A Theory of Asymmetric Price Adjustment

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Abstract

Empirical evidence suggests that prices respond more rapidly to cost increases than to cost decreases. We develop a search theoretic model which is consistent with this evidence and allows for additional testable predictions. Our results are based on the assumption that buyers do not observe the sellers' costs, but know that cost changes are positively correlated across sellers.

We show that buyers have a greater incentive to search when they observe large price increases or small price decreases; and little incentive to search when prices increase by a little or decrease by a lot. This implies that small cost increases or large cost decreases are fully reflected on price; whereas small cost decreases and large cost increases are less then reflected in price. Specifically, sellers do not change price when cost decreases by a small amount.

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1 Introduction

Studies of various products and services, including gasoline, agricultural products, bank deposit rates, all find that prices are more likely to rise in response to input price increases than they are to decrease in the wake of cost reductions.[1] Recent work by Peltzman (2001) significantly broadens the evidence for this asymmetrical price behavior. In a study of 77 consumer and 165 producer goods, he finds that on average the immediate response to a cost increase is at least twice the response to a cost decrease.

This phenomenon presents more than an interesting empirical regularity to explain. As Peltzman argues, it poses a real challenge to conventional economic theorizing. According to any conventional microeconomic models — whether monopoly, perfect or imperfect competition — prices should respond symmetrically to cost increases and cost reductions.

This paper presents a search theoretic model which is consistent with an asymmetric price adjustment. The idea is as follows. Suppose a consumer's regular vendor increases its price. Should he or she search for a lower price? If competing vendors' production costs are positively correlated (because they use the same or similar inputs in their production processes), then a price increase at one vendor is bad news to consumers about the entire industry: it is reasonable to suppose that competitors' costs — and hence competitors' prices — have also increased. If search is costly, it is reasonable for consumers to accept a moderate price increase rather than search. This suggests that sellers can increase prices moderately without losing customers in response to cost increases. The same reasoning does not apply to a moderate cost decrease. A price reduction at one firm is "good news" to consumers about the entire industry because it carries the possibility of even greater price reductions at other firms. Therefore a moderate price reduction runs the risk of encouraging customers to search elsewhere in the hope of finding still greater bargains. Hence, to avoid "rocking the boat" a seller's optimal response to moderate cost decreases is to keep prices unchanged.

The same logic implies a reverse asymmetry in the case of large cost changes. If prices decline by a lot, it is unlikely that further search will reveal even lower prices. Hence, large cost reductions may lead to commensurately large price reductions. By contrast, if search costs are not too high, a large price increase might well trigger consumer search because there is the likelihood that competitors' prices have risen by substantially less. Therefore, large cost increases may result in only moderate price increases.

[1] Karrenbrock (1991); Neumark and Sharpe (1992); Jackson (1997); Borenstein, Cameron and Gilbert (1997). There are more references which will be added later.

The paper is structured as follows. In Section 2, we lay down the basic model structure. Next we completely solve for a particular numerical example (Section 3). From here we move on to our general results (Section 4). Section 5 derives empirical testable implications and Section 6 discusses the results, namely in relation to previous literature. We conclude with Section 7.

2 Model

Our basic model consists of two firms competing over two periods, 0 and 1. At the beginning of period 0, firm i is endowed with constant marginal cost $c_i^0 \in I\!R_0^+$, $i = 1, 2$. The values of c_i^0 are common knowledge to firms and consumers. The firms then simultaneously set prices p_i^0. Each consumer observes one of the prices (for free). We assume there is a continuum of consumers of mass 2 who are equally divided between observing each of the two prices. Upon observing a price, each consumer must decide whether to pay a search cost s to observe the other price. Finally, each consumer purchases a quantity $q(p)$, where p is the lowest observed price.

At the beginning of the second period Nature generates c_i, firm i's cost, according to a commonly known stochastic process.[2] Only firm i observes c_i. The firms then simultaneously set prices p_i. Each consumer observes (for free) one of the prices and decides whether to pay a search cost s to observe the other price. Finally, each consumer purchases a quantity $q(p)$, where p is the lowest observed price.

