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Business as Usual: A Consumer Search Theory of Sticky Prices and Asymmetric Price Adjustment

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This draft: August 2011

Abstract. Empirical evidence suggests that prices are sticky with respect to cost changes. Moreover, 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. In equilibrium, a change in price is likely to induce consumer search, which explains sticky prices. Moreover, the signal conveyed by a price decrease is different from the signal conveyed by a price increase, which explains asymmetry in price adjustment.

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1. Introduction

Empirical evidence suggests that prices are sticky: firms do not immediately adjust to changes in costs. For example, in a survey of 200 firms, Blinder et al. (1998) found that the median firm adjusts prices about once a year. Hall, Walsh, and Yates (2000) obtained similar results in a survey of 654 British companies. In a study of newsstand prices of 38 American magazines over 1953–79, Cecchetti (1986) determined that the number of years since the last price change ranged from 1.8 to 14 years. Kashyap (1995), in a study of the monthly prices of mail-order catalog goods, found an average of 14.7 months between price changes. MacDonald and Aaronson (2001) determined that restaurant prices display a median duration of about 10 months. In a broad sample of consumer goods, Klenow and Kryvtsov (2008) found that the median consumer good changes prices every 4.3 months.

The purpose of this paper is to develop a search theoretic model of sticky consumer prices. We consider an industry where input costs are sticky and show that consumer search costs lead to output prices that are stickier than input costs. To understand the mechanism for this "increasing stickiness" pattern, suppose that consumer prices are currently in equilibrium (specifically, in a Diamond-type equilibrium). The idea is that, if firm i's cost changes by a small amount, then firm i is better off by not changing its price. In fact, if price remains constant then consumers rationally believe there have been no cost shocks, and consequently refrain from searching: it's business as usual. By contrast, changing price "rocks the boat," that is, leads consumers to search; and the potential loss from consumers searching rivals' prices outweighs the potential gain from adjusting price to its new optimal level.

While our analysis is motivated by evidence of price stickiness, we are also interested in the stylized fact that prices adjust (upward) more quickly to cost increases than (downward) to cost decreases (see Peltzman, 2000, and references therein). Our model accounts for such asymmetric behavior in a natural way. The idea is that a small price increase (decrease) signals a positive (negative) cost shock. As a result, the potential gains from search are greater following a small price decrease than a small price increase. This implies that the above effect ("business as usual" beats "rocking the boat") is especially relevant following a small cost decrease.

A common explanation for price stickiness is that there is a fixed physical cost that firms must pay whenever they change a price — a menu cost (e.g, Sheshinski and Weiss, 1977, Levy, Bergen, Dutta, and Venable, 1997)). This approach is often criticized on the grounds that for most products it is hard to identify significant fixed physical costs of changing prices. Several other papers develop models in which consumer frictions lead to incomplete price adjustment. Stiglitz (1987) shows that a model with convex search costs can be consistent with real and nominal rigidities. Klemperer (1995), Klesshchelski and Vincent (2007) and Menzio (2006) show that rigidities may arise if it is costly for consumers to switch sellers. Nakamura and Steinsson (2005) show that prices might not fully adjust to cost increases when consumers form habits in individual goods which lock them in with specific sellers. Rotemberg (2005) develops a model in which firms may fail to increase prices in order not to antagonize customers, a hypothesis which is supported empirically by Anderson and Simester (2010). Mankiw and Reis (2002) and Reis (2006) develop models in which it is costly for firms to absorb, process and interpret information about costs and consequently only adjust prices at certain dates. Lewis (2005), Tappata (2009) and Yang and Ye (2008) develop search theoretic models to explain asymmetric price adjustment. Most closely related to our model are Benabou and Gertner (1993) and Fishman (1995), who use a similar framework to analyze equilibrium pricing when firms costs are determined as the product of a common inflationary factor and a privately observed idiosyncratic shock.

Although our paper shares various features with the above literature, we make a distinctive contribution: we show that search costs imply a magnification in the degree of price stickiness, that is, equilibrium output prices are stickier than input prices.

We then consider an extension of our model to allow for the possibility that the occurrence *and* the direction of cost changes are correlated across firms. In addition to price stickiness, this version of the model also implies asymmetric price adjustment: a small cost increase leads to a small price increase, for consumers expect the other firm's cost (and price) also to have increased, and thus refrain from searching; a small cost decrease, however, leads to no price change, for the same reason as before, that is, because the firm fears inducing consumer search.

