecast and Pricing Decisions

Table B1: Forecast Decisions**,** *BASE* Subjects 1-24.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Subj. ID	c_{1i}	c_{2i}	β_{1i}	β_{2i}	β_{3i}	β_{4i}	β_{5i}	β_{6i}	R^2	*Q-stat*	*F-stat*
1	-1.45	-0.77	0.53	-0.04	0.19	0.36	-0.06	0.11	0.99	**51.96**	**12.62**
2	9.12	5.98	0.32	0.42	-0.08	0.03	-0.24	-0.07	0.88	43.61	**7.88**
3	8.59	5.88	-0.04	0.06	0.42	0.24	0.06	-0.33	0.93	19.28	**14.87**
4	4.45	2.88	0.31	0.41	0.14	-0.10	-0.10	0.01	0.87	40.57	1.77
5	2.20	0.78	0.75	-0.10	0.27	0.18	-0.32	0.11	0.99	39.43	**4.12**
6	3.83	3.56	0.65	0.02	0.25	0.08	-0.28	-0.04	0.95	25.82	**6.66**
7	13.34	10.41	-0.11	0.51	0.08	0.05	-0.30	-0.17	0.93	**102.51**	**20.42**
8	0.59	0.44	0.82	-0.36	0.05	0.48	-0.05	0.02	1.00	44.70	**9.13**
9	7.19	6.03	0.52	0.11	0.19	-0.17	-0.14	-0.04	0.98	**62.48**	**23.19**
10	14.28	11.77	0.39	0.18	0.33	-0.41	-0.27	-0.26	0.96	**96.67**	**37.32**
11	0.84	0.22	0.80	-0.03	-0.02	0.14	0.06	0.00	1.00	27.56	0.78
12	14.27	11.15	0.36	0.20	0.22	-0.35	-0.24	-0.20	0.95	**119.99**	**26.00**
13	12.28	9.64	0.34	-0.15	0.22	-0.10	-0.16	-0.08	0.95	20.44	**15.58**
14	-4.12	-2.50	0.69	-0.28	0.34	0.60	-0.21	0.14	0.92	31.10	**11.36**
15	1.96	1.58	0.93	0.73	-0.17	-0.37	-0.17	-0.10	0.98	19.16	**3.84**
16	4.09	2.56	1.12	0.32	-0.17	-0.50	-0.05	0.01	0.99	15.42	**7.12**
17	1.76	0.76	0.60	0.31	0.12	0.04	-0.23	0.04	0.99	17.25	0.96
18	3.20	2.41	1.22	0.55	-0.29	-0.35	-0.18	-0.19	0.98	21.86	**4.89**
19	3.57	3.72	-0.29	0.20	0.16	0.92	-0.21	-0.06	0.98	26.80	**15.76**
20	2.42	2.52	1.36	0.04	-0.17	-0.60	-0.06	0.24	0.98	13.73	**6.77**
21	3.46	3.80	1.25	-0.22	0.14	-0.40	-0.03	-0.03	0.96	15.50	**6.00**
22	3.68	3.47	0.91	0.14	0.09	-0.18	-0.14	-0.10	0.97	9.20	**5.03**
23	2.72	2.70	1.25	-0.74	0.03	-0.34	0.48	0.12	0.96	**52.82**	**5.52**
24	-0.23	-0.23	1.03	-0.04	0.17	0.02	-0.15	-0.01	1.00	33.11	1.90

Notes: Tables B1 and B2 report least squares estimates of the encompassing forecasting model in Section 5.1. Columns (1) to (8) of each table show parameter estimates and column (9) lists the R^2 of each regression. Column (10) reports Ljung-Box Q-statistics of autocorrelation in the residuals up to 34-th order. Bolded entries indicate rejection of H_o, of no autocorrelation at a 5% significance level. Column (11) lists F-statistics of the restriction $H_0 : c_{2i} = \beta_{4i} = \beta_{5i} = \beta_{6i} = 0$. In column (11) bolded entries indicate rejection of H_0 at 5% significance level.. As explained in the text, for eight participants we cannot reject either hypothesis.

Table B2: Forecast Decisions *BASE* Subjects 25-48

Subj. ID	(1) c_{1i}	(2) c_{2i}	(3) β_{1i}	(4) β_{2i}	(5) β_{3i}	(6) β_{4i}	(7) β_{5i}	(8) β_{6i}	(9) R^2	(10) *Q-stat*	(11) *F-stat*
25	6.49	4.82	0.51	0.24	0.18	-0.12	-0.24	-0.04	0.98	**90.31**	**29.03**
26	1.34	1.27	1.09	-0.46	0.16	0.21	-0.20	0.09	0.98	**52.59**	**7.12**
27	0.68	0.74	1.03	-0.48	0.23	0.39	-0.22	0.00	0.99	35.17	**5.45**
28	6.19	3.19	0.95	0.32	0.18	-0.18	-0.55	-0.11	0.96	**109.44**	**14.50**
29	1.84	0.68	0.85	-0.19	-0.04	0.33	-0.05	-0.01	0.99	**53.78**	**4.01**
30	2.79	2.14	0.96	-0.28	-0.02	0.16	-0.14	0.10	0.98	**80.46**	**10.16**
31	7.48	4.10	0.57	-0.16	-0.04	0.18	-0.08	0.06	0.95	**72.11**	**14.50**
32	8.76	4.46	0.81	0.24	-0.10	-0.30	-0.13	-0.05	0.95	**54.18**	**9.52**
33	-0.61	0.63	0.79	0.04	-0.09	0.10	0.18	0.00	0.98	44.39	1.64
34	5.45	4.34	0.08	-0.08	-0.07	0.53	0.02	0.11	0.95	23.60	**28.81**
35	9.37	6.25	0.65	0.35	-0.07	-0.33	-0.17	-0.07	0.98	**117.30**	**32.58**
36	4.22	2.17	1.06	-0.29	-0.19	0.01	0.15	0.00	0.95	33.33	**3.05**
37	11.65	8.33	0.46	0.33	-0.12	-0.36	-0.11	-0.04	0.94	40.62	**27.47**
38	0.81	1.26	1.02	-0.26	0.36	0.13	-0.25	-0.08	0.99	21.10	**6.58**
39	18.15	8.77	1.12	-0.48	-0.61	0.03	-0.11	-0.06	0.76	14.92	**8.41**
40	2.30	0.70	1.21	-0.48	0.09	0.09	-0.04	0.00	0.96	28.44	0.64
41	2.21	0.88	0.87	-0.05	0.18	-0.01	-0.09	-0.02	0.97	29.01	1.49
42	11.93	6.65	0.93	0.02	-0.05	-0.25	-0.20	-0.21	0.93	36.18	**18.68**
43	7.23	8.03	0.43	0.05	0.08	-0.19	-0.06	0.09	0.98	**82.88**	**33.35**
44	-0.73	-0.42	0.23	0.82	0.28	-0.22	-0.09	0.03	0.99	34.87	1.49
45	18.00	15.89	-0.16	-0.91	0.61	0.04	0.30	-0.19	0.83	**64.00**	**13.75**
46	-0.13	-0.07	0.86	0.57	-0.06	-0.29	0.04	-0.11	1.00	29.21	**3.86**
47	9.28	9.26	0.26	-0.04	0.16	-0.05	-0.02	-0.03	0.92	23.96	**8.63**
48	10.43	10.17	0.45	0.07	0.37	-0.30	-0.18	-0.20	0.98	**92.32**	**39.88**

Notes: See notes to Table B1.

Table B3: Price Decisions**,** *BASE* Subjects 1-24.