Let $\mu(p)$ be the consumer's surplus from buying at price p and $\pi(p, c)$ a firm's profit given price p, cost c, and a mass one of consumers. We assume that $\pi(p, c)$ is quasi-concave and denote by $p^m(c)$ the monopoly price for a firm with cost c.

3 An example

In order to understand the main intuition, it helps to begin by considering a specific numerical example. Suppose that, in the first period, both firms have a cost of $c_i^0 = \frac{1}{2}$. With a probability $1 - \gamma$, second period cost is the same as in the first period. With probability γ, either both costs increase or both costs decrease. Given that costs change, they are independently and uniformly distributed in $[0, \frac{1}{2}]$ (if costs increase) or $[\frac{1}{2}, 1]$ (if costs increase). We will assume that that the value of γ is very small. For the purpose of deriving the equilibrium, it helps to think of the set of states when costs change as measure zero (thus, $\gamma = 0$), though, by continuity, the

[2] A more consistent notation would be c_i^1. However, since most of the paper focuses on solving the equilibrium in period 1, we drop the superscript to simplify notation.

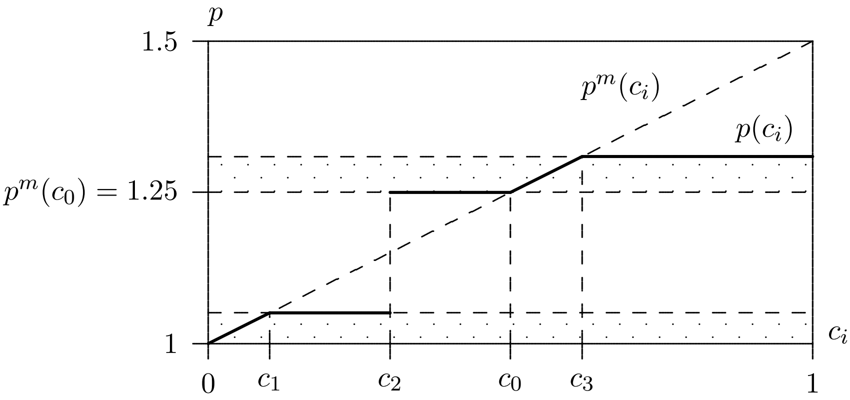

Figure 1: Equilibrium price as a function of cost in numerical example. Costs are uniformly distributed; demand is linear: $q = 2 - p$; initial cost is $c_0 = .5$ for both firms. The equilibrium cost thresholds are given by $c_1 = .102, c_2 = .301, c_3 = .619$.

results will also hold for small γ. Finally, suppose that demand is given by $q = a - p$ and the search cost is $s = 1/200$.

Let us first consider pricing in the first period. The situation is analogous to the Diamond (1971) pricing game. In equilibrium, both firms set their monopoly price. Monopoly price is given by $p^m(c) = (a + c)/2$, which in our example yields $p_i^0 = 1.25$. Notice that this is indeed an equilibrium. Since both firms set the same price, consumers have no incentive to search. Since consumers do not search, no firm has an incentive to set a different price. In fact, as Diamond (1971) has shown, this is the unique equilibrium.

Let us now focus on pricing in the second period. We will show that the following constitutes a Perfect Bayesian Equilibrium (see Figure 1 for a graphical representation). The sellers' pricing policy is as follows:

$$p = \begin{cases} p^m(c) & \text{if} \quad c \leq c_1 \\ p^m(c_1) & \text{if} \quad c_1 < c \leq c_2 \\ p_0 & \text{if} \quad c_2 < c \leq c_0 \\ p^m(c) & \text{if} \quad c_0 < c \leq c_3 \\ p^m(c_3) & \text{if} \quad c > c_3 \end{cases}$$

Regarding buyers, their strategy is as follows:

if	$p \leq p^m(c_1)$	then do not search
if	$p^m(c_1) < p < p_0$	then search
if	$p_0 \leq p \leq p^m(c_3)$	then do not search
if	$p > p^m(c_3)$	then search

We first show that the buyers' strategy is optimal and their beliefs consistent. If price is very small, then the potential gains from search are also small, and thus for a given s search is not optimal.