The paper is structured as follows. In Section 2, we lay down the basic model structure. In Section 3, we present our main result regarding sticky prices. Section 4 considers an extension of the model which leads to a a pattern of asymmetric adjustment of prices to costs. We conclude with Section 5.

2. Model

We consider a model with a continuum of firms (of mass two) and a continuum of consumers (of mass two as well). The firms are divided into two groups of equal size, A and B. Firm costs are identical within each group. For simplicity, we will refer to two firms, A and B, although there is a mass one of each type of firm.

Time is infinite and discrete: $t = 1, 2, \ldots$ In each period, each consumer is randomly assigned to a firm, leaving each firm with an assigned consumer. Together with the assumption that there is a continuum of firms, this implies that each firm maximizes profits considering exclusively its current consumer's actions. In other words, each firm's future value function does not depend on current actions.

Each firm sets its price p and each consumer demands a quantity $q(p) = a - p$ from the seller with the lowest price observed by that consumer. Specifically, while a consumer is assigned to a given firm, he has the option to search for another firm's price by paying a cost $s > 0$.[1] We have in mind a product which is consumed repeatedly and for which the quantity demanded is sensitive to price. Examples include cable, cell phone, and restaurant services, when the buyer is the final consumer;[2] and production inputs (such as flour), when the buyer is a firm (such as a bakery).

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

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[1] We assume that consumers can distinguish between a type A and a type B firm.

[2] The demand for cable and cell phone services is downward sloping to the extent that following a price increase consumers switch to a lower q tier or plan, respectively. The demand for restaurant meals is downward sloping to the extent that, as prices increase, consumers dine out less frequently or skip desert, wine, more expensive dishes, etc.
The model could also accommodate the case of unit demand by introducing heterogenous consumers with different reservation prices. This would lead to a more complicated model.

Firm i's unit cost at time t, c_{it}, evolves according to a Markov process where the state is given by both firms' costs. The Markov transition function is common knowledge, but not the cost levels. At each period t, firm i is informed about its own cost.

Consumers, by contrast, have limited information regarding firms. In each period, they observe the price set by the firm they are assigned to. Moreover, they observe the market's cost and price distribution at odd periods (i.e., at $t = 1, 3, 5$, and so on). However, any changes in other firms' prices (or in the cost or price distribution) which occur at even periods (i.e., at $t = 2, 4$, and so on) are not observed.[3] Similarly, Firm A (resp. B) observes the cost of Firm B (resp. A) at odd periods but does not observe any changes in the other firms' cost which occur at even periods.

The idea of the above model assumption is that it is too costly for agents to continually update and interpret information about the economy, so agents are "inattentive" to new information most of the time and only update information at pre-specified intervals. The assumption that this updating is coordinated between consumers is clearly artificial and is made for tractability — in a richer model the frequency of information gathering would be endogenously derived from model parameters and the dates at which information is updated might be distributed across individuals.

The probability of a change in the state from one period to the next is given by γ; that is, with probability $1 - \gamma$ both sellers' costs are the same as in the previous period. Moreover, if there is a cost change, we assume the new value of c_{it} is uniformly distributed in $[c_L, c_H]$. By an appropriate change in units — and with no loss in generality — we normalize $c_L = 0$ and $c_H = 1$.

To summarize and recap: in each period, consumers are assigned to firms. Each consumer observes its firm's price and decides whether to search for another firm's price (at a cost s). After all search decisions have been made, each consumer buys $a - p$ from the firm with the lowest observed price.

In what follows, we will be looking at Bayesian Equilibria (BE) of the above game.

3. Sticky prices

Let us first consider pricing in period $t = 1$ (or, more generally, in an odd numbered period). Since strategies and beliefs in $t = 2$ do not depend on $t = 1$ prices, the situation is analogous to the Diamond (1971) pricing game. In equilibrium, if the search cost s is sufficiently large with respect to the firms' cost difference $\mid c_{A1} - c_{B1} \mid$, both firms set their monopoly price, which is given by $p^m(c_{i1}) = (a + c_{i1})/2$. To see that this is indeed a Nash equilibrium, notice that, if each firm sets $p^m(c_{i1})$ and $\mid c_{A1} - c_{B1} \mid$ is small with respect to s, then the difference is prices is also small with respect to s, and 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. Below we will also consider the case when $\mid c_{A1} - c_{B1} \mid$ is large.

