Nominal Price Shocks in Monopolistically Competitive Markets: An Experimental Analysis

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We report a market experiment that examines the capacity of price and information frictions to explain real responses to nominal price shocks. As predicted by the standard dynamic adjustment models, we find that both price and information frictions impede the response to a nominal shock. We also find, however, that the observed adjustment delays far exceed predicted levels. Results of a pair of subsequent treatments indicate that a combination of announcing the shock privately to all sellers (rather than publicly) and a failure of many sellers to best respond to their expectations explains the observed adjustment inertia.

Keywords: market experiments, price rigidities, information rigidities, bounded rationality

JEL classification: C9, E42, E47

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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. Perhaps more than any area in economics, the notion that experiments (other than occasional 'natural' experiments) can provide useful data has been met with skepticism in macroeconomics. The economy-wide scale of macroeconomic phenomenon undoubtedly calls into question the notion of constructing pertinent laboratory environments.[3] However, the increased focus in macroeconomics on models in which agents optimize in a specific institutional framework raises questions about how individuals actually behave in such relatively narrow circumstances and for this reason, creates a natural context for behavioral investigation with laboratory tools.[4]

The role of frictions in explaining real responses to nominal shock is an important case in point. The debate over the real effects of nominal shocks centers on seller responses to different sorts of frictions in a monopolistically competitive price-setting environment. Literally thousands of laboratory experiments have been conducted to examine variations in institutional features on market performance using paid human subjects.[5] Thus, the use of experimental

[3] Admirable attempts, however, have recently been made to construct large scale laboratory economies. For example Noussair, Plott and Reizeman (2007) report an experiment conducted in a design that included sessions of 50 participants who interacted in 21 markets.

[4] Duffy (2008) comprehensively reviews the fairly large and growing macroeconomic experimental literature developed over the last twenty years. He also develops more fully a justification for the use of laboratory tools to evaluate issues in macroeconomics. Macroeconomic experiments, he argues, need not be elephantine, rather they merely need to address questions that pertain to macroeconomic models.

[5] We note that the subject pool for these experiments typically consists of undergraduate students. (This is true of the present study as well.) The effects of using alternative subject pools have been examined at some length. In

methods to examine the predicted effects of price and informational rigidities in a price-setting context is a natural extension.

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.[6] Our interest 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 consider a structure that deviates considerably from the Wilson monopoly design. Our design differs most distinctly from that examined by Wilson in two 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 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,

market games of the type examined here, very little suggests that undergraduate students behave differently than agents with experience in pertinent natural contexts. Traders and college undergraduates, for example, exhibit the same tendency toward speculative pricing bubbles in laboratory asset market experiments (King et al. 1993, Lei et al. 2001). Similarly, the use of contractors in common value auctions does not eliminate the winner's curse (Dyer et al. 1989), and the average price/quality choices of corporate auditors in a sealed offer bidding game do not differ from those of college undergraduates (DeJong et al., 1988), Although subject pool effects have been identified in laboratory economics experiments, those effects tend to involve differences in economic fundamentals, such as generosity, risk preferences or discount rates rather than differences in market performance.

[6] Adam (2007) also 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 below, use laboratory methods to examine adaptive expectations and psychological factors such as money illusion as drivers of slow responses to an announced nominal shock.

suggesting that something other than price or information frictions drives adjustment delays in our markets.

Further experimentation indicates that two factors largely explain the unexpectedly slow adjustment process. First, a private announcement of the shock to all sellers (rather than a public announcement) allows some participants to initially miss the announcement and for several periods tempers an updating of expectations and prices as sellers do not share common knowledge of the shock. Second, many sellers fail to best respond to their expectations. Combining a public announcement of the shock and a requirement that sellers best respond to their price forecasts causes markets to respond almost instantaneously and completely to a nominal shock.

The remainder of this paper is organized 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. Section 5 present results of additional treatments. The paper concludes with a short sixth section.