Specifically, suppose buyers observe a very low price. Given the sellers' pricing strategy, buyers infer that costs have decreased, in particular that each seller's cost is independently and uniformly distributed in $[0, \frac{1}{2}]$. So, faced with a price $p = p^m(c)$, the expected surplus in case the buyer searches for the lowest price is given by

$$\frac{1}{c_0}\left(\int_0^c \mu\Big(p^m(x)\Big)\,d\,x + (c_0 - c)\,\mu\Big(p^m(c)\Big)\right).$$

In words, if seller j's cost is $x < c$, then the buyer receives surplus $\mu\Big(p^m(x)\Big)$. If, on the other hand, $x > c$, then the buyer sticks with seller i's $p^m(c)$ and earns a surplus $\mu\Big(p^m(c)\Big)$.

By not searching, the buyer receives a surplus $\mu\Big(p^m(c)\Big)$. Given our assumption of linear demand, we have

$$\begin{aligned} p^m(c) &= \frac{1}{2}\,(a + c) \\ \mu(p) &= \frac{1}{2}\,(a - p)^2. \end{aligned}$$

Substituting in the above expressions and simplifying, we get a *net* expected benefit from searching equal to

$$R(c) = \frac{c_0\,\Big(a^3 - (a - c)^3\Big)}{24\,c_0} - \frac{(a - c)^2\,c}{8\,c_0}.$$

The derivative of $R(c)$ with respect to c is given by $\frac{(a-c)\,c}{4\,c_0}$, which is positive. Moreover, $R(0) = 0$. It follows that there exists a positive value of c such that the net benefit from search is equal to the search cost. Let c_1 be such value, that is, $R(c_1) = s$. It follows that, for $p \leq p^m(c_1)$, buyers are better off by not searching.

By the same token, if $p(c_1) < c < p_0$, then buyers prefer to search. The fact $p < p_0$ signals that costs are uniformly distributed in $[0, \frac{1}{2}]$, as in the previous case; and since $R(c) > s$, it pays to search.

Now suppose that p is greater than, but close to, p_0. Given the sellers' pricing strategy, buyers infer that costs are uniformly distributed in $[\frac{1}{2}, 1]$. By searching, a buyer receives an expected surplus

$$\frac{1}{(1-c_0)} \left(\int_{c_0}^{c} \mu\Big(p^m(x)\Big)\, d\, x + (1-c_0)\, \mu\Big(p^m(c)\Big) \right).$$

In words, if seller j's cost is $x < c$, then the buyer receives surplus $\mu\Big(p^m(x)\Big)$. If, on the other hand, $x > c$, then the buyer sticks with firm i's $p^m(c)$.

By not searching, the buyer receives a surplus $\mu\Big(p^m(c)\Big)$. Given our assumption of linear demand, we get a *net* expected benefit from searching equal to

$$R(c) = \frac{\Big((a-c_0)^3 - (a-c)^3\Big)}{24\, c_0} + \frac{(a-c)^2\,(c_0-c)}{8\,(1-c_0)}.$$

The derivative of this expression with respect to c is given by $\frac{(a-c)\,(c-c_0)}{4\,(1-c_0)}$, which is positive. Moreover, $R(c_0) = 0$. It follows that there exists a value of c greater than c_0 such that the net benefit from search is equal to the search cost. Let c_3 be such value, that is, $R(c_3) = s$. It follows that, for $p_0 < p \le p^m(c_3)$, consumers are better off by not searching.

By the same token, if $p > p^m(c_3)$, then consumers prefer to search. The fact $p > p_0$ signals that costs are uniformly distributed in $[\frac{1}{2}, 1]$, as in the previous case; and since $R(c) > s$, it pays to search.

This concludes the proof that the buyers' strategy is a best response to the seller's strategy; and that the buyers' beliefs are consistent with the sellers' strategy. Next we show that the sellers' strategy is optimal given the buyers' strategy and beliefs.

First notice that, given the other seller's strategy as well as the buyers' strategies, in equilibrium the other seller's buyers do not search. It follows that a seller should not take into account the possibility of gaining more buyers, only the danger of losing buyers. Consequently, if c is such that $p^m(c)$ is in a price interval such that buyers do not search then it is optimal to set $p = p^m(c)$. This shows that the strategy for $0 < c \le c_1$ and $c_0 < c < c_3$ is indeed optimal.