Our main result concerns pricing at $t = 2$ (more generally, pricing at even periods). Before presenting our formal result, we first provide an informal description of the main intuition. We first note that generally a simple repetition of the pricing equilibrium in period 0 is unlikely to be an equilibrium. Specifically, suppose that γ is small and that firm A experiences a small cost change. (Below we determine quantitative limits to the value of γ, as a function of s, so that the result holds.) Should firm A set a price equal to monopoly price as in the previous period? The answer is no. By changing its price, firm A signals to consumers that its cost has likely changed. Conditionally on firm A's cost having changed, firm B's cost has also changed (with probability one); in fact, it is uniformly distributed between 0 and 1. This implies that there are significant gains from consumer search. This implies in turn that there is a good chance firm A will lose its customers. By contrast, sticking to a constant price — not "rocking the boat" — assures firm A that there won't be any search. In fact, since the probability of a cost change is small, consumers rightly believe that, conditional on a sticky price, the likelihood of a cost change is small, and thus the gains from search are lower than the search cost. Our main result (which is illustrated by Figure 1) makes this statement more precise.

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[3] More generally, our results are also valid for the case when consumers observe seller' costs every k periods, that is, at $t = 1, k + 1, 2\,k + 1$, and so on, where k is a positive integer. Between periods $n\,k + 1$ and $(n + 1)\,k$ consumers only observe the price of the firm they are attached to.

Proposition 1. *Suppose that* $\mid p^m(c_{A1}) - p^m(c_{B1}) \mid < s$. *There exist* s°, γ° *such that, if* $0 < s < s^\circ$ *and* $\gamma < \gamma^\circ$, *then the following constitutes a Bayesian Equilibrium. The sellers' pricing policy is as follows:*

$$p_{i2} = \begin{cases} p^m(c_{i2}) & \text{if} \quad c_{i2} \le c' \\ p^m(c') & \text{if} \quad c' < c_{i2} \le c''(c_{i1}) \\ p_{i1} & \text{if} \quad c_{i2} > c''(c_{i1}) \end{cases}$$

The buyers strategy is as follows:

If $p = p_{i1}$ *or* $p \le p^m(c')$, *then do not search.*

Otherwise, search.

where $c' < c''(c_{i1}) < c_{i1}$, *all for* $i = A, B$.

Proof of Proposition 1: We show that the above strategies are indeed a Bayesian equilibrium.

We begin by showing that the consumers' strategy is optimal and their beliefs consistent.

If the consumer observes a price $p_{i2} = p_{i1}$, then with probability $1 - \gamma$ costs have not changed; and, given the firm's strategy, the rival firm's price has not changed either. This implies that if γ is sufficiently small, then the gains from search are lower than the search cost.

Suppose now that the consumer observes $p_{i2} \ne p_{i1}$. Given the firms' equilibrium strategies, this implies the belief that costs have changed. In particular, the rival firm's cost, c_{j2}, is believed to be uniformly distributed in $[0, 1]$. For $p_{i2} < p^m(c')$, expected surplus in case the consumer searches for the lowest price is given by

$$\int_0^c \mu\big(p^m(x)\big)\, dx + (1 - c)\, \mu\big(p^m(c)\big)\,.$$

where c is the cost level such that $p_{i2} = p^m(c)$. To understand the above expression, note first that $p_{i2} < p^m(c')$ and the equilibrium strategy together imply that if $c_{j2} < c$ then

$p_{j2} = p^m(c_{j2})$. We then have two possibilities: if firm j's cost is lower than c, then the consumer receives surplus $\mu\big(p^m(c_{j2})\big)$. This corresponds to the first term, where we apply the belief that firm j' cost is uniformly distributed between 0 and 1. If, on the other hand, firm j's cost is greater than c, then the consumer sticks with firm i's $p^m(c)$ and earns a surplus $\mu\big(p^m(c)\big)$. This corresponds to the second term.

If the consumer does not search, then surplus is given by $\mu\big(p^m(c)\big)$.

Since $q(p) = a - p$, 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

$$R(c) = \int_0^c \mu\big(p^m(x)\big)\,dx + (1-c)\,\mu\big(p^m(c)\big) - \mu\big(p^m(c)\big) = c^2\Big(\frac{a}{8} - \frac{c}{12}\Big)$$

The net benefit from search function, $R(c)$, plays an important role in the proof.

Lemma 1. *(a)* $R(0) = 0$*; (b)* $R'(c) = \frac{(a-c)\,c}{4} > 0$.

Lemma 1 implies that there exists a positive value of c, say c', such that, given the above seller strategies, the net benefit from search is positive if and only if $p_{i2} > p^m(c')$ (and $p_{i2} \neq p_{i1}$). Specifically, c' is given by $R(c') = s$.