Subj. ID	(1) c_{1i}	(2) c_{2i}	(3) β_{1i}	(4) β_{2i}	(5) β_{3i}	(6) β_{4i}	(7) β_{5i}	(8) β_{6i}	(9) R^2	(10) *Q-stat*	(11) *F-stat*
1	-1.45	-0.77	0.53	-0.04	0.19	0.36	-0.06	0.11	0.99	**51.96**	**12.62**
2	9.12	5.98	0.32	0.42	-0.08	0.03	-0.24	-0.07	0.88	43.61	**7.88**
3	8.59	5.88	-0.04	0.06	0.42	0.24	0.06	-0.33	0.93	19.28	**14.87**
4	4.45	2.88	0.31	0.41	0.14	-0.10	-0.10	0.01	0.87	40.57	1.77
5	2.20	0.78	0.75	-0.10	0.27	0.18	-0.32	0.11	0.99	39.43	**4.12**
6	3.83	3.56	0.65	0.02	0.25	0.08	-0.28	-0.04	0.95	25.82	**6.66**
7	13.34	10.41	-0.11	0.51	0.08	0.05	-0.30	-0.17	0.93	**102.51**	**20.42**
8	0.59	0.44	0.82	-0.36	0.05	0.48	-0.05	0.02	1.00	44.70	**9.13**
9	7.19	6.03	0.52	0.11	0.19	-0.17	-0.14	-0.04	0.98	**62.48**	**23.19**
10	14.28	11.77	0.39	0.18	0.33	-0.41	-0.27	-0.26	0.96	**96.67**	**37.32**
11	0.84	0.22	0.80	-0.03	-0.02	0.14	0.06	0.00	1.00	27.56	0.78
12	14.27	11.15	0.36	0.20	0.22	-0.35	-0.24	-0.20	0.95	**119.99**	**26.00**
13	12.28	9.64	0.34	-0.15	0.22	-0.10	-0.16	-0.08	0.95	20.44	**15.58**
14	-4.12	-2.50	0.69	-0.28	0.34	0.60	-0.21	0.14	0.92	31.10	**11.36**
15	1.96	1.58	0.93	0.73	-0.17	-0.37	-0.17	-0.10	0.98	19.16	**3.84**
16	4.09	2.56	1.12	0.32	-0.17	-0.50	-0.05	0.01	0.99	15.42	**7.12**
17	1.76	0.76	0.60	0.31	0.12	0.04	-0.23	0.04	0.99	17.25	0.96
18	3.20	2.41	1.22	0.55	-0.29	-0.35	-0.18	-0.19	0.98	21.86	**4.89**
19	3.57	3.72	-0.29	0.20	0.16	0.92	-0.21	-0.06	0.98	26.80	**15.76**
20	2.42	2.52	1.36	0.04	-0.17	-0.60	-0.06	0.24	0.98	13.73	**6.77**
21	3.46	3.80	1.25	-0.22	0.14	-0.40	-0.03	-0.03	0.96	15.50	**6.00**
22	3.68	3.47	0.91	0.14	0.09	-0.18	-0.14	-0.10	0.97	9.20	**5.03**
23	2.72	2.70	1.25	-0.74	0.03	-0.34	0.48	0.12	0.96	**52.82**	**5.52**
24	-0.23	-0.23	1.03	-0.04	0.17	0.02	-0.15	-0.01	1.00	33.11	1.90

Notes: Tables B3 and B4 report least squares estimates of the encompassing pricing model in Section 5.4. Columns (1) to (8) of each table show parameter estimates and column (9) lists the R^2 of each regression. Column (10) reports Ljung-Box Q-statistics of autocorrelation in the residuals up to 34-th order. Bolded entries indicate rejection of H_o, of no autocorrelation at a 5% significance level. Column (11) lists F-statistics of the restriction $H_0 : c_{2i} = \beta_{4i} = \beta_{5i} = \beta_{6i} = 0$. In column (11) bolded entries indicate rejection of H_0 at 5% significance level. As explained in the text, for eight participants we cannot reject either hypothesis.

Table B4: Price Decisions**,** *BASE* Subjects 25-48.

Subj. ID	(1) c_{1i}	(2) c_{2i}	(3) β_{1i}	(4) β_{2i}	(5) β_{3i}	(6) β_{4i}	(7) β_{5i}	(8) β_{6i}	(9) R^2	(10) *Q-stat*	(11) *F-stat*
25	6.49	4.82	0.51	0.24	0.18	-0.12	-0.24	-0.04	0.98	**90.31**	**29.03**
26	1.34	1.27	1.09	-0.46	0.16	0.21	-0.20	0.09	0.98	**52.59**	**7.12**
27	0.68	0.74	1.03	-0.48	0.23	0.39	-0.22	0.00	0.99	35.17	**5.45**
28	6.19	3.19	0.95	0.32	0.18	-0.18	-0.55	-0.11	0.96	**109.44**	**14.50**
29	1.84	0.68	0.85	-0.19	-0.04	0.33	-0.05	-0.01	0.99	**53.78**	**4.01**
30	2.79	2.14	0.96	-0.28	-0.02	0.16	-0.14	0.10	0.98	**80.46**	**10.16**
31	7.48	4.10	0.57	-0.16	-0.04	0.18	-0.08	0.06	0.95	**72.11**	**14.50**
32	8.76	4.46	0.81	0.24	-0.10	-0.30	-0.13	-0.05	0.95	**54.18**	**9.52**
33	-0.61	0.63	0.79	0.04	-0.09	0.10	0.18	0.00	0.98	44.39	1.64
34	5.45	4.34	0.08	-0.08	-0.07	0.53	0.02	0.11	0.95	23.60	**28.81**
35	9.37	6.25	0.65	0.35	-0.07	-0.33	-0.17	-0.07	0.98	**117.30**	**32.58**
36	4.22	2.17	1.06	-0.29	-0.19	0.01	0.15	0.00	0.95	33.33	**3.05**
37	11.65	8.33	0.46	0.33	-0.12	-0.36	-0.11	-0.04	0.94	40.62	**27.47**
38	0.81	1.26	1.02	-0.26	0.36	0.13	-0.25	-0.08	0.99	21.10	**6.58**
39	18.15	8.77	1.12	-0.48	-0.61	0.03	-0.11	-0.06	0.76	14.92	**8.41**
40	2.30	0.70	1.21	-0.48	0.09	0.09	-0.04	0.00	0.96	28.44	0.64
41	2.21	0.88	0.87	-0.05	0.18	-0.01	-0.09	-0.02	0.97	29.01	1.49
42	11.93	6.65	0.93	0.02	-0.05	-0.25	-0.20	-0.21	0.93	36.18	**18.68**
43	7.23	8.03	0.43	0.05	0.08	-0.19	-0.06	0.09	0.98	**82.88**	**33.35**
44	-0.73	-0.42	0.23	0.82	0.28	-0.22	-0.09	0.03	0.99	34.87	1.49
45	18.00	15.89	-0.16	-0.91	0.61	0.04	0.30	-0.19	0.83	**64.00**	**13.75**
46	-0.13	-0.07	0.86	0.57	-0.06	-0.29	0.04	-0.11	1.00	29.21	**3.86**
47	9.28	9.26	0.26	-0.04	0.16	-0.05	-0.02	-0.03	0.92	23.96	**8.63**
48	10.43	10.17	0.45	0.07	0.37	-0.30	-0.18	-0.20	0.98	**92.32**	**39.88**

Notes: See notes to Table B3.

References

Adam K. (2007) “Experimental Evidence on the Persistence of Output and Inflation” *The Economic Journal*, 117, 603–636.

Blanchard, O.J., and Kiyotaki, N. (1987) “Monopolistic Competition and the Effects of Aggregate Demand” *American Economic Review*, 77(4), 647–666.

Calvo, Guillermo A. (1983) “Staggered Prices in a Utility Maximizing Framework” *Journal of Monetary Economics*, XII, 383–398.

Christiano L., Eichenbaum M., and Evans, C. (2005) “Nominal Rigidities and the Dynamic Effects of a Shock to Monetary Policy” *Journal of Political Economy*, 113(1), 1–45.

Davis, Douglas D. (2002) “Strategic Interactions, Market Information and Mergers in Differentiated Product Markets: An Experimental Investigation,” *International Journal of Industrial Organization* 20(9), 1277-1312.

Davis, Douglas D. and Bart J. Wilson (2005) “Differentiated Product Competition and the Antitrust Logit Model: An Experimental Analysis,” *Journal of Economic Behavior and Organization* 57(1), 89-113.

Fehr, Ernst and Jean-Robert Tyran (2001) “Does Money Illusion Matter?” *American Economic Review*, 91(5), 1239-1262.

Fehr, Ernst and Jean-Robert Tyran (2008) “Limited Rationality and Strategic Interaction: The Impact of the Strategic Environment on Nominal Inertia” *Econometrica* 76, 353-394.

Fischer, Stanley (1977) "Long-Term Contracts, Rational Expectations and the Optimal Money Supply Rule," Journal of Political Economy, 191-206.

Gali J., and Gertler, M. (1999) “Inflation Dynamics: A Structural Econometric Analysis” *Journal of Monetary Economics*, 44, 195–222.

Garcia-Gallego, Aurora (1998) “Oligopoly Experimentation of Learning with Simulated Markets” *Journal of Economic Behavior and Organization* 35, 333-355

Garcia-Gallego, Aurora and Nikolaos Georgantzis (2001) “Multiproduct Activity in an experimental Differentiated Oligopoly” *International Journal of Industrial Organization*, 19, 493-518.