Consider now the case when $c_1 < c < c_0$. Setting any price between $p^m(c_1)$ and p_0 induces buyers to search. Given the rival seller's pricing strategy, the deviating seller keeps its buyers if and only if the rival's cost is greater than c_2, which happens with probability $(c_0 - c_2)/c_0$. Of all the price levels between $p^m(c_1)$ and p_0, the deviating seller prefers $p^m(c)$: it maximizes profits given a set of buyers; and the set of buyers does not depend on price (within that interval). If follows that the deviation profit is given by

$$\frac{c_0 - c_2}{c_0} \Big(a - p^m(c)\Big) \Big(p^m(c) - c\Big).$$

Since the profit function is quasi-concave, the best alternative price levels are $p^m(c_1)$ and p_0. We thus has the no-deviation constraints

$$\begin{aligned}
\frac{c_0 - c_2}{c_0} \left(a - p^m(c)\right) \left(p^m(c) - c\right) &\leq \left(a - p^m(c_1)\right) \left(p^m(c_1) - c\right) \\
\frac{c_0 - c_2}{c_0} \left(a - p^m(c)\right) \left(p^m(c) - c\right) &\leq \left(a - p_0\right) \left(p_0 - c\right).
\end{aligned}$$

We are not aware of a general analytical proof that these conditions hold. In the linear case, a sufficient condition is given by $a > \frac{1}{2}\left(1 + \sqrt{2}\right) c_0$, which holds for the particular parameters we consider in our example.[3]

Given that the seller does not want to price in the $\left(p^m(c_1), p_0\right)$ interval, we are left to determine whether it is best to pool at $p = p^m(c_1)$ or to pool at $p = p_0$. The seller prefers $p = p^m(c_1)$ if and only if

$$\left(a - p^m(c_1)\right) \left(p^m(c_1) - c\right) > \left(a - p_0\right) \left(p_0 - c\right).$$

In the linear case we are considering, it can be shown that

$$\left(a - p^M(c_1)\right) \left(p^M(c_1) - c\right) - \left(a - p_0\right) \left(p_0 - c\right) = \frac{1}{2}\left(c_0 - c_1\right) \left(\frac{c_0 + c_1}{2} - c\right).$$

Let $c_2 \equiv \frac{c_0 + c_1}{2}$. Clearly, the above difference is positive if and only if $c < c_2$. This confirms the seller's strategy for $c \in (c_1, c_0)$.

Finally, for $c > c_3$, any price greater than $p^m(c_3)$ induces search and zero demand. It follows that $p = p^m(c_3)$ is optimal so long as $p^m(c_3) > c$. In our example, $p^m(1) > 1$, and so the condition is satisfied.

■ **Uniqueness.** While we have shown that the above is a Perfect Bayesian Equilibrium (PBE), we should also note that it is generically not the unique PBE. To see this, consider a perturbed version of the previous example whereby firm i's initial cost is ϵ higher than firm j's, where ϵ is a small number. By continuity, an equilibrium like to one we considered before exists, namely one where prices do not change if costs do not change.

Consider the following alternative PBE. If costs do not change, then seller i increases price by ϵ^2, whereas seller j keeps the same price as before. If costs are in the $[c_2, c_0]$ interval, then each seller sets the same price as when costs do not change. Otherwise, the equilibrium price strategy is as before.

It can be shown that this pricing strategy is consistent with a PBE. Out-of-equilibrium beliefs are as before: any price p in the $\left(p^m(c_1), p_0 + \epsilon^2\right)$ interval (firm

[3] The condition $a > \frac{1}{2}\left(1 + \sqrt{2}\right) c_0$ is obtained by making $c = c_2$ and $c_2 = c_0/2$. It is necessary and sufficient if $c = c_2$ and $c_1 = 0$. For $c_1 > 0$ or $c \neq c_2$, it is sufficient.

i) or $\Big(p^m(c_1), p_0\Big)$ interval (firm j) leads to the beliefs that prices decreased, which in turn implies that search is the buyer's best response. This in turn implies that seller i is indeed better off by setting $p = p^m(c) + \epsilon^2$ even if cost does not change. In fact, keeping $p = p_0$ would lead to higher profits for a given number of buyers; but buyers would search and flock to the rival firm. Finally, the fact that the price increase seller i is asked to follow is one order of magnitude lower than the price difference with respect to the rival implies that undercutting seller j makes seller i strictly worse off; in other words, the gap with respect to seller i's optimal price would be much greater.