In the above analysis of the consumer strategy, we have assumed that $\gamma < \gamma^\circ$. In particular, if $\gamma^c irc$ is small, then observing no change in price consumers assume that costs have not changed. In the Appendix, we explicitly determine the upper bound γ°. For example, if $a = 2$, $s = 1/200$ and $c_{i1} = c_{j1} = \frac{1}{2}$, then we get $\gamma < \gamma^\circ \approx .133$. If $s = 1/100$, then $\gamma < \gamma^\circ \approx .266$; if $s = 1/20$, then $\gamma < \gamma^\circ \approx .979$. So, while our general result assumes that γ is small, the above example suggests that we don't need γ to be particularly close to zero.

Consider now the firm's strategy. Notice that, along the equilibrium path, no search takes place. This implies that, in considering what price to set, each firm is only concerned about its customers' search behavior. In other words, at best a firm manages not to lose its customers; it will never attract its rival's customers. If $c < c'$, the firm's strategy is clearly optimal: consumers do not search even as the firm sets its monopoly price.

If $c > c'$, then there are two possibilities to take into account. Suppose that $c_{A1} > c_{B1}$ and consider firm B's pricing problem. If $p^m(c') < p_{B2} < p_{B1}$, then consumers search. Given the rival firm's pricing strategy, the deviating firm keeps its customers if and only if the rival's cost is greater than $c''(c_{A1})$, which happens with probability $1 - c''(c_{A1})$. Of all the price levels between $p^m(c')$ and p_{B1}, the deviating firm 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

$$\Big(1 - c''(c_{A1})\Big)\Big(a - p^m(c)\Big)\Big(p^m(c) - c\Big)$$

Since the profit function is quasi-concave, the best alternative price levels are $p^m(c')$ and p_{B1}. The firm prefers $p = p^m(c')$ if and only if

$$\Big(a - p^m(c')\Big)\Big(p^m(c') - c\Big) > (a - p_{B1})(p_{B1} - c)$$

Since $p^m(c) = (a + c)/2$ and $p_{B1} = p^m(c_{B1})$, this becomes

$$\left(a - \frac{a + c'}{2}\right)\left(\frac{a + c'}{2} - c\right) > \left(a - \frac{a + c_{B1}}{2}\right)\left(\frac{a + c_{B1}}{2} - c\right)$$

which is equivalent to

$$c < c''(c_{B1}) \equiv \frac{c_{B1} + c'}{2}$$

It follows that the firm's best alternative to $p^m(c)$ is $p^m(c')$ if $c < c''(c_{B1})$ and p_{B1} otherwise. The no-deviation constraint is most binding precisely when $c = c''(c_{B1})$, in which case it becomes

$$\Big(1 - c''(c_{A1})\Big)\Big(a - p^m(c''(c_{B1}))\Big)\Big(p^m(c''(c_{B1})) - c''(c_{B1})\Big) \le (a - p_{B1})(p_{B1} - c)\,.$$

It can be shown that, if $c_{B1} < 1 < a$ (as we assume), then this conditions holds.

Consider next firm A's pricing problem. The main difference with respect to firm B's problem is that, by setting $p_{A2} \in [p_{B1}, p_{A1}]$, firm A loses all of its customers regardless of the value of c_{B2}. However, as we saw above, the choice of intermediate values of p_{i2} is dominated by the options $p^m(c')$ or p_{i1}. If this is true for firm B, this is true a fortiori for firm A.

To conclude the analysis of the firm's strategy, notice that pricing above p_{i1} is clearly a dominated strategy as the firm would lose all of its customers. (Notice that the maximum value of cost is lower than p_{i1}, so the seller can always make a positive profit.)