Haltiwanger John and Michael Waldman, (1989) “Limited Rationality and Strategic Complements: The Implications for Macroeconomics” *The Quarterly Journal of Economics*, 104(3), 463-483.

Heemeijer Peter, Cars Hommes, Joep Sonnemans, Jan Tuinstra (2009) "Price Stability and Volatility in Markets with Positive and Negative Expectations Feedback: An Experimental Investigation" *Journal of Economic Dynamics and Control* 33, 1052-1072.

Huck Steffen, Hans-Theo Normann and Jorg Oechssler (2002) "Stability of the Cournot process: Experimental Evidence" *International Journal of Game Theory*, 2002, Vol. 31, 123-136

Huck Steffen, Hans-Theo Normann and Jorg Oechssler (2000) "Does Information about Competitors' Actions Increase or Decrease Competition in Experimental Oligopoly Markets?" *International Journal of Industrial Organization* 18, 39-57

Mankiw, Gregory N. and Ricardo Reis (2002) "Sticky Information versus Sticky Prices: A Proposal to Replace the New Keynesian Phillips Curve" *The Quarterly Journal of Economics* 117 (4), 1295–1328

Romer, David (2001) *Advanced Macroeconomics*, 2nd ed., McGraw Hill, New York, NY.

Sargent, Thomas J. (1987) *Macroeconomic Theory*, 2nd ed., Academic Press, New York, NY.

Smets F, and Wouters R. (2003) "An Estimated Dynamic Stochastic General Equilibrium Model of the Euro Area" *Journal of the European Economic Association*, 1(5), 1123–1175.

Smith, Vernon L, Gerry L. Suchanek, and Arlington W. Williams (1988) "Bubbles, Crashes and Endogeneous Expectations in Experimental Sport Asset Market," *Econometrica*, *56*, 1119-1152.

Taylor, John B. (1980), "Aggregate Dynamics and Staggered Contracts," *Journal of Political Economy*. 88(1), 1-23..

Vives, X., 1999. *Oligopoly Pricing: Old Ideas and New Tools*. MIT Press, Cambridge, MA.

Williams, Arlington W. (1987) "The Formation of Price Forecasts in Experimental Markets" *Journal of Money, Credit, and Banking*, 19(1), 1-18.

Wilson, B.J. (1998) "Menu Costs and Nominal Price Friction: An Experimental Examination" *Journal of Economic Behavior and Organization*, 35, 371-388.

Woodford, Michael (2003) *Interest and Prices: Foundations of a Theory of Monetary Policy*, Princeton University Press, Princeton, NJ.

INSTRUCTIONS

Overview

This is an experiment in the economics of decision-making. Various research foundations have provided funds for this research. The instructions are simple, and if you follow them carefully and make good decisions, you may earn a considerable amount of money that will be paid to you in CASH at the end of the experiment. Your earnings will be determined partly by your decisions and partly by the decisions of others. We appreciate your participation, and wish to stress that during the experiment your communications with others should occur ONLY via computer. Please do not talk to each other or share information in any other way.

General Description

1. You run a firm that produces and sells a certain product. Besides you there are 5 other firms in your industry producing similar but not identical products.
2. The market consists of 80 periods.
3. Trading Mechanism
   I. You (a seller):
      A. In each period, your primary task is to set the price at which your product will be available for sale.
      - Your price and the average market price (the average of all six firms' prices) determine your sales: The *higher your price*, the *fewer* units you sell. (If your price is too high you'll sell nothing). The *higher the average market price*, the *more* units you sell.
      - For each unit you sell, you earn profit by selling at prices above costs. All firms produce at the same cost. Initially, this cost will be $10 per unit.
      - An Excel profit calculator will help you to calculate your earnings. It computes your earnings for any choice of your price and the average market price that you enter.

      B. In addition to setting price, you will also forecast the average market price.
      - You earn a forecast prize of $2 if your prediction is within 50 cents of the actual average market price.

      C. You and all sellers will have one minute in which to make decisions.

   II. The Buyer:
      Each period the automated buyer will purchase units from you according to the following rule:

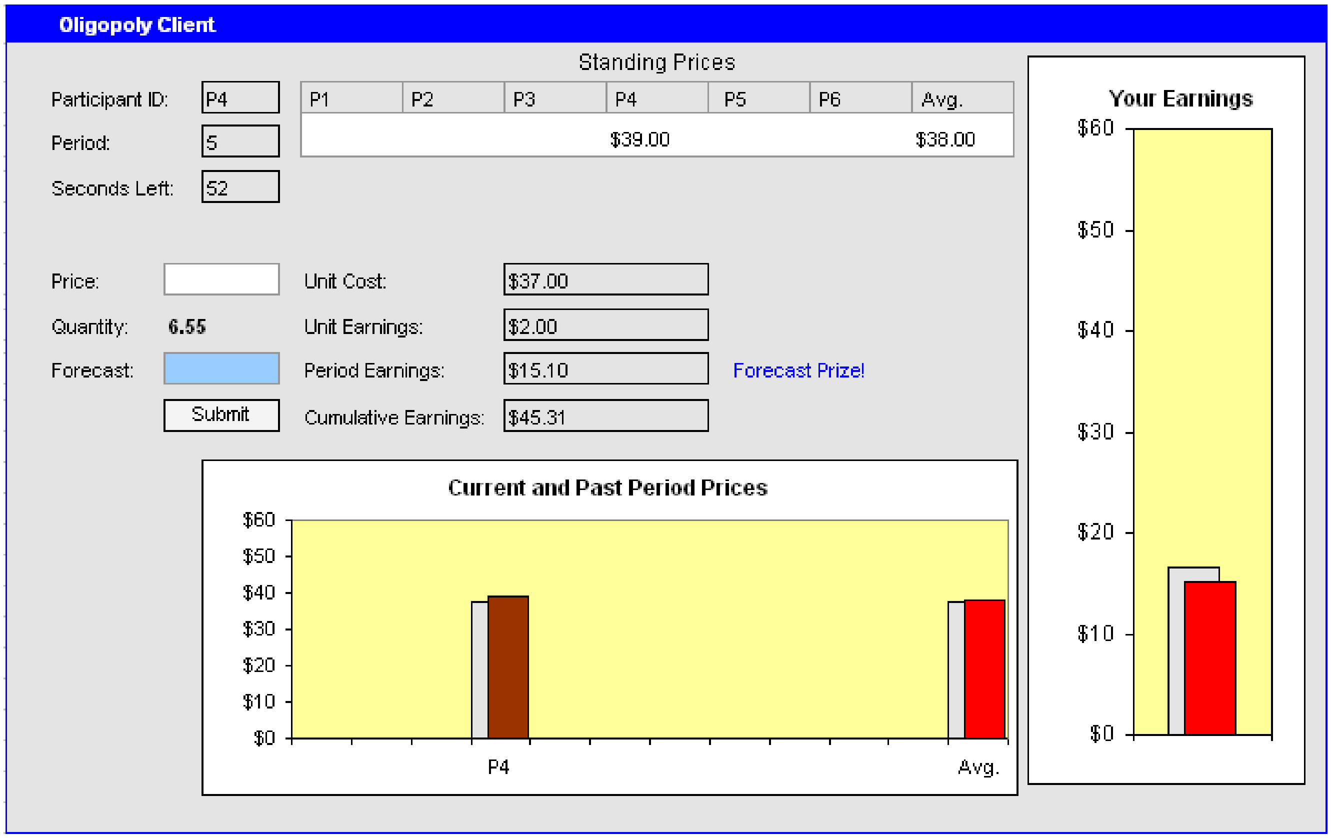
$$\text{Your Units Sold} = 9.23 - 2.54 \times (\text{Your Price}) + 2.31 \times (\text{Average Market Price})$$

      As you can see, the buyer purchase rule implies that the *higher your price*, the *fewer* units you sell. The *higher the average market price*, the *more* units you sell.

4. Costs, prices, and profits are presented in Lab dollars. Initially, the exchange rate is 1 U.S. dollar for every 100 dollars earned in the Lab.

A Sample Screen: Below is a sample screen for a seller P4 at the start of period 5. (All numbers in this example are provided only to give an EXAMPLE of the screen display; they SUGGEST NOTHING about how you should play.)

In period 5, P4 must enter a price in the “Price” box and a forecast of the average market price in the “Forecast” box, given the cost of $37 per unit. Seller P4 has 52 seconds to make her choices and to submit her decision by clicking the “Submit” button.