Proposition 1 *Consider the set of PBE such that, if costs do not change, then prices do not change either. If γ is sufficiently small, then the equilibrium derived above is unique among this set.*

Proof: See Appendix. ■

4 Main results

Our general results depend on some key assumptions regarding the stochastic process governing costs. In words, the assumptions below imply that (a) there is some stickiness in costs; (b) cost changes are positively correlated across firms, but not perfectly correlated. There are different ways of formally expressing these properties and we could write down a different set of assumptions from the ones below. While the exact way in which the assumptions are formulated is not critical, the two features (stickiness and imperfect positive correlation) are crucial. We return to this in Section 6.

Assumption 1 *With probability $1 - \gamma$, second period costs are identical to first period's costs.*

Assumption 2 *If second period costs are different from first period costs, then either both costs increase or both costs decrease.*

Let $F^+(c_i, c_j \mid c_i^0, c_j^0)$ and $F^-(c_i, c_j \mid c_i^0, c_j^0)$ be the joint density of costs in the second period (conditional on costs moving up or down, respectively). Let $F_i^+(c_i \mid c_j, c_i^0, c_j^0)$ and $F_i^-(c_i \mid c_j, c_i^0, c_j^0)$ be the corresponding marginal distributions. Let $f^x(c_i, c_j)$ and $f_i^x(c_i)$ ($x \in \{+, -\}$) be the corresponding densities, where for simplicity we omit the second set of arguments.

Assumption 3 *(a) f^x and f_i^x are continuous everywhere; (b) there exists a $\rho < 1$ such that $1 - \rho \leq \frac{f_i^x f_j^x}{f^x} \leq 1 + \rho$ for all c_i, c_j; (c) there exist $\underline{f}, \overline{f}$ such that $0 < \underline{f} \leq f_i^x \leq \overline{f} < \infty$ for all i, x, c_i, c_j.*

Equilibrium prices in the first period can be analyzed as part of a one-shot game. This case has previously been analyzed in the literature. We thus have

Proposition 2 (Reinganum, 1979) *Suppose, without loss of generality, that $c_i^0 \leq c_j^0$. Equilibrium prices in the first period are given by*

$$\begin{aligned} p_i^0 &= p^m(c_i^0) \\ p_j^0 &= \min\left\{\widehat{p}_i(c_i^0), p^m(c_j^0)\right\}, \end{aligned}$$

where $\widehat{p}(c_i^0)$ is given by the equation

$$\mu\Big(p^m\left(c_i^0\right)\Big) - \mu\Big(\widehat{p}\left(c_i^0\right)\Big) = s.$$

In words, Proposition 2 states that, if costs are similar, then both firms set their monopoly price. If however firm j's cost is much higher than firm i's cost, then firm j is "limit priced" by firm i, that is, firm j sets the highest price such that firm j's buyers have no incentive to search.

The main focus of our analysis is on second period prices. As we mentioned in the previous section, one can easily find multiple equilibria by conveniently manipulating buyer beliefs. In the example of the previous section and in the results that follow we restrict our attention to equilibria such that, if costs do not change, prices do not change either.

Definition 1 (status quo) *A Perfect Bayesian Equilibrium satisfies the status quo property if prices do not change when costs do not change.*

Our results presume Assumptions 1–3 and are restricted to Perfect Bayesian Equilibria as in Definition 1.

Proposition 3 (large cost changes) *If s, ρ, γ are sufficiently small, then*

(a) If c_i is sufficiently lower than c_i^0 then $p_i = p^m(c_i)$.

(a) If c_i is sufficiently greater than c_i^0 then $p_i < p^m(c_i)$.