■

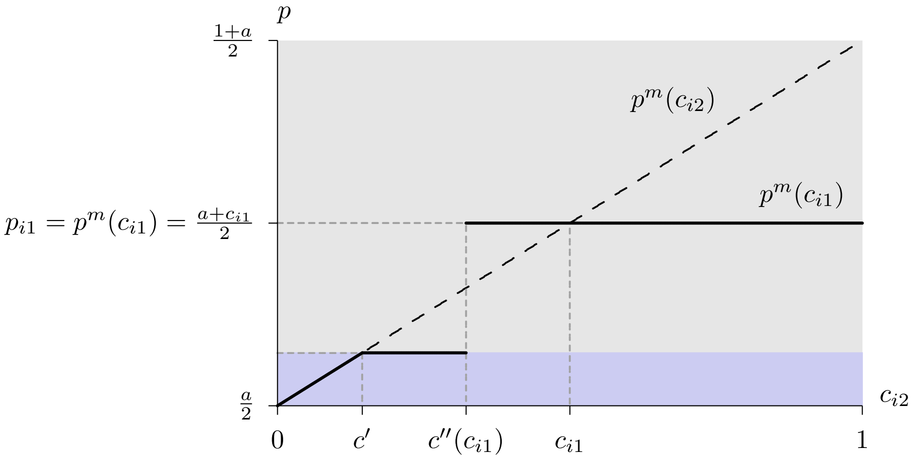
Figure 1 provides a graphical representation of the equilibrium strategies (for simplicity, we assume $c_{A1} = c_{B1}$). Notice that, if costs do not change, then prices do not change either. Moreover, there is a wide range of values of c_{i2} (specifically, $c_{i2} \in [c'', 1]$) such that prices remain unchanged even though costs change. In this sense, equilibrium pricing *magnifies* the stickiness of input costs: in period 2 (and more generally in an even period), prices remain constant with greater probability than costs remain constant.

Suppose costs change from $t = 1$ to $t = 2$ but not from $t = 2$ to $t = 3$. Our assumptions regarding consumer information imply that, at $t = 3$, a Diamond type equilibrium is played again. Together with Proposition 1, this implies that prices do not change from $t = 1$ to $t = 2$ but they do change from $t = 2$ to $t = 3$ (that is, the move from one Diamond equilibrium to another Diamond equilibrium). In this sense, the pattern implied by the equilibrium above is one of delayed impact of cost changes on prices.

Moreover, considering a model extension whereby consumers are only informed about costs every k periods, where $k > 2$, we could have several small cost changes in periods $2, 3, \ldots, k$, none of which would be reflected in a price change. In this sense, the above result suggests the possibility that output prices change with lower frequency than input prices.

Figure 1

Equilibrium price as a function of cost. For values of cost greater than $c''(c_{i1})$, firm i sets the same price as in the previous period: sticky prices.



To summarize, the implication of the above equilibrium strategies is a pattern of sticky prices, that is, prices that respond slowly to cost changes. The intuition for this pattern is that a price change signals to consumers that costs have changed; and when costs change the expected gains from search are greater. Not wishing to induce search, firms stick to their previous price. For a given set of customers, a different price would lead to higher profits, but factoring in the expected losses from lost customers a price change becomes suboptimal. Formally, we show that the gains from adjusting price to a small cost change are of second order (by the envelope theorem), whereas the expected loss due to consumer searching and switching is of first order.

■ **Uniqueness.** While we have shown that the above is a Bayesian Equilibrium (BE), we should also note that it is not the unique BE. To see this, consider the situation when firm i's initial cost is ϵ higher than firm j's, where ϵ is a small number. Suppose that, if costs do not change, then seller i increases price by ϵ^2, whereas seller j keeps the same price as before. Otherwise, the equilibrium price strategy is as before.

This pricing strategy is consistent with a BE. Out-of-equilibrium beliefs are as before: any price $p_{i2} \neq p_{i1} + \epsilon^2$ and $p_{i2} > p^m(c')$ leads consumers to search. Suppose there is no cost change. If firm i sets any price other than $p_{i1} + \epsilon^2$, it will either make less money on a per consumer basis or lose all consumers.[4]

By the above token, we can construct a *continuum* of BE. Our selection, that is, the equilibrium implicit in Proposition 1, is based on a criterion that we think makes sense: if costs do not change, then prices do not change either.[5] However, we should reinforce the idea that, while we are making this equilibrium selection assumption, we are *not* getting price stickiness by assumption. In fact, the thrust of Proposition 1 is that equilibrium strategies *magnify* the degree of stickiness in costs.

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[4] Equilibria of this type can also be found when initial costs are identical. For example, suppose equilibrium calls for both firms to decrease price by ϵ even if costs have not changed. If a firm does not change its price, then consumers will search, find a firm with a slightly lower price (a firm who followed equilibrium strategies) and switch. It follows that the designated strategy is indeed an equilibrium strategy.

[5] However, it is not the only criterion that makes sense. Specifically, there are situations where equilibrium calls for firms to play mixed strategies, so that prices change even if costs have not changed.