2. Nominal Shocks in Monopolistically Competitive Economies with Rigidities

We implement a variant of 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

$$q_i = \alpha - \beta p_i + \theta \bar{p}, \qquad (1)$$

where $\alpha > 0$ and $\beta > \theta > 0$.[7] Given the demand function, a firm maximizes its profit

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

First order conditions yield the optimal price response in terms of the overall price level and cost.

$$p_i^{mc} = \alpha' + c/2 + \phi \bar{p} \qquad (2)$$

[7] Similar to the demand equation in Blanchard and Kiyotaki (1987), quantity demanded moves inversely with own price but directly 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 and Oechssler (2000), and Davis (2002).

where $\alpha' = \frac{\alpha}{2\beta}$ and $\phi = \frac{\theta}{2\beta}$. Invoking symmetry and solving (2) for p^{mc} yields an optimal price,

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

Monopolistically competitive predictions have the convenient feature that strategic considerations do not affect optimal seller price choices, an assumption that facilitates the analysis of dynamic price adjustment paths. For this reason we are interested in approximating monopolistically competitive conditions in our laboratory implementation, a condition we facilitate by having sellers base price choices on own and the overall average price, as described below. The organizing power of monopolistically competitive outcomes represents our first conjecture.

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

Although monopolistically competitive predictions represent a desirable baseline condition, given the limited number of sellers in our markets, we recognize that sellers may not view their pricing decisions as having no impact on the overall average market price. For this reason we also present Nash predictions as a reference, and we assess market outcomes largely in terms of their convergence to a price range bound by the monopolistically competitive and Nash predictions. Fortunately, given the size of our markets (n=6), Nash and monopolistically competitive outcomes are quite close.[8] The emergence of Nash rather than monopolistically competitive predictions does not damage seriously our behavioral analysis (although it does potentially complicate analysis of the dynamic adjustment path).

To help assess the organizing power of the monopolistically competitive/Nash predictions, 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

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

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

[8] Online Appendix A develops symmetric Nash equilibrium predictions as well as the relationship between Nash and monopolistically competitive predictions.

2.1 Price Rigidities

We 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

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

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.[9] 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.*

*** Figure 1 about here ***

We observe that the predicted effects of price and information frictions here are quite similar.[10] 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

[9] Detailed solutions can be found in online Appendix B.

[10] 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 by reducing the number of sellers who can adjust prices each period. Still larger differences can be induced by using a probabilistic updating rule. Our concern that such lengthy adjustment delays might undermine market convergence altogether deterred us from inducing longer adjustment delays in our design.

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, P^{NE} = \$12.90 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 sellers' screens at the beginning of the first period when M changes. Post shock, C=\$20 making $P^{W'}$ =\$20, $P^{MC'}$= \$25.00, $P^{NE'}$ = \$25.80 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 reads 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 5-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.[11]

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 $6 appearance fee, and were dismissed one at a time.

[11] Our forecasting game emulates the expectations elicitation techniques used in some early asset market experiments (e.g., Williams, 1987 and Smith et al., 1988). As in these earlier experiments, we intentionally kept the compensation rate for an accurate forecast low, in order to deter participants from altering their pricing decisions in order to secure the forecast prize.

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

The charting of mean transaction prices for the eight markets in each treatment, shown as Figure 2, provides an overview of market performance. In the figure, we standardize market outcomes about the period of the shock, which we label as period 35, a convention that makes period 76 the last common period.

*** Figure 2 about here ***

Several general observations about market performance are readily apparent from inspection of the figure. Observe first that initial market adjustment is quite rapid: in both the *BASE* and *SI* treatments sellers adjust almost immediately to prices quite close to the $P^{MC} – P^{NE}$ range. Our initialization of prices at unit costs mechanically slows initial equilibration in the *SP* treatment, but even here markets converged after five periods.[12] Notice second that toward the end of the pre- and post- shock sequences mean transaction prices in all treatments ultimately converge toward the $P^{MC} – P^{NE}$ (or, post-shock, the $P^{MC'} – P^{NE'}$) range. Defining percentage deviations in terms of the price range between P^{W} and P^{JPM}, (or $P^{W'}$ and $P^{JPM'}$ post-shock) mean transaction prices for the last five pre-shock periods are within 5.3% of P^{MC} and within 2.6% of P^{NE}. In the last five post-shock periods, mean transaction prices for all three treatments similarly fall close to the $P^{MC'} – P^{NE'}$ range, with mean transaction prices within 2.4% of the relevant post-shock range from $P^{MC'}$ and within 3.07% of $P^{NE'}$. These observed deviations are very small relative to deviations from P^{W} and $P^{W'}$(which were no smaller than 16.3% of the relevant pre- or post-shock range) and P^{JPM} and $P^{JPM'}$(which were similarly no smaller than

[12] The relatively slow initial adjustment for the *SP* markets provides some precedent for much longer adjustment observed following the period 35 shock.