The rest of the screen allows you to track results from the immediately preceding periods. The entry aside “Quantity” below the “Price” box shows quantity sold in period 4 (here 6.55).

The “Standing Prices” box, at the top of the screen, shows previous period own and average prices. Here, in period 4, P4 posted a price of $39, and the market average was $38. The red bars in the “Current and Past Period Prices” box, at the bottom of the screen, provide a graphical version of price information for the period that just ended (here period 4) and the gray bars show prices for the prior period (here period 3). You can see that relative to period 3 seller P4 increased her price and overall average price went up slightly.

The “Unit Earnings” and “Period Earnings” boxes, in the middle of the screen, report earnings per unit ($2) and total earnings ($15.10) in the just completed period. The blue “Forecast Prize!” message indicates that in period 4 P4 forecast was within 50 cents from $38. The “Cumulative Earnings” box adds up earnings from all periods. Unit and period earnings are calculated for you using these formulas:

Unit Earnings = Price-Cost =$39-$37 =$2
Period Earnings = Unit Earnings × Quantity + Forecast Prize=$2×6.55+$2=$15.10

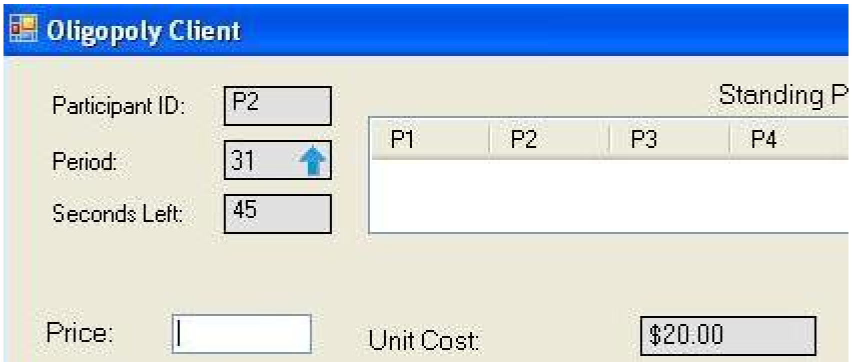
Period 3 and 4 earnings are also presented graphically as gray and red bars on the “Your Earnings” Graph. Here, P4 earnings fell in period 4 relative to period 3.

General Description (continued)

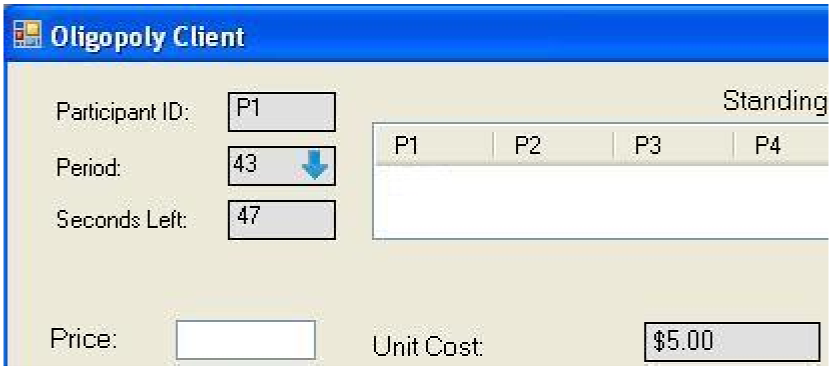
5. In every period up to period 30, unit costs, the buyer purchase rule, and the exchange rate will remain unchanged.

6. During one of the next 20 periods (e.g., one of the periods 31 to 50) economic conditions will either change **up** or change **down** (Note “up” and “down” are just names; they do not imply that conditions become better or worse than in previous periods).

   If conditions change **up**:
   - unit costs increase to $20;
   - the buyer purchase rule changes to:
     Your Units Sold = 9.23 - 1.27 × (Your Price)+1.15 × (Average Market Price)
   - the exchange rate changes to 1 U.S. dollar for every 200 dollars earned in the Lab.
   - Below is a part of a screen for a seller P2 at the start of period 31. Notice that next to the period number there is a blue arrow pointing <u>up</u>. Also, you can see on the screen that unit costs went up to $20.



   If conditions change **down**:
   - unit costs decrease to $5;
   - the buyer purchase rule changes to:
     Your Units Sold = 9.23 - 5.08 × (Your Price)+4.62 × (Average Market Price)
   - the exchange rate changes to 1 U.S. dollar for every 50 dollars earned in the Lab.
   - Below is a part of a screen for a seller P1 at the start of period 43. Notice that next to the period number there is a blue arrow pointing <u>down</u>. Also, you can see on the screen that unit costs went down to $5.



7. After this single change all economic conditions will remain permanent until the end of the experiment.

Questionnaire and Practice Sessions

It is important that you all understand these instructions. Prior to starting the experiment, we will do two things to facilitate your comprehension. First, we will ask you to answer the following questions. Once you have all completed your answers we will review them together. Second, we will conduct a pair of 6-period practice sessions. In the first practice session, we will have an **up** change after period 5. In the second, a **down** change will occur after period 5.

If you have any questions, please ask now and during the practice sessions. Once we finish the practice sessions, you will not be allowed to ask further questions.

Questions

1. Suppose in period 2 you posted a price of, say $27, and the market average price was $22. If in period 3 you post the same $27 price, but the market average goes down to $20, will you sell more or less?

2. Consider again the same condition as in question 1, but now suppose that that you decrease your price to $25, but that the market price stays the same at $22. What will happen to your sales?

3. Suppose it is period 28. How might cost change in period 29 relative to current cost?

4. Suppose economic conditions change **down** in period 46. Your unit costs fall to $5, and the buyer purchasing rule changes as indicated in the instructions. How will you know that the change has occurred?

5. Suppose you earn 100 dollars in period 41. In period 42 market demand conditions change **up**, but you again earn 100 dollars. How many U.S. dollars you have earned in these two periods?

Questions *(Response Script – to be read once responses are complete)*

1. Suppose in period 2 you posted a price of, say $27, and the market average price was $22. If in period 3 you post the same $27 price, but the market average goes down to $20, will you sell more or less?

Response: You will sell less. The lower the average market price, the fewer units you sell. Your sales quantities move together with the average price.

2. Consider again the same condition as in question 1, but now suppose that that you decrease your price to $25, but that the market price stays the same at $22. What will happen to your sales?

Response: Your sales quantity will increase. The lower your price, the more units you sell. Your sales quantities move opposite to you own price.

3. Suppose it is period 28. How might cost change in period 29 relative to current cost?

Response: No change. Up to period 30 conditions remain unchanged.

4. Suppose economic conditions change **down** in period 46. Your unit costs fall to $5, and the buyer purchasing rule changes as indicated in the instructions. How will you know that the change has occurred?

*Response: If economic conditions change **down**, on the screen, next to the period number, there will be a blue arrow pointing <u>down</u>. Also, in the "Unit Cost" box, costs will decrease from $10 to $5.*

5. Suppose you earn 100 dollars in period 41. In period 42 market demand conditions change **up**, but you again earn 100 dollars. How many U.S. dollars you have earned in these two periods?

*Response: If economic conditions change **up**, the exchange rate will change from 1 U.S. dollar per every 100 dollars earned in the lab to 1 U.S. dollar per every 200 dollars earned in the lab. Thus, your period earnings fell from 1 U.S. dollar in period 41 to 50 cents in period 42. In two periods, you have earned 1.5 U.S. dollars.*

INSTRUCTIONS

Overview

This is an experiment in the economics of decision-making. Various research foundations have provided funds for this research. The instructions are simple, and if you follow them carefully and make good decisions, you may earn a considerable amount of money that will be paid to you in CASH at the end of the experiment. Your earnings will be determined partly by your decisions and partly by the decisions of others. We appreciate your participation, and wish to stress that during the experiment your communications with others should occur ONLY via computer. Please do not talk to each other or share information in any other way.