■ **Large cost differences.** The above result assumes that, in period $t = 1$, firms' costs are sufficiently close that each firm's equilibrium price is its monopoly price. We now consider the case when they are not. Specifically, suppose that $c_{A1} \gg c_{B1}$. Then, as proved by Reinganum (1979), equilibrium prices (at $t = 1$) are given by $p_{B1} = p^m(c_{B1})$ and $p_{A1} = \min\{\hat{p}_{A1}, p^m(c_{A1})\}$, where $\hat{p}$ is (implicitly) defined by $\mu\big(p^m(c_{B1})\big) - \mu\big(\hat{p}_{A1}\big) = s$. Thus, if $c_{A1} - c_{B1}$ is sufficiently large, then $p_{A1} < p^m(c_{A1})$.

Now consider what happens at $t = 2$. Suppose first that there is no cost change. Then neither firm A nor firm B have an incentive to change their price (for the same reasons as before). This is clear for firm B, who is pricing at monopoly level. It is also true for firm A because any price change would lead consumers to search, which in turn would lead firm A to lose all of its customers (unless it prices below firm B, in which case it keeps the same number of customers but makes less profit per customer).

Consider now the case when there is a small cost change. If firm B's cost decreases by a small amount or increases by any amount, then, by the same argument as in Proposition 1, firm B is better off by keeping its price fixed. In fact, adjusting price to its new optimal level would lead to a second-order increase in profit per customer. However, conditionally on costs having changed, there is a positive probability that the rival's cost decreases by a large amount; and since a price change leads to search, there is a positive probability that firm B is left with no consumers.

Consider now firm A's case. Suppose its cost changes by a small amount. Now it's no longer the case that keeping price fixed is necessarily optimal, because firm A's gain from adjusting price might be of first-order magnitude. Therefore, it is conceivable that for some parameter values firm A is better off by adjusting its price in the direction of its monopoly price level.

In sum, when cost differences are large we can only guarantee price stickiness by the lower cost firm. Overall, our results imply that price stickiness occurs with positive probability.

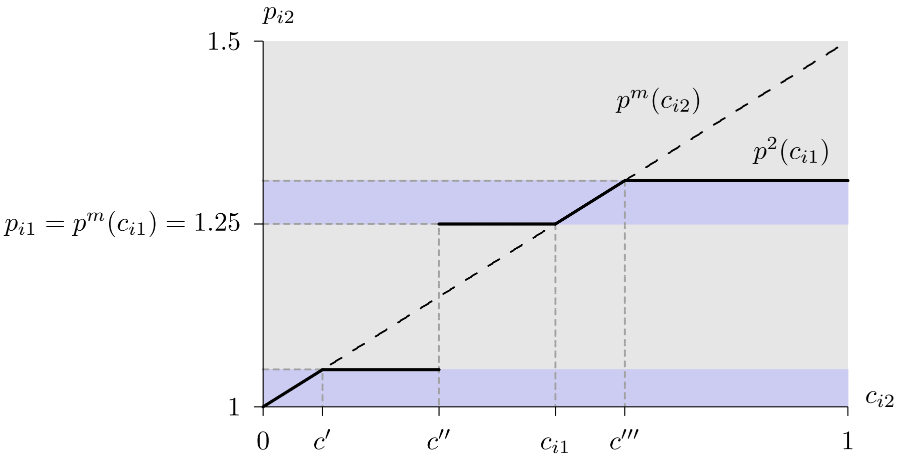
4. Asymmetric price adjustment

Several studies (Peltzman, 2000, and references therein) indicate that prices decrease more slowly when costs go down than they increase when costs go up. In this section we show that our model can accommodate this pattern in a natural way. Until now we assumed that, conditional on a cost change, firm i's cost is independent of firm j's. One would expect some positive correlation between firm costs when they change. We now consider a revised version of our model where costs are correlated.

As before, costs change with a (small) probability γ. We now assume that, if costs change, then either both costs increase or both costs decrease. Specifically, costs are independently and uniformly distributed in $[0, c_{i1}]$ (if costs decrease) or $[c_{i1}, 1]$ (if costs increase). For simplicity, we also assume that $c_{i1} = c_{j1}$.

The derivation of a BE is similar to Section 3. The crucial difference is that firms increase prices when their cost increases. The reason is that a price increase by firm i signals a cost increase by firm i. And, to the extent that costs are correlated, it also signals

Figure 2
Equilibrium price as a function of cost in numerical example. Costs are uniformly distributed; demand is linear: $q = 2 - p$; initial cost is $c_{i1} = .5$ for both firms. The equilibrium cost thresholds are given by $c' = .102$, $c'' = .301$, $c''' = .619$.



an increase in firm j's price. It follows that consumers may prefer not to search despite a cost increase, provided it's small enough.