Proof: See Appendix. ■

In words, Proposition 3 states that, if cost is close to the lower bound of its distribution then a firm is better off by setting monopoly price. In fact, no search will take place as consumers know that they can't get better than the current price. If however cost is close to the upper bound then low search cost buyers will search. In such a situation, a high cost firm will not set its monopoly price but rather a lower price.

The reason for the asymmetry between large cost decreases and large cost increases is that the latter lead to search, whereas the former do not. We next turn to the case of small cost changes, and conclude that something different happens: in equilibrium no search takes place with either small or large cost changes; but in order for that to happen sellers keep their prices fixed when prices decrease by a small amount.

Proposition 4 (small cost changes) *There exist values of ρ, γ and s sufficiently close to zero such that*

(a) If c_i is lower than, but close to, c_i^0, then $p_i = p_i^0$.

(b) If c_i is greater than, but close to, c_i^0, then $p_i = p^m(c_i) > p_i^0$.

Proof: See Appendix. ■

In words, Proposition 4 states that small cost increases are fully reflected in cost. That is, the seller sets the price he would set if he were a monopolist with captive customer base; or equivalently, he sets the same price as if consumers could perfectly observe the sellers' costs. If costs decrease by a little bit, however, then price does not change.

The reasons for this asymmetry is that the news that costs have increased leads consumers not to search for a better price when they observe their seller increase its price by a little bit. If however consumers observe a small price decrease then they expect significant potential gains from search. It follows that the seller is better off by not changing price.

5 Empirical implications

As mentioned in the introduction, Pertzman (2001) observes that prices rise faster than they decline. Consider an extension of our theoretical model to include a third period when consumers learn the firm's costs. The idea is that the second period

Table 1: Frequency and size of price change in the Euro area. Source: Dhyne et al (2004).

	Product category					Total
	UPF	PF	EN	NEIG	SER	
Frequency (%)						
Increase	15	7	42	4	4	8
Decrease	13	6	36	3	1	6
Size (%)						
Increase	15	7	3	9	7	8
Decrease	16	8	2	11	9	10

Key: UPF: unprocessed food; PF: processed food; EN: energy; NEIG: non-energy industrial goods; SER: services

represents the short run, whereas the third period represents the long run. The assumption that consumers know costs in the long run is a bit extreme—just as the assumption that consumers cannot observe any signal of costs in the short run. However, these assumptions seem a good approximation to the idea that it takes time for consumers to learn about shocks to the sellers' costs.

In the third period, the game played by sellers and buyers will be similar to that in the first period (though possibly with different cost levels). Prices are then determined by Proposition 2. Consistently with Assumption 1, suppose that, with probability close to 1, costs do not change between the second and third periods. It then follows that, for small cost changes, the there-period extension of our theoretical models is consistent with the Peltzman (2001) prediction: cost increases are immediately reflected in price, whereas cost decreases take longer to be reflected in price.

Proposition 4 and in particular the example presented in Section 3 suggest that price decreases are less frequent than price increases. In a world of zero inflation, this also implies that the average price decrease is greater (in absolute value) than the average price increase.

Evidence for the Euro area seems consistent with the above predictions. Table 1 indicates that on a given month prices increase with probability 8% but decrease with probability of only 6%. The average price increase is 8%, whereas the average price decrease is 10%. Regarding the size of price changes in the U.S., Bils and Krivstov (2004) report average values of 13% (price decreases) and 8% (price increases).

It is also interesting to notice the variation across classes of products. Again for the Euro area, Dhyne et al (2004) report that "price changes are very frequent for energy products (oil products) and unprocessed food, while they are relatively infrequent for non-energy industrial goods and particularly services" (p 16). The authors claim that the same result is obtained for the U.S. B.L.S. data used by Bils and Klenow (2004). While we don't have a complete explanation for this variation, it seems reasonable to assume that, for unprocessed foods and oil products buyers are better aware of cost variations. In our model, this would imply the absence of stickiness due to search costs.

Our theoretical model considers a zero-inflation environment. It is not clear how it should be adapted to take into account the fact there is a positive expected change in cost (and price). Dhyne et al (2003) regress the size of price increases and decreases on a variety of controls, including inflation, product dummies and country dummies. The constant for price increases is 0.043, and that for price decreases 0.057. Both are significant at the 5% confidence level. This seems broadly consistent with our theoretical prediction. Moreover, empirical evidence suggests that, in Europe and in the U.S., price volatility is fairly significant with respect to overall inflation. In this sense the situation may not be very far from the no-inflation reference point.