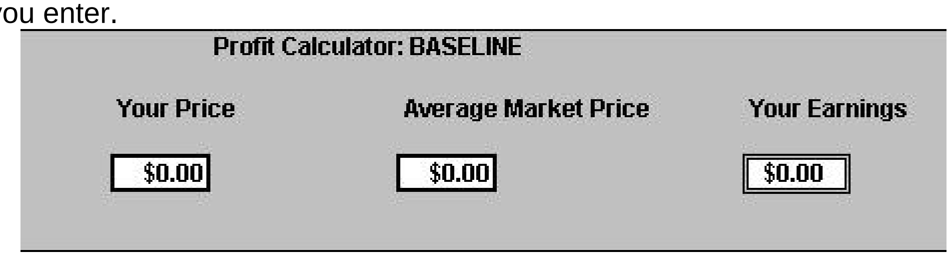
General Description

1. You run a firm that produces and sells a certain product. Besides you there are 5 other firms in your industry producing similar but not identical products.
2. The market consists of 80 periods.
3. Every period only 2 out of the 6 firms may change prices: Two firms will be able to change prices in one period. Two other firms will be able to change prices in the next period, and the remaining two firms will be able to change prices in the period after that.
4. Trading Mechanism

   I. You (a seller):

   A. Every 3rd period, your primary task is to set the price at which your product will be available for sale during this and the next two periods

   - Your price and the average market price (the average of all six firms' prices) determine your sales: The *higher your price*, the *fewer* units you sell. (If your price is too high you'll sell nothing). The *higher the average market price*, the *more* units you sell.
   - For each unit you sell, you earn profit by selling at prices above costs. All firms produce at the same cost. Initially, this cost will be $10 per unit.
   - An Excel profit calculator will help you to calculate your earnings. It computes your earnings for any choice of your price and the average market price that you enter.



   B. Also you will forecast the average market price EVERY PERIOD.

   - You earn a forecast prize of $2 if your prediction is within 50 cents of the actual average market price.

   C. You and all sellers will have one minute in which to make decisions.

   II. The Buyer:

   Each period the automated buyer will purchase units from you according to the following rule:

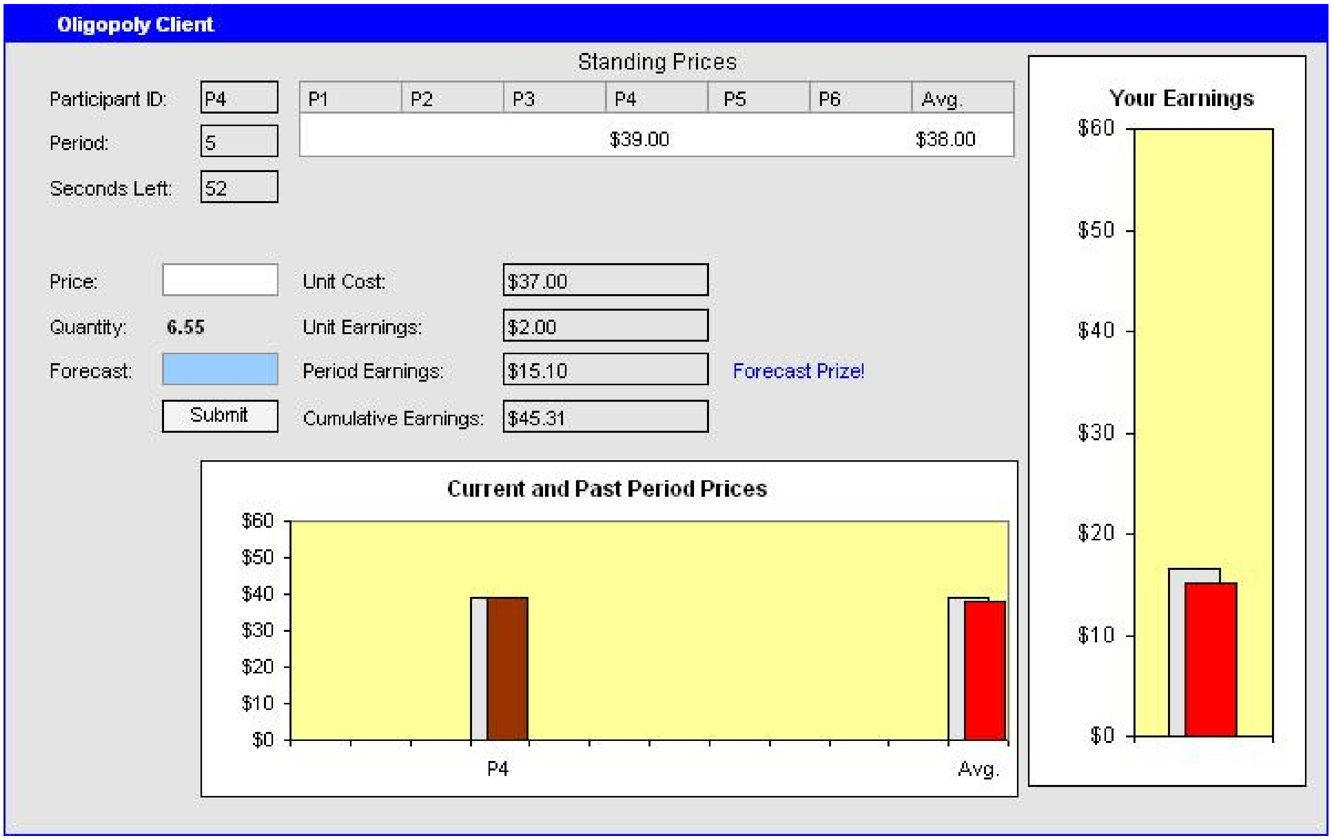
   Your Units Sold = 9.23 - 2.54 × (Your Price)+2.31 × (Average Market Price)

   As you can see, the buyer purchase rule implies that the *higher your price*, the *fewer* units you sell. The *higher the average market price*, the *more* units you sell.

5. Costs, prices, and profits are presented in Lab dollars. Initially, the exchange rate is 1 U.S. dollar for every 100 dollars earned in the Lab.

A Sample Screen: Below is a sample screen for a seller P4 at the start of period 5. (All numbers in this example are provided only to give an EXAMPLE of the screen display; they SUGGEST NOTHING about how you should play.)

In period 5, P4 must enter a price in the “Price” box and a forecast of the average market price in the “Forecast” box, given the cost of $37 per unit. The price will stay constant for the periods 5, 6, and 7. Seller P4 has 52 seconds to make her choices and to submit her decision by clicking the “Submit” button.



The rest of the screen allows you to track results from the immediately preceding periods. The entry aside “Quantity” below the “Price” box shows quantity sold in period 4 (here 6.55).

The “Standing Prices” box, at the top of the screen, shows previous period own and average prices. Here, in period 4, P4’s price was $39, and the market average was $38. The red bars in the “Current and Past Period Prices” box, at the bottom of the screen, provide a graphical version of price information for the period that just ended (here period 4) and the gray bars show prices for the prior period (here period 3). You can see that P4’s price was constant in periods 3 and 4; you can also see that the average price went down slightly.

The Unit Earnings” and “Period Earnings” boxes, in the middle of the screen, report earnings per unit ($2) and total earnings ($15.10) in the just completed period. The blue “Forecast Prize!” message indicates that in period 4 P4 forecast was within 50 cents from $38. The “Cumulative Earnings” box adds up earnings from all periods. Unit and period earnings are calculated for you using these formulas:

Unit Earnings = Price-Cost = $39-$37 =$2

Period Earnings = Unit Earnings × Quantity + Forecast Prize = $2×6.55 + $2=$15.10

Period 3 and 4 earnings are also presented graphically as gray and red bars on the “Your Earnings” Graph. Here, P4 earnings fell in period 4 relative to period 3.

Constant Price: In periods 6 and 7, since sellers set price only every 3rd period, P4 can not change the price she posted in period 5. As shown in the partial screen shot below, in periods 6 and 7 the "Price" box color changes to grey and shows price entered in period 5 (here $39). The message "You can't adjust this period" appears below the "Submit" button,

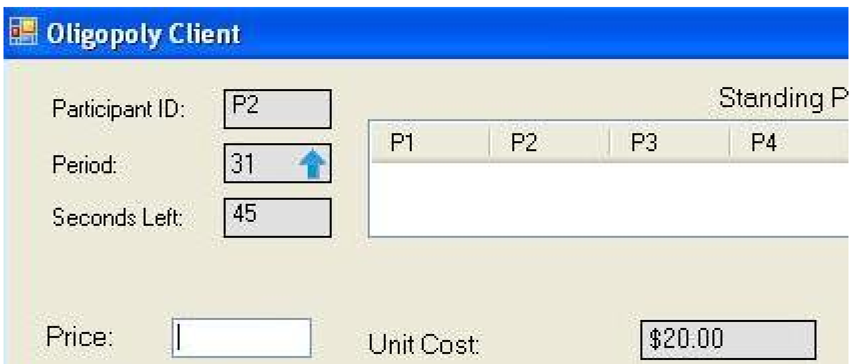
Nevertheless, even in periods where a seller can not change her price, she must enter Forecast of the average market price in the Forecast box and submit her forecast by clicking the Submit button.