Proposition 2. *Suppose that* $\mid p^m(c_{A1}) - p^m(c_{B1}) \mid < s$. *There exist* s°, γ° *such that, if* $0 < s < s^\circ$ *and* $\gamma < \gamma^\circ$, *then the following constitutes a Bayesian Equilibrium. The sellers' pricing policy is as follows:*

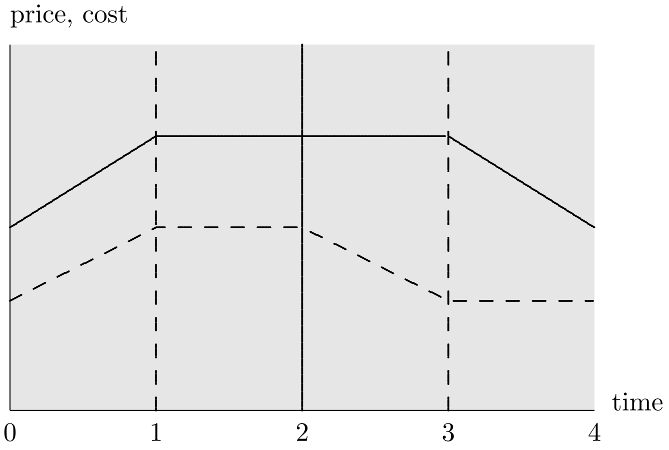
$$p_{i2} = \begin{cases} p^m(c_{i2}) & \text{if} \quad c_{i2} \leq c' \\ p^m(c') & \text{if} \quad c' < c_{i2} \leq c''(c_{i1}) \\ p_{i1} & \text{if} \quad c''(c_{i1}) < c_{i2} \leq c_{i1} \\ p^m(c_{i2}) & \text{if} \quad c_{i1} < c_{i2} \leq c''' \\ p^m(c''') & \text{if} \quad c_{i2} > c''' \end{cases}$$

The buyers' strategy is as follows:

if	$p_{i2} \leq p^m(c')$	*then do not search*
if	$p^m(c') < p_{i2} < p_{i1}$	*then search*
if	$p_{i1} \leq p_{i2} \leq p^m(c''')$	*then do not search*
if	$p_{i2} > p^m(c''')$	*then search*

These equilibrium strategies are illustrated in Figure 2. Similarly to Section 3, they imply a pattern of price stickiness whereby (a) prices vary less frequently than costs, and (b) prices respond slowly to cost changes. Moreover, we now notice a clear asymmetry in the way prices respond to small cost changes: prices remain unchanged following small cost decreases but increase following small cost increases. Finally, we never observe large price increases, whereas we do observe large price decreases.

Figure 3
Cost changes and price changes.



■ **Empirical implications.** Proposition 2 shows that when the *direction* of cost change is sufficiently correlated across firms, then, for small cost changes, prices respond more rapidly to cost increases than to cost decreases. We now derive a series of empirical implications of this theoretical result.

☐ **Speed of price response to cost changes.** As Figure 3 illustrates, our equilibrium seems consistent with the idea that, for small cost changes, prices respond more rapidly to cost increases than to cost increases. Specifically, the figure considers a situation where costs increase by a bit from $t = 1$ to $t = 2$ and then decrease by a bit from $t = 3$ to $t = 4$. As can be seen, a cost increase is immediately reflected in a price increase; whereas a cost decrease results in a price decrease with a lag. Peltzman (2000) presents evidence that is consistent with the pattern illustrated by Figure 3.

☐ **Correlation between cost changes and price changes.** A related empirical implication is that there is a greater correlation between cost changes and price changes on the way up than on the way down. Buckle and Carlson (1998) survey New Zealand businesses and ask them in separate questions whether prices were raised or lowered in a particular quarter; and whether costs increased or decreased. They find that price and cost increases paired more frequently in the same quarter than price and cost decreases.

☐ **Frequency and size of price changes.** Our model also suggests that price decreases are less frequent than price increases; and that the absolute value of price increases is smaller than the absolute value of price decreases. The empirical evidence seems consistent with this prediction. See Klenow and Kryvstov (2008) for the U.S. and Dhyne et al (2004) for the Euro area.