78.1% of the relevant ranges).[13] The tendency of markets to converge closely toward the monopolistically competitive/ Nash predictions range in each treatment represents a first finding.

Finding 1*: Pre-shock, convergence toward the* P^{MC}–P^{NE} *range is both rapid and reasonably complete. Post-shock, prices ultimately converge to the* $P^{MC'}$ – $P^{NE'}$ *range.*

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). 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.[14] 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

Our primary interest, however, is in the response to the nominal shock. As indicated by the heterogeneous and generally slow upward drift of the transaction price paths, adjustment was neither uniform nor nearly as rapid as predicted. Consider first across-treatment differences in the price adjustment process, the subject of conjecture 2. Table 1 reports differences in mean transaction prices between treatment pairs for the 12 periods following the shock.[15] 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

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[13] Table C1 in online Appendix C provides a more complete assessment of convergence tendencies in the final periods pre- and post-shock.

[14] We do observe that in several markets some sellers attempted to raise prices by posting price 'spikes', or very large single-period price increases. In the pre-shock phase posting a price at the upper bound of \$50 would result in sales of zero units, but would raise the average posted price over the monopolistically competitive prediction by \$6.25, which in turn might prompt sellers to raise their prices in future periods. As suggested by the generally competitive prices in the pre-shock periods, the effects of such efforts were minor at best. Given the relatively large size of the market and the disproportionate sales volume going to the low-pricing sellers each period, the incapacity of such attempts at signaling is unsurprising. Sellers largely terminated such signaling efforts in the post-shock environment. We observe that the capacity of sellers to signal by posting irrelevantly high prices is a peculiarity of our design that is without parallel in naturally occurring contexts. In future experiments along these lines we plan to eliminate the effects of such price postings by reporting only the average of price postings that resulted in sales.

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

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 1 about here ***

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 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.*

4.3. Predicted versus Observed Responses to the Nominal Shock

Our most prominent finding, however, 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 2 document quantitatively the differences between predicted and observed responses to the nominal shock.[16]

*** Table 2 about here ***

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 44, 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 information frictions, which are at most two to three periods.[17] 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.*

Although other investigators have also observed adjustment lags after nominal shocks in laboratory price setting games, the adjustment delays, particularly in response to an announced positive shock (rather than a negative shock) have been much less pronounced. 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.[18]

5. Public Information, Non-Best Responses and Delayed Price Adjustments

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

[17] 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.

[18] Fehr and Tyran attribute the differential market responses to positive and negative shocks to the asymmetrical 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.

We turn our attention now to possible reasons for the generically slower-than-predicted responses to the nominal shock in our markets. For this discussion, we focus on *BASE* treatment outcomes, since analysis of the adjustment lag in these markets requires no adjustment for either information or price frictions. Inspection of *BASE* treatment results suggests two possible sources of adjustment delay. First, we announced the shock privately to all sellers rather than publicly, raising the possibility that some sellers may have simply missed the announcement.[19] Many sellers did in fact appear to miss the initial announcement. In the eight *BASE* markets, 22 of the 48 sellers missed the shock in the sense that they posted a price below the new $20 unit cost in the period of the shock. Although all sellers quite quickly appreciated that the shock had occurred, it may be the case that the initial failure of some sellers to notice the shock caused sellers to adjust downward their expectations thus lowering their own prices and delaying the adjustment.[20]

Second, we observe a marked propensity for sellers to deviate substantially from best responding to their forecasts. Rather, many sellers exhibited a pronounced tendency to set a price close to their forecasts of the future average price. For example, in the first five post-shock periods of the *BASE* markets, 69% of seller pricing decisions were within $1.50 of their forecast of the average price, compared to only 41% of decisions within $1.50 of the best response to that forecast. More generally, in those five post shock periods 71% of price decisions were closer to forecasts than to best responses.[21] A tendency to imitate expectations in this way can delay adjustment to a positive shock because when prices are below the equilibrium, the best response to an expected price increase is an even higher price.[22]

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[19] Such an announcement would have made it impossible to introduce information frictions in our *SI* environment. To allow comparability across treatments, we announced privately the shock on each participant's computer screen in all treatments

[20] In period 36 only six sellers priced below unit costs, and only four of those really 'missed' the shock (one seller lowered price below cost in response to a low price by a rival, and another posted a price of $19). By period 37 only two sellers clearly acted in ignorance of the shock.