6 Discussion

In this section, we reexamine some of the assumptions of our theory, namely our assumptions regarding the stochastic cost process. We also relate our theory to other theories of asymmetric price adjustment.

■ **Cost assumptions.** It is first important to note that we do not need to make any assumption of asymmetric cost dynamics in order to obtain asymmetric pricing dynamics. Specifically, the example we considered in Section 3 features a symmetric cost process. The example — and the general results — regarding small cost changes are based on assumptions that require a discontinuity in the the distribution of costs. In fact, as Assumption 2 states, if firm i's cost increases then firm j's cost increases as well; and if firm i's cost decreases then firm j's cost decreases as well. Given Assumption 3, namely the assumption that the density of the cost distribution is bounded away from zero, Assumption 2 implies a discontinuity at c_i^0.

However, while our set of assumptions is sufficient to obtain the desired results, it is not necessary. Consider the following variation on the example presented in

Section 3. As before, suppose that $c_i^0 = c_j^0 = \frac{1}{2}$, but now consider the case when

$$f(c_j \mid c_i) = \begin{cases} \max\left\{0, \frac{1}{2} - c_i\right\}(1 - 2\,c_i) & \text{if} \quad 0 \leq c_j < \frac{1}{2} \\ \max\left\{0, c_i - \frac{1}{2}\right\}(2\,c_i - 1) & \text{if} \quad \frac{1}{2} < c_j \leq 1 \end{cases}$$

and there is a mass point $1 - \frac{1}{4}\left|\frac{1}{2} - c_i\right|$ at $c_j = \frac{1}{2}$. This distribution is continuous at $c_i = \frac{1}{2}$. We conjecture that the main feature of the results in Section 3 also apply in this case.

■ **Related literature.** There are various possible explanations for price rigidity and the asymmetry of price responses to cost changes. Borenstein, Cameron and Gilbert (1997) provide an informal discussion based on oligopoly market power. We are only aware of two formal models that relate asymmetric price adjustment to buyer search costs: Lewis (2005) and Tappata (2006).

Lewis (2005) develops a reference price search model with homogenous firms and consumers that form adaptive expectations about the current price distribution. In his model consumers search sequentially and optimally with respect to past prices but not necessarily with respect to actual prices.

Tappata (2005) develops a non-sequential search model with homogenous firms a la Varian and rational consumers. When consumers expect costs to be high, they expect less price dispersion and search less, giving firms more market power. When consumers expect costs to be low, they expect greater price dispersion, search more intensively and firms price more competitively. When costs were low in the past consumers expect current cost to be high as well, hence pricing is more competitive and cost increases are more fully passed to prices. When past costs were high, consumers expect current costs to be high as well, hence they search less and firms have less of an incentive to lower prices.

To be completed.

7 Conclusion

We propose a consumer search theory of asymmetric price adjustment. The basic intuition for our theory is that consumers have a greater propensity to search when they observe a large cost increase or a small cost decrease; and have no incentive to search when costs increase by a little or decrease by a lot. This implies that firms are reluctant to change prices when costs decrease by a little bit; and don't fully reflect on price large costs changes.

To be completed.

Appendix

Proof of Proposition 1: Let c' be defined by

$$\mu\Big(p^m(c')\Big) - \Big(p^m(0)\Big) = s.$$

If $p < p^m(c')$, then the buyers' best response is not to search. If fact, even if the rival seller were to set the lowest price, $p^m(0)$, with probability 1, it wouldn't pay to search. It follows that, if $0 < c < c'$, then it is optimal for sellers to set $p = p^m(c)$; and for $c > c'$, optimal price is greater or equal to $p^m(c')$. In particular, given that the profit function is quasiconcave, it does not pay to set a price lower than $p^m(c')$.