☐ **Asymmetry in the small.** In our revised model, the asymmetry in frequency of price changes results from the fact that small cost decreases lead to no change in price. More generally, we expect that the asymmetry in rates of price adjustment is particularly high for small cost changes. Levy et al (2005) present evidence that seems consistent with this prediction. Analyzing scanner data that cover 29 product categories over a eight-year period from a large Mid-western supermarket chain, they show that small price increases occur more frequently than small price decreases; no such asymmetry is found for larger price changes.

5. Conclusion

Much of the current literature on price rigidity is based on the idea of menu costs. However, in order to fit the stylized facts on price rigidity the required size of menus costs is rather high. In this paper, we present a consumer search theory of price rigidity that does not require menu costs. To some extent, one may reinterpret the idea of menu costs to include a decrease in seller profit resulting from price change. In this broad sense, our model does feature menu costs. However, such loose interpretation of menu costs is of little help: the size of such menu cost is not fixed as in the traditional physical menu cost case; in particular, it will be different depending on whether price increases or decreases.

Appendix

■ **Derivation of upper bound on γ.** Conditional on observing no price change, the posterior that there has been a cost shock is given by

$$\frac{\Big(1 - c''(c_{i1})\Big)\ \gamma}{\Big(1 - c''(c_{i1})\Big)\ \gamma + 1 - \gamma}$$

Conditional on a cost shock, the expected extra surplus in case of search is given by

$$\left(\int_0^{c'} \mu\big(p^m(x)\big)\ d\,x + \Big(c''(c_{i1}) - c'\Big)\ \mu\Big(p^m(c')\Big) + \Big(1 - c''(c_{i1})\Big)\ \mu(p_1)\right) - \mu(p_1) =$$

$$= \int_0^{c'} \mu\big(p^m(x)\big)\ d\,x + \Big(c''(c_{i1}\Big) - c'\big)\,\mu\Big(p^m(c')\Big) - c''(c_{i1})\ \mu(p_1)$$

The no-search condition thus becomes

$$\frac{\Big(1 - c''(c_{i1})\Big)\ \gamma}{\Big(1 - c''(c_{i1})\Big)\ \gamma + 1 - \gamma}$$
$$\left(\int_0^{c'} \mu\big(p^m(x)\big)\ d\,x + \Big(c''(c_{i1}) - c'\Big)\ \mu\Big(p^m(c')\Big) - c''(c_{i1})\ \mu(p_1)\right) \le s$$

Assuming $a = 2, s = 1/200$ and $c_{i1} = c_{j1} = \frac{1}{2}$, we get $\gamma < \gamma^\circ \approx .133$. If $s = 1/100$, then $\gamma < \gamma^\circ \approx .266$; if $s = 1/20$, then $\gamma < \gamma^\circ \approx .979$. ■

Proof of Proposition 2: We now show that the above strategies constitute a Bayesian equilibrium. For low values of c, the seller's strategy is similar to Section 3. As before, we have threshold levels c' and c''. One difference is that, by observing a price lower than p_{i1}, consumers believe costs to be distributed in $[0, c_{i1}]$. This implies greater expected benefits from searching. As a result, we obtain lower values of c', c'' than in Section 3.

Now suppose that p_{i2} is greater than, but close to, p_{i1}. Given the sellers' pricing strategy, buyers infer that costs are uniformly distributed in $[c_{i1}, 1]$. By searching, a buyer receives an expected surplus

$$\frac{1}{(1 - c_{i1})}\ \left(\int_{c_{i1}}^{c} \mu\big(p^m(x)\big)\ d\,x + (1 - c_{i1})\ \mu\big(p^m(c)\big)\right).$$

where c is the cost level such that $p = p^m(c)$. 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

$$R(c) = \frac{(a - c_{i1})^3 - (a - c)^3}{24\, c_{i1}} + \frac{(a - c)^2\,(c_{i1} - c)}{8\,(1 - c_{i1})}.$$

The derivative of this expression with respect to c is given by $\frac{(a-c)\,(c-c_{i1})}{4\,(1-c_{i1})}$, which is positive. Moreover, $R(c_{i1}) = 0$. It follows that there exists a value of c greater than c_{i1} such that the net benefit from search is equal to the search cost. Let c''' be such value, that is, $R(c''') = s$. It follows that, for $p_{i1} < p_{i2} \leq p^m(c''')$, consumers are better off by not searching.

By the same token, if $p_{i2} > p^m(c''')$, then consumers prefer to search. The fact $p_{i2} > p_{i1}$ signals that costs are uniformly distributed in $[c_{i1}, 1]$, 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. Regarding the seller's strategy, the argument is essentially identical to Section 3. ■

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