[21] Figure C1 in an online Appendix C illustrates more completely seller forecasts and their pricing decisions in the first five post-shock periods.

[22] This tendency for sellers to imitate their expectation of the average choice rather than to best respond to that expectation has often been observed in laboratory oligopolies. For example, Huck, Norman and Oechssler (2002) conclude that the tendency for sellers to engage in 'imitative' behavior explains the 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. Also interesting is that the tendency for sellers to imitate rather than best respond to forecasts should speed the response to downward shocks. In a market environment very different from the one examined here Davis and Korenok (2009) find some evidence of this 'balloons and bricks' response to respective positive and negative shocks.

These results suggest two additional treatments. First, to examine the effects of providing only private information about the shock, we conduct a '*PUB'* treatment, which replicates procedures for the *BASE* treatment in all respects except that the incidence of the shock is publicly announced. Prior to the shock we a monitor pauses the session and says aloud that the shock is about to occur. Second, to examine the effects of sellers' failure to best respond to their expectations, we conduct a *PUB/BR* treatment which is identical to the *PUB* treatment, except that sellers submit only forecasts rather than prices.[23] Prices are calculated as the best responses to those forecasts. We conjecture that one or both of these treatments will speed the post-shock adjustment process.

As in the previous treatments, we conducted a series of eight six-seller markets. Other procedures were also similar: participants were drawn from the same subject pool as in the initial sessions, no one participated in more than one session and no one who had previously participated in an initial session participated again here.[24] Sessions were conducted at Virginia Commonwealth University in the Spring Semester of 2011. Earnings, for the 96 participants in the new sessions ranged from \$15.75 to \$35.25 and averaged \$21.50 (inclusive of a \$6 appearance fee).

Figure 3 (formatted as Figure 2) illustrates mean transaction prices paths in the *PUB* and *PUB/BR* treatments. For reference, the figure illustrates *BASE* treatment results as well. A first result evident from the figure is that the public announcement of the shock considerably speeds the initial adjustment to the shock observed in the *BASE* treatment: mean transaction prices for both the *PUB* and *PUB/BR* treatments jumped toward the $P^{MC'}$ prediction immediately following the shock, leading us to conclude that to a large degree the very sizable deviations observed in initial periods following the shock are attributable to a failure of many sellers to initially notice the shock.

*** Figure 3 about here ***

[23] We thank a referee for suggesting this treatment. A number of investigators have solicited forecasts and then computed prices for sellers as best responses (see, e.g,. Adam, 2007, Heemeijer et al., 2009 and Marimon et al., 1993).

[24] Two minor differences distinguish procedures in these additional sessions from those used in the initial sessions. First, some of the sessions in these latter two treatments involved three rather than two simultaneous markets. Second, all eight *PUB/BR* markets and three of the eight *PUB* markets used Z-Tree software (Fischbacher, 2007) rather than the custom program used for the original sessions. Instructions and the screen interface for participants, however, did not change and this alteration in the underlying program was invisible to participants.

A second result regards the final adjustment of markets toward the P^{MC}– P^{NE} range post-shock. Notice that despite nearly identical responses for the *PUB* and *PUB/BR* treatments in the first two post-shock periods, adjustment paths differ thereafter. In the *PUB* treatment prices begin to drift slowly downward, where they remain until they intersect the adjustment path for the *BASE* treatment in period 45. Thereafter *PUB* and *BASE* treatments move together, evolving very slowly toward the $P^{MC'}$ prediction, roughly by period 60. In the *PUB/BR* treatment, by way of contrast, transaction prices quickly lock onto the $P^{MC'}$ prediction and remain there throughout the remainder of the session.