General Description (continued)

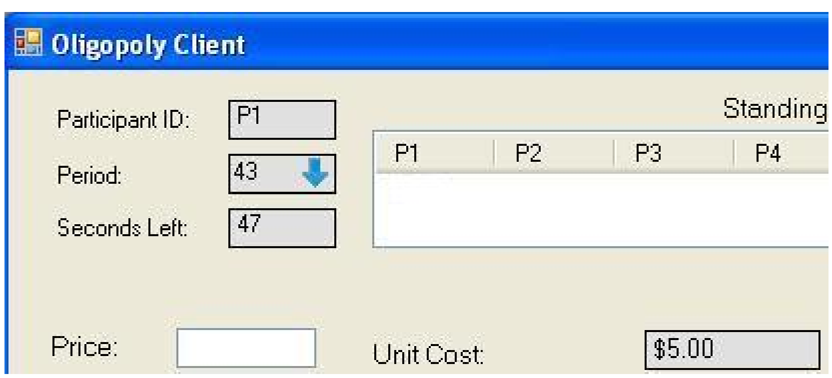
6. In every period up to period 30, unit costs, the buyer purchase rule, and the exchange rate will remain unchanged.

7. During one of the next 20 periods (e.g., one of the periods 31 to 50) economic conditions will either change **up** or change **down** (Note "up" and "down" are just names; they do not imply that conditions become better or worse than in previous periods).

   If conditions change **up**:
   - unit costs increase to $20;
   - the buyer purchase rule changes to:
     Your Units Sold = 9.23 - 1.27 × (Your Price)+1.15 × (Average Market Price)
   - the exchange rate changes to 1 U.S. dollar for every 200 dollars earned in the Lab.
   - Below is a part of a screen for a seller P2 at the start of period 31. Notice that next to the period number there is a blue arrow pointing <u>up</u>. Also, you can see on the screen that unit costs went up to $20.



   If conditions change **down**:
   - unit costs decrease to $5;
   - the buyer purchase rule changes to:
     Your Units Sold = 9.23 - 5.08 × (Your Price) + 4.62 × (Average Market Price)
   - the exchange rate changes to 1 U.S. dollar for every 50 dollars earned in the Lab.
   - Below is a part of a screen for a seller P1 at the start of period 43. Notice that next to the period number there is a blue arrow pointing <u>down</u>. Also, you can see on the screen that unit costs went down to $5.



8. After this single change all economic conditions will remain permanent until the end of the experiment.

Questionnaire and Practice Sessions

It is important that you all understand these instructions. Prior to starting the experiment, we will do two things to facilitate your comprehension. First, we will ask you to answer the following questions. Once you have all completed your answers we will review them together. Second, we will conduct a pair of 6-period practice sessions. In the first practice session, we will have an **up** change after period 5. In the second, a **down** change will occur after period 5.

If you have any questions, please ask now and during the practice sessions. Once we finish the practice sessions, you will not be allowed to ask further questions.

Questions

1. Suppose in period 2 you posted a price of, say $27, and the market average price was $22. If in period 5 you post the same $27 price, but the market average goes down to $20, will you sell more or less?

2. Consider again the same condition as in question 1, but now suppose that that you decrease your price to $25, but that the market price stays the same at $22. What will happen to your sales?

3. Suppose it is period 28. How might cost change in period 29 relative to current cost?

4. Suppose economic conditions change **down** in period 46. Your unit costs fall to $5, and the buyer purchasing rule changes as indicated in the instructions. How will you know that the change has occurred?

5. Suppose economic conditions change **up** in period 35, but you changed your price in period 34. How long your price will remain constant at the level that you set in period 34? In what period will you be able to change your price?

6. Suppose you earn 100 dollars in period 41. In period 42 market demand conditions change **up**, but you again earn 100 dollars. How many U.S. dollars you have earned in these two periods?

Questions *(Response Script – to be read once responses are complete)*

1. Suppose in period 2 you posted a price of, say $27, and the market average price was $22. If in period 3 you post the same $27 price, but the market average goes down to $20, will you sell more or less?

Response: You will sell less. The lower the average market price, the fewer units you sell. Your sales quantities move together with the average price.

2. Consider again the same condition as in question 1, but now suppose that that you decrease your price to $25, but that the market price stays the same at $22. What will happen to your sales?

Response: Your sales quantity will increase. The lower your price, the more units you sell. Your sales quantities move opposite to you own price.

3. Suppose it is period 28. How might cost change in period 29 relative to current cost?

Response: No change. Up to period 30 conditions remain unchanged.

4. Suppose economic conditions change **down** in period 46. Your unit costs fall to $5, and the buyer purchasing rule changes as indicated in the instructions. How will you know that the change has occurred?

Response: If economic conditions change ***down****, on the screen, next to the period number, there will be a blue arrow pointing* *<u>down</u>**. Also, in the "Unit Cost" box, costs will decrease from $10 to $5.*

5. Suppose economic conditions change **up** in period 35, but you changed your price in period 34. How long your price will remain constant at the level that you set in period 34? In what period will you be able to change your price?

Response: The price that you set in period 34 will remain constant during periods 34, 35, and 36. You will be able to change your price in period 37.

6. Suppose you earn 100 dollars in period 41. In period 42 market demand conditions change **up**, but you again earn 100 dollars. How many U.S. dollars you have earned in these two periods?

Response: If economic conditions change ***up****, the exchange rate will change from 1 U.S. dollar per every 100 dollars earned in the lab to 1 U.S. dollar per every 200 dollars earned in the lab. Thus, your period earnings fell from 1 U.S. dollar in period 41 to 50 cents in period 42. In two periods, you have earned 1.5 U.S. dollars.*

INSTRUCTIONS

Overview
This is an experiment in the economics of decision-making. Various research foundations have provided funds for this research. The instructions are simple, and if you follow them carefully and make good decisions, you may earn a considerable amount of money that will be paid to you in CASH at the end of the experiment. Your earnings will be determined partly by your decisions and partly by the decisions of others. We appreciate your participation, and wish to stress that during the experiment your communications with others should occur ONLY via computer. Please do not talk to each other or share information in any other way.

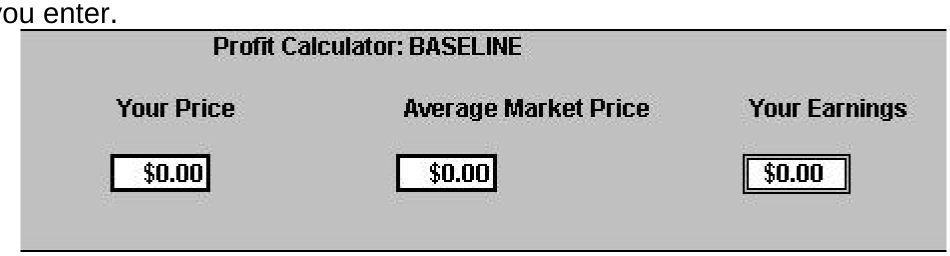
General Description

1. You run a firm that produces and sells a certain product. Besides you there are 5 other firms in your industry producing similar but not identical products.
2. The market consists of 80 periods.
3. Every period only 2 firms see current (the latest) market results, 2 firms see market results that are one period old, while the rest 2 firms see market results that are 2 periods old. Firms take turns: Each firm will see current (the latest) market results every 3rd period.
4. Trading Mechanism

   I. You (a seller):

   A. In each period, your primary task is to set the price at which your product will be available for sale.

   - Your price and the average market price (the average of all six firms' prices) determine your sales: The *higher your price*, the *fewer* units you sell. (If your price is too high you'll sell nothing). The *higher the average market price*, the *more* units you sell.
   - For each unit you sell, you earn profit by selling at prices above costs. All firms produce at the same cost. Initially, this cost will be $10 per unit.
   - An Excel profit calculator will help you to calculate your earnings. It computes your earnings for any choice of your price and the average market price that you enter.



   B. In addition to setting price, you will also forecast the average market price.

   - You earn a forecast prize of $2 if your prediction is within 50 cents of the actual average market price.