Given the sellers' strategy, an upper bound to the utility a buyer can expect from switching sellers is

$$\frac{1}{c_0}\left(\int_0^{c'} \mu\Big(p^m(x)\Big)\,dx + (c_0 - c')\,\mu\Big(p^m(c')\Big)\right).$$

Let c'' be defined by

$$\mu\Big(p^m(c'')\Big) - \frac{1}{c_0}\left(\int_0^{c'} \mu\Big(p^m(x)\Big)\,dx + (c_0 - c')\,\mu\Big(p^m(c')\Big)\right) = s.$$

It follows that, if $0 < c < c''$, then it is optimal for sellers to set $p = p^m(c)$; and for $c > c''$, optimal price is greater or equal to $p^m(c'')$. In particular, given that the profit function is quasiconcave, it does not pay to set a price lower than $p^m(c'')$.

Notice that $c'' > c'$. This process can be repeated, obtaining a strictly increasing, bounded sequence $c', c'', c''', \ldots$ which converges to a value c^ℓ given by:

$$\mu\Big(p^m(c^\ell)\Big) - \frac{1}{c_0}\left(\int_0^{c^\ell} \mu\Big(p^m(x)\Big)\,dx + (c_0 - c^\ell)\,\mu\Big(p^m(c^\ell)\Big)\right) = s.$$

But this is exactly the value c_1 derived above.

Since we are computing lower bounds to the value of search, it follows that, if $p^m(c_1) < p < p_0$, then buyers search. This uniquely leads to the equilibrium price strategy for $c_1 < c < c_0$. For increases in cost, an analogous, if simpler, argument follows. ■

Proof of Proposition 3: Suppose that $c_i = 0$ and firm i sets $p_i = p^m(0)$. The potential gain from search is zero, since seller j's price is greater or equal to $p^m(0)$. If follows that there is no search by seller i's buyers. This in turn implies that seller

i is doing its best by setting $p_i = p^m(0)$. In fact, seller i does not lose any of its buyers. Moreover, the only case when firm j's buyers would search is when p_j is strictly greater than $p^m(0)$, in which case seller i would capture those buyers by setting $p_i = p^m(0)$. Since the above inequalities are strict, the result follows by continuity for c_i sufficiently close to zero.

Consider now the case of a large cost increase. If $c_i > p_i^0$, then it must be that $p_i(c_i) > p_i^0$ (no seller would set a price below cost). If search costs are sufficiently small, then the buyer's net expected payoff from search is positive. But if buyers search, then $p_i(c_i) < p^m(c_i)$. To see why, consider the highest possible cost. Given a monotonic pricing function, the probability that such a seller will have positive sales is zero. Since $p^m(c_i) > c_i$, it pays to reduce price. ■

Proof of proposition 4: Suppose that $c_j = c_j^0 - \epsilon$. A lower price by firm j is interpreted by consumers as a lower cost by firm i. Assumption 3 and the first part of Proposition 3 imply that the expected benefit from search is strictly positive. If s is sufficiently small, then consumers would prefer to search. If that is the case, then firm j prefers not to change its price: even if no consumers were to move away from firm j, the gain in adjusting price would be of second order; but the potential loss of consumers is a first-order effect. In fact, by keeping price constant no search will take place: if γ is sufficiently close to zero (for given values of ρ and s) then by Assumption 1 buyers rightly believe that most likely no change in cost has taken place and so the expected net gain from search is negative.

Consider now the case when $c_i = c_i^0 + \epsilon$ and suppose that firm i sets its new monopoly price: $p_i = p^m(c_i^0 + \epsilon)$. In the initial period, the net expected gain from search was (weakly) negative (cf Proposition 2). The news that firm i's cost increased is bad news regarding firm j's price. It follows that, if ϵ is small enough, then the net expected game from search is now strictly negative. This implies that firm i is doing its best. In fact, firm i's customer base is independent of price (in the relevant range). The only case in which firm i might increase its customer base is when firm j's customers search. But this only happens when firm j prices at a higher level than firm i's current price, in which case firm i's price increase has no impact on the number of consumers, only on sales per consumer. Finally, notice that a higher p_i is correctly interpreted by consumers as meaning a higher c_i (and thus a higher c_j). If firm i's cost had not changed or had decreased then firm i would be better off by not changing price rather than by increasing it to $p^m(c_i^0 + \epsilon)$. ■

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