Table 3, which lists the deviations of mean transaction prices from $P^{MC'}$ for the *PUB* and *PUB/BR* treatments for period 35 and the first 20 periods post-shock provides more complete insight into this adjustment process. Examining deviations for the *PUB* treatment, listed in column (2) of the table, observe that deviations for the first post-shock periods are much smaller than for the *BASE* treatment, shown in column (1). In fact, following period 35 the deviation from $P^{MC'}$ did not significantly exceed zero for three periods (periods 36, 37 and 38). After period 38, however, deviations in the *PUB* treatment begin to increase and remain fairly large for the remainder of the periods summarized in the table. For example, in 12 of the 17 periods 39-55 the deviation exceeded 90¢. These deviations also often differ significantly from zero: over the same 17 period sequence, the mean transaction price deviated significantly from $P^{MC'}$ at $p<.05$ in 12 instances and a $p<.10$ in another three instances. In contrast in the *PUB/BR* treatment, deviations for periods 39-55 were uniformly less than 25¢ and differed significantly from zero only in periods 54 and 55, when prices edged up above $P^{MC'}$ (into $P^{MC'}$ – $P^{NE'}$ range). We summarize these observations as a fourth finding.

Finding 4: *A combination of private (rather than public) information about a shock as well as a failure of many sellers to best respond to their expectations drives the theoretically unpredicted adjustment lags in our frictionless baseline markets.*

*** Table 3 about here ***

The adjustment-improving effects of the *PUB* and *PUB/BR* treatments have some precedent in the literature. The publicity of the shock announcement not only eliminates an immediate initial adjustment lag caused by some sellers missing the message, but also the associated tempering of expectations regarding price adjustments due to the (revealed) lack of common knowledge about the shock. This is the sort of phenomenon analyzed by Haltiwanger and Waldman (1998).[25] Similarly, the tendency for many sellers to price closer to their expectations rather than to the best responses to those expectations is typical of the sort of 'herding' behavior discussed frequently in the behavioral finance literature (See, e.g., Hirshleifer and Teoh, 2003). Sellers, uncertain of the appropriate price action, cluster about how they expect others to act. The effects of tempered expectations due to a perceived privacy of information about the shock combined with a propensity of sellers to set prices close to the expected average actions both contribute to the very slow adjustment process in our markets.

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.

Results of two additional treatments explain the pervasive adjustment delays in our markets. In a first treatment we paused the session and announced publicly that the shock was about to occur. We find that the public announcement importantly speeds the initial response to the shock. However, the public announcement alone is insufficient to drive markets completely to the range of post-shock equilibrium prices. In a second treatment, in addition to publicly announcing the shock, we confined seller choices to their forecasts of the price level. Prices were subsequently determined for each seller as the optimal response to his or her forecast. Here, we find that adjustment to the monopolistically competitive prediction is both complete and nearly instantaneous. Comparison of the post-shock adjustment process in these treatments with those in the frictionless baseline treatment suggests that a combination of sellers' learning

[25] Haltiwanger and Waldman posit that a subset of agents are boundedly rational in the sense that they have backward rather than forward looking expectations (similar to the sellers in our markets who initially missed the announcement of the shock). 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. Fehr and Tyran (2008) report some experimental results that support this theory. In our markets, sellers' propensities to imitate rather than best respond to expectations further slows the response to a shock.

about the shock privately (rather than publicly) and a propensity for sellers to 'imitate' the expected behavior of rivals very persistently slows the adjustment to a positive shock.

In closing, we observe that with our experiment, we have not and did not aspire to isolate the 'true' source of frictions that drive real responses to nominal shocks. However, by injecting a controlled and fully identified nominal shock into a laboratory implementation of the market structure assumed in the theoretical models, we have hoped to generate observations regarding the interactions between underlying economic institutions and the agents that populate those institutions that may either resonate with the perceptions of macroeconomists, or suggest that alternative institutional settings or frictions may provide a more appropriate underlying institutional context.

More specifically, a failure of some agents to appreciate the notification of a change in circumstances is, at least to us, certainly plausible (perhaps distressingly so when viewed in light of our regular interactions with students). To some extent, this notion is captured by the sticky information model. The sticky information model, however, assumes that all subjects best respond to their circumstances, while our results suggest that a failure to best respond may create additional adjustment inertia. Anchoring pricing decisions on the expected average price rather than on the best response to that price, while unquestionably non-optimizing, does have a number of features that can make it a prominent behavioral attractor. Not only does such behavior accord with the intuitive notion of pricing to 'meet the competition,' but many agents may view pricing close to the expected price of rivals as 'safe' in the sense that it truncates the risk associated with erring in one's calculations of optimality and being left out of the market. To the extent that the behaviors we observe here have parallels in the pertinent natural contexts, the real effects of nominal shocks may be both substantial and persistent and may far exceed the effects of frictions conventionally assumed in the literature.