   C. You and all sellers will have one minute in which to make decisions.

   II. The Buyer:

   Each period the automated buyer will purchase units from you according to the following rule:

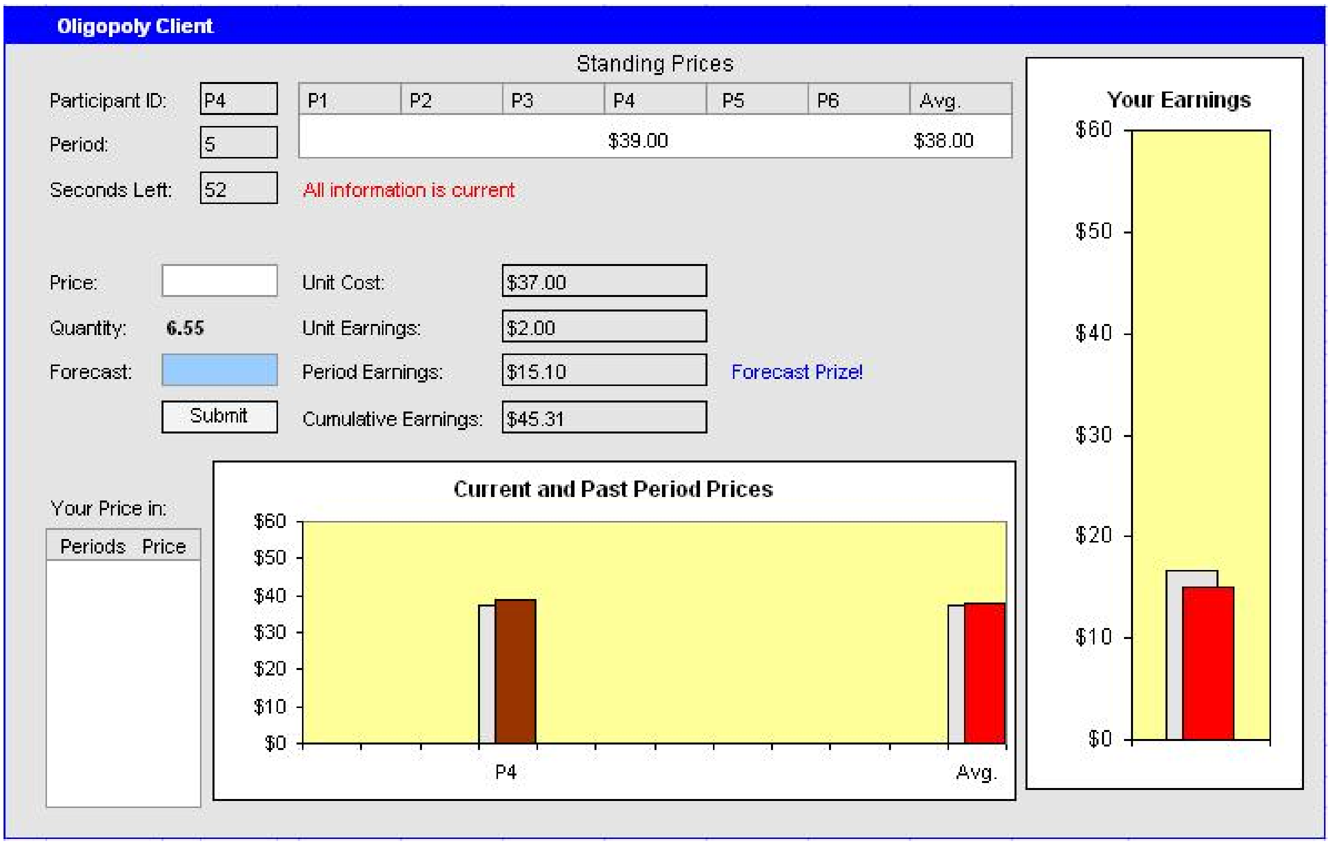
   Your Units Sold = 9.23 - 2.54 × (Your Price)+2.31 × (Average Market Price)

   As you can see, the buyer purchase rule implies that the *higher your price*, the *fewer* units you sell. The *higher the average market price*, the *more* units you sell.

5. Costs, prices, and profits are presented in Lab dollars. Initially, the exchange rate is 1 U.S. dollar for every 100 dollars earned in the Lab.

Sample Screens: Below is a sample screen for a seller P4 at the start of period 5. (All numbers in this example are provided only to give an EXAMPLE of the screen display; they SUGGEST NOTHING about how you should play.)

In period 5, P4 must enter a price in the "Price" box and a forecast of the average market price in the "Forecast" box, given the cost of $37 per unit. Seller P4 has 52 seconds to make her choices and to submit her decision by clicking the "Submit" button. A sentence below the Standing Prices box indicates that all information on the screen is current.



Thus, the rest of the screen allows you to track results from the immediately preceding periods. The entry aside "Quantity" below the "Price" box The Quantity shows quantity sold in period 4 (here 6.55).

The "Standing Prices" box, at the top of the screen, shows previous period own and average prices. Here, reports that in period 4, P4 posted a price of $39, and the market average was $38. The red bars in the "Current and Past Period Prices" box, at the bottom of the screen, provide a graphical version of price information for the period that just ended (here period 4) and the gray bars show prices for the prior period (here period 3). You can see that relative to period 3 seller P4 increased her price and overall average price went up slightly.

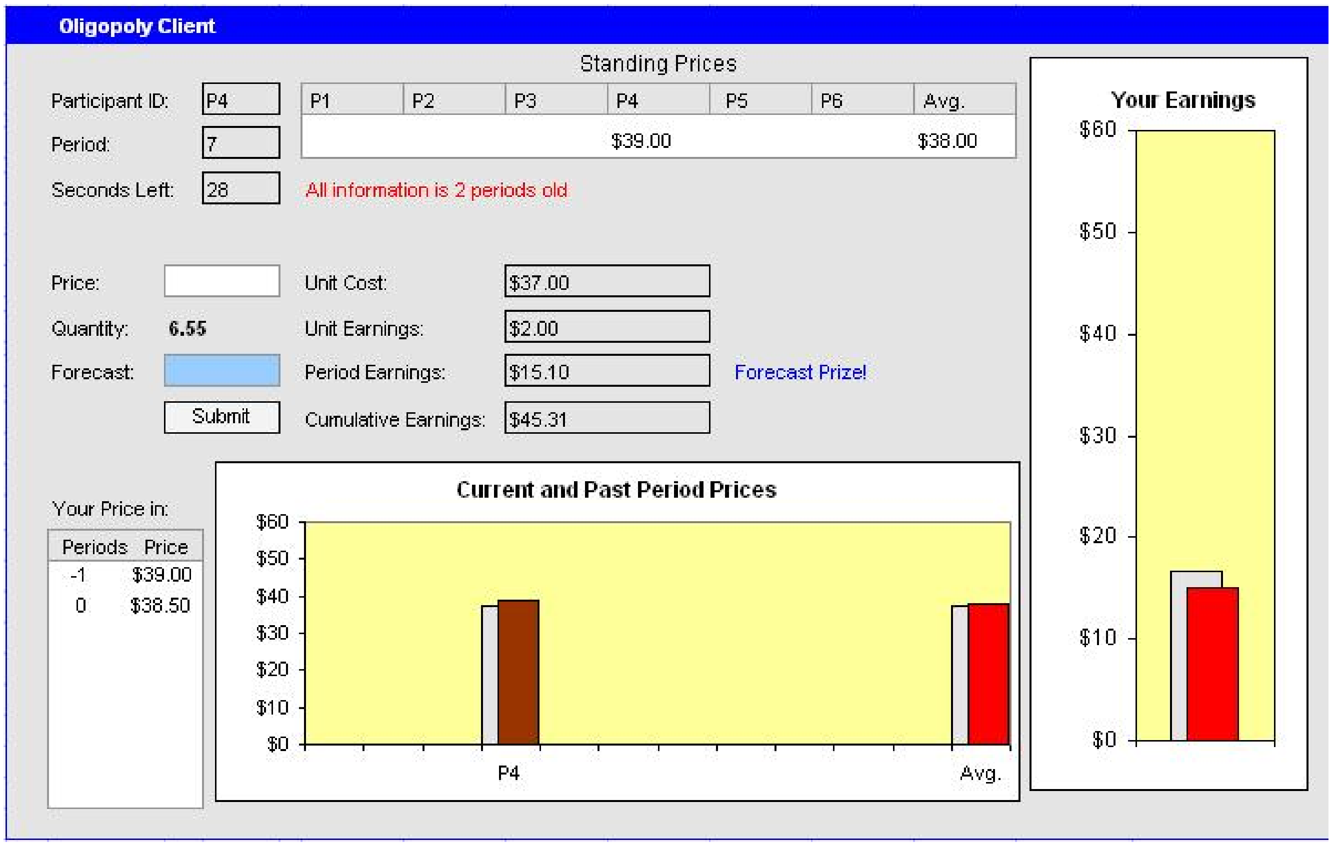
The "Unit Earnings" and "Period Earnings" boxes, in the middle of the screen, report earnings per unit ($2) and total earnings ($15.10) in the just completed period. The blue "Forecast Prize!" message indicates that in period 4 P4 forecast was within 50 cents from $38. The "Cumulative Earnings" box adds up earnings from all periods. Unit and period earnings are calculated for you using these formulas:

Unit Earnings = Price-Cost =$39-$37 =$2
Period Earnings = Unit Earnings ×* Quantity + Forecast Prize=$2×6.55+$2=$15.10

Period 3 and 4 earnings are also presented graphically as gray and red bars on the "Your Earnings" Graph. Here, P4 earnings fell in period 4 relative to period 3.