References

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

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

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

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 Oleg Korenok (2009) “Posted-Offer Markets in Near Continuous Time: An Experimental Investigation,” *Economic Inquiry*, 47, 446-466.

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, 89-113.

DeJong, Douglas V., Robert Forsythe and Wilfred C. Uecker (1988) “A Note on the Use of Businessmen as Subjects in Sealed Offer Markets,” *Journal of Economic Behavior and Organization*, 9, 87-100.

Dyer, Douglas, John H. Kagel, and Dan Levin (1989) “A Comparison of Naive and Experienced Bidders in Common Value Offer Auctions: A Laboratory Analysis,” *Economic Journal*, 99, 108-115.

Duffy, John (2008), “Macroeconomics: A Survey of Laboratory Research,” manuscript, University of Pittsburgh.

Fehr, Ernst and Jean-Robert Tyran (2001) “Does Money Illusion Matter?” *American Economic Review*, 91, 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*, 85(1), 191-206.

Fischbacher, Urs (2007) “z-Tree: Zurich Toolbox for Ready-made Economic Experiments,” *Experimental Economics*, 10, 171-178.

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.

Hirshleifer, David and Siew Hong Teoh (2003) “Herd Behaviour and Cascading in Capital Markets: a Review and Synthesis,” *European Financial Management*, 9, 25–66.

Huck Steffen, Hans-Theo Normann and Jorg Oechssler (2002) “Stability of the Cournot Process: Experimental Evidence,” *International Journal of Game Theory*, 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.

King, Ronald R., Vernon L. Smith, Arlington W. Williams, and Mark Van Boening (1993) “The Robustness of Bubbles and Crashes in Experimental Stock Markets,” In *Nonlinear Dynamics and Evolutionary Economics*, ed. Richard Day and Ping Chen, 183–200. Oxford: Oxford University Press.

Lei, Vivian, Charles N. Noussair, and Charles R. Plott (2001) “Nonspeculative Bubbles in Experimental Asset Markets: Lack of Common Knowledge of Rationality vs. Actual Irrationality,” *Econometrica*, 69, 831–859.

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*, 1295–1328.

Marimon, Ramon. Stephen E. Spear and Shyam Sunder (1993) “Expectationally Driven Market Volatility: An Experimental Study,” *Journal of Economic Theory*, 61, 74-103.

Noussair, Charles N., Charles R. Plott and Raymond G. Reizeman (2007) “Production, Trade, Prices, Exchange Rates and Equilibration in Large Experimental Economies,” *European Economic Review*, 51, 49-76.

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

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, 1-18.

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.

Table 1: 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).

Table 2. 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.

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

Period	(1) $\overline{P}_B^T - \overline{P}^{MC}$	(2) $\overline{P}_{PUB}^T - \overline{P}^{MC}$	(3) $\overline{P}_{PUB/BR}^T - \overline{P}^{MC}$
35	-9.58**	-1.49**	-1.12**
36	-4.60**	-0.47	-0.39
37	-3.72**	-0.69	-0.15
38	-3.44**	-0.72	-0.11
39	-3.31**	-1.02**	-0.20
40	-2.43**	-0.97**	-0.16
41	-2.22**	-0.92**	-0.21
42	-1.84**	-0.97*	-0.18
43	-1.56**	-0.68	-0.14
44	-1.26**	-0.73	-0.18
45	-0.91*	-0.81**	-0.17
46	-0.75	-1.02**	-0.16
47	-0.63	-1.05**	-0.06
48	-0.67	-0.91**	-0.01
49	-1.73**	-1.25**	-0.23
50	-1.03*	-1.06**	-0.24
51	-0.94**	-1.69*	-0.03
52	-0.90**	-0.78*	0.02
53	-0.86*	-0.86**	0.04
54	-0.71*	-1.02**	0.07*
55	-0.62	-1.07**	0.10**

Notes: Asterisks denote rejection of $H_o : \overline{P}_i^T - \overline{P}^{mc}\ i = \{B, PUB, PUB/BR\}$ ** *p*<.05, * *p*<.10 (two tailed Wilcoxon tests).

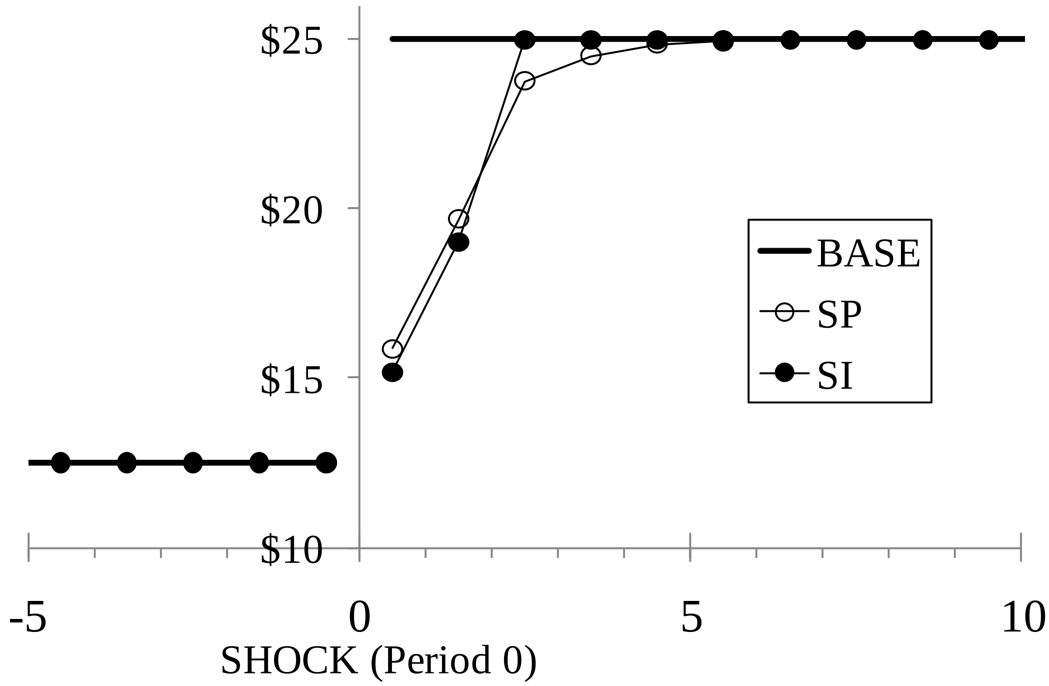

Figure 1. Predicted transaction price adjustment to a 100% increase in a nominal scale variable in a frictionless narket ('*BASE'*), a market with price frictions ('*SP'*) and a market with information frictions ('*SI').*