Information Delay: Since each firm sees current (the latest) market results every 3rd period, most information on P4's screen will not change in periods 6 or 7. Below is a sample screen for a seller P4 at the start of period 7. A sentence below the "Standing Prices" box indicates that all information is 2 periods old. The period 7 screen is almost identical to the period 5 screen.

Only three boxes contain current (the latest) information. The "Period" box indicates current period (here period 7), the "Seconds Left" box indicates that 28 seconds left, finally, the "Your price in:" box shows history of your choices. Here P4 chose $39 price in period 5 (this information is 1 period old as indicated by "-1") and $38.5 price in period 6 (this information is current as indicated by "0").



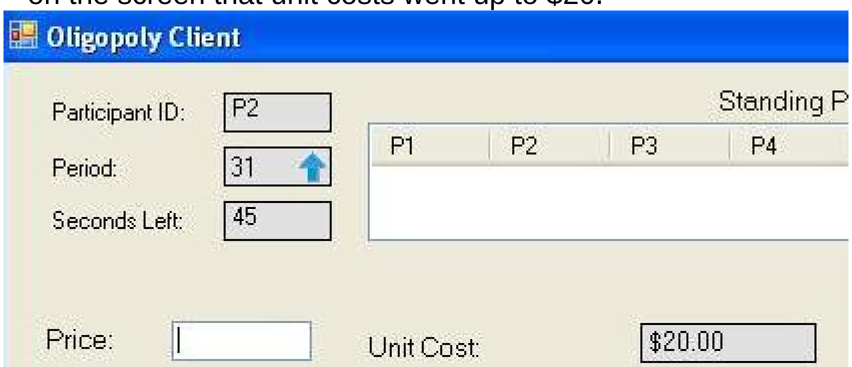
To proceed, P4 must enter a price in the "Price" box and a forecast of the average market price in the "Forecast" box and submit her decision by clicking the Submit button.

General Description (continued)

6. In every period up to period 30, unit costs, the buyer purchase rule, and the exchange rate will remain unchanged.
7. During one of the next 20 periods (e.g., one of the periods 31 to 50) economic conditions will either change **up** or change **down** (Note “up” and “down” are just names; they do not imply that conditions become better or worse than in previous periods).

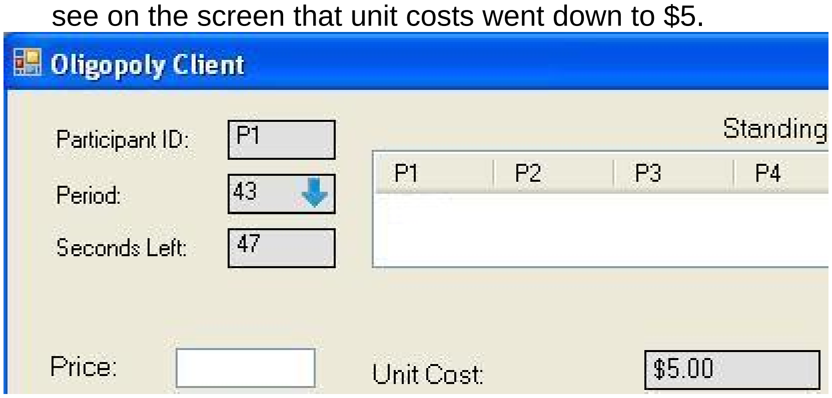
If conditions change **up**:

- unit costs increase to $20;
- the buyer purchase rule changes to:
  Your Units Sold = 9.23 - 1.27 × (Your Price)+1.15 × (Average Market Price)
- the exchange rate changes to 1 U.S. dollar for every 200 dollars earned in the Lab.
- Below is a part of a screen for a seller P2 at the start of period 31. Notice that next to the period number there is a blue arrow pointing <u>up</u>. Also, you can see on the screen that unit costs went up to $20.



If conditions change **down**:

- unit costs decrease to $5;
- the buyer purchase rule changes to:
  Your Units Sold = 9.23 - 5.08 × (Your Price)+4.62 × (Average Market Price)
- the exchange rate changes to 1 U.S. dollar for every 50 dollars earned in the Lab.
- Below is a part of a screen for a seller P1 at the start of period 43. Notice that next to the period number there is a blue arrow pointing <u>down</u>. Also, you can see on the screen that unit costs went down to $5.



8. Only 2 sellers that see the change immediately, 2 sellers will learn about the change after a one period delay, while 2 sellers will learn about the change with a two period delay. PLEASE, KEEP THIS INFORMATION TO YOURSELF.
9. After this single change all economic conditions will remain permanent until the end of the experiment.

Questionnaire and Practice Sessions
It is important that you all understand these instructions. Prior to starting the experiment, we will do two things to facilitate your comprehension. First, we will ask you to answer the following questions. Once you have all completed your answers we will review them together. Second, we will conduct a pair of 6-period practice sessions. In the first practice session, we will have an **up** change after period 5. In the second, a **down** change will occur after period 5.

If you have any questions, please ask now and during the practice sessions. Once we finish the practice sessions, you will not be allowed to ask further questions.

Questions

1. Suppose in period 2 you posted a price of, say $27, and the market average price was $22. If in period 3 you post the same $27 price, but the market average goes down to $20, will you sell more or less?

2. Consider again the same condition as in question 1, but now suppose that that you decrease your price to $25, but that the market price stays the same at $22. What will happen to your sales?

3. Suppose it is period 28. How might cost change in period 29 relative to current cost?

4. Suppose economic conditions change **down** in period 46, and that all information on your screen is current. Your unit costs fall to $5, and the buyer purchasing rule changes as indicated in the instructions. How will you know that the change has occurred?

5. Suppose economic conditions change **up** in period 35, but the information on your screen is one period old. In what period and how will you find out that the change has occurred?

6. Suppose you earn 100 dollars in period 41. In period 42 market demand conditions change **up**, but you again earn 100 dollars. How many U.S. dollars you have earned in these two periods?

Questions *(Response Script – to be read once responses are complete)*

1. Suppose in period 2 you posted a price of, say $27, and the market average price was $22. If in period 3 you post the same $27 price, but the market average goes down to $20, will you sell more or less?

Response: You will sell less. The lower the average market price, the fewer units you sell. Your sales quantities move together with the average price.

2. Consider again the same condition as in question 1, but now suppose that that you decrease your price to $25, but that the market price stays the same at $22. What will happen to your sales?

Response: Your sales quantity will increase. The lower your price, the more units you sell. Your sales quantities move opposite to you own price.

3. Suppose it is period 28. How might cost change in period 29 relative to current cost?

Response: No change. Up to period 30 conditions remain unchanged.

4. Suppose economic conditions change **down** in period 46, and that all information on your screen is current. Your unit costs fall to $5, and the buyer purchasing rule changes as indicated in the instructions. How will you know that the change has occurred?

*Response: If economic conditions change **down**, on the screen, next to the period number, there will be a blue arrow pointing down. Also, in the "Unit Cost" box, costs will decrease from $10 to $5.*

5. Suppose economic conditions change **up** in period 35, but the information on your screen is one period old. In what period and how will you find out that the change has occurred?

Response: In period 36 information on your screen will be two period old. In period 37 all information on your screen will be current. You will see, next to the period number, there will be a blue arrow pointing up. Also, in the "Unit Cost" box, costs will increase from $10 to $20.

6. Suppose you earn 100 dollars in period 41. In period 42 market demand conditions change **up**, but you again earn 100 dollars. How many U.S. dollars you have earned in these two periods?

*Response: If economic conditions change **up**, the exchange rate will change from 1 U.S. dollar per every 100 dollars earned in the lab to 1 U.S. dollar per every 200 dollars earned in the lab. Thus, your period earnings fell from 1 U.S. dollar in period 41 to 50 cents in period 42. In two periods, you have earned 1.5 U.S. dollars.*