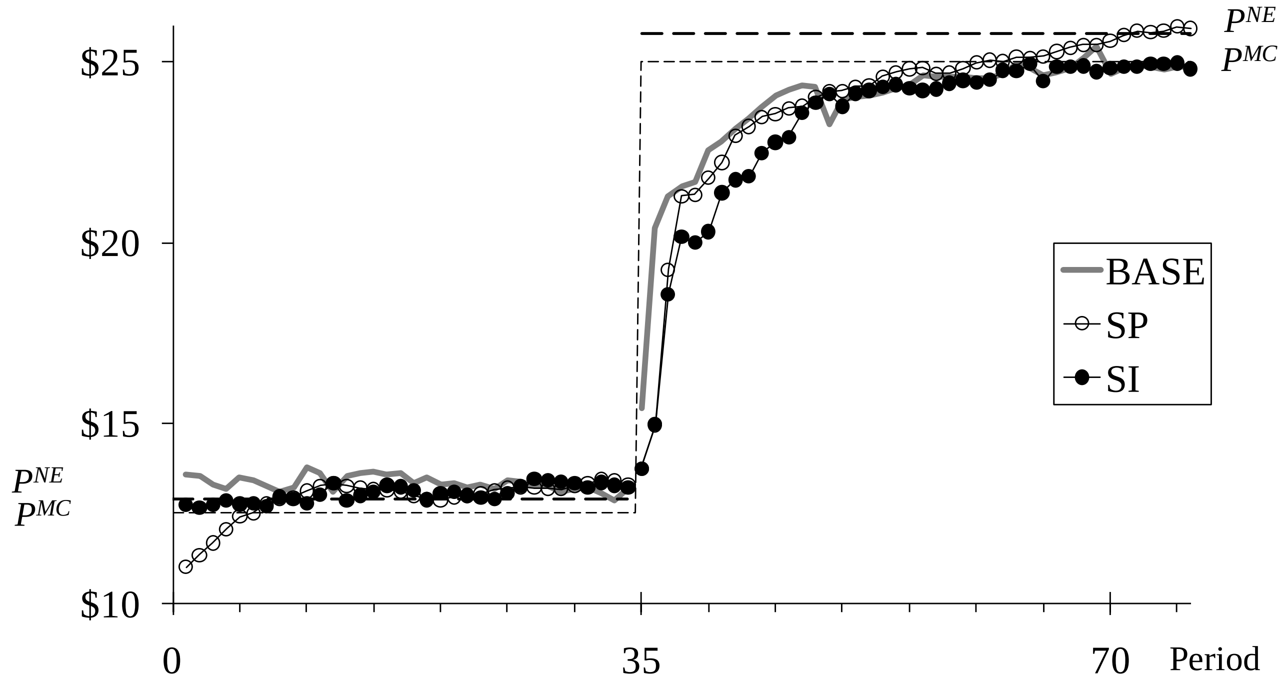

Figure 2. Mean transaction prices for markets in *BASE, SP* and *SI* treatments.

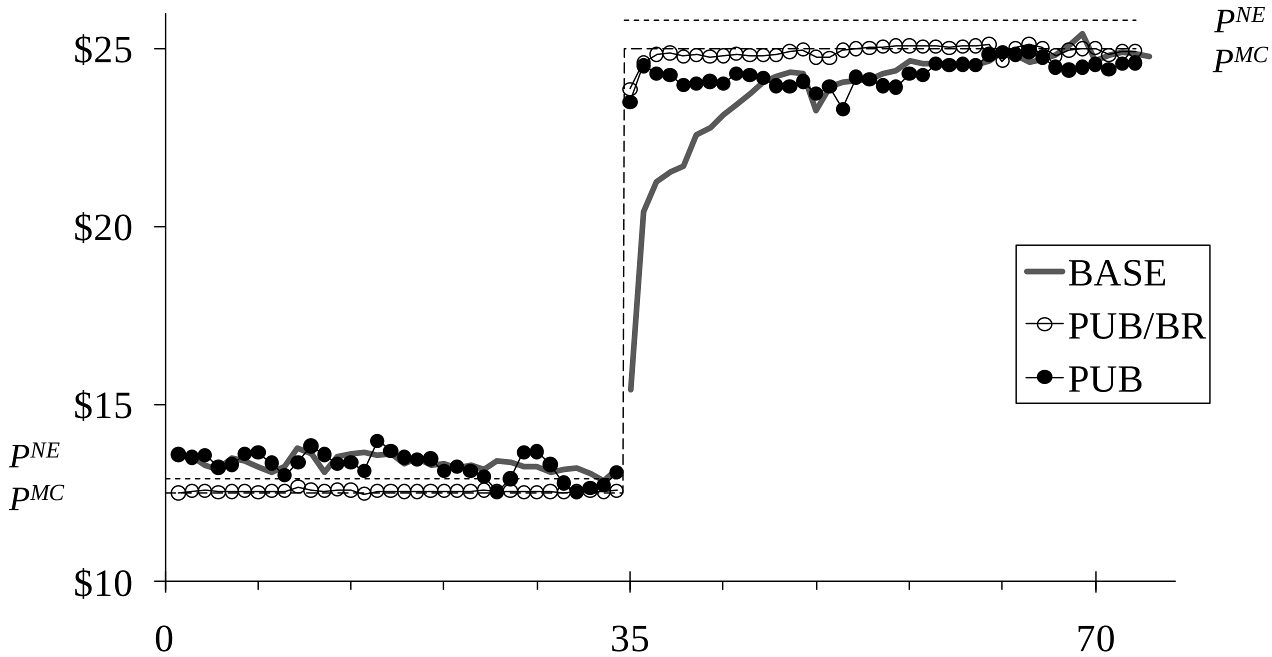

Figure 3. Mean Transaction Prices *BASE*, *PUB* and *PUB/BR* Treatments.