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A THEORY OF PRICE INERTIA

by

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ABSTRACT

I present a theory of price inertia in a market characterized by dual informational frictions. At the firm specific level, buyers must invest in costly search to learn the price of any seller. At the aggregate level, there is imperfect information about inflation. Thus, knowledge of a particular seller's nominal price only imperfectly conveys its real price. However, buyers can resolve aggregate uncertainty in advance of trade by acquiring additional information from an external source at a small cost. In equilibrium, buyers in fact do become informed. Thus, all market participants are well informed in advance of trade. Nevertheless the equilibrium price of the search good is unresponsive to inflation.

1 INTRODUCTION

Much of the "new" Keynesian macroeconomics emphasizes the role of nominal price rigidities in monopolistically competitive markets (e.g., Akerloff and Yellen (1985), Benabou (1988), Blanchard and Kiyotaki (1987), Mankiw (1985), Parkin (1986), Rotemberg (1987), Sheshinski and Weiss (1977)).

According to this view, real costs of changing prices may keep nominal prices from adjusting to inflation. Both casual observation and formal research support this view. For example, Cachetti (1986) found that the real prices of newsstand magazines eroded by as much as twenty five percent before increasing and Kashyap (1991) reports similar findings for prices in retail catalogue. And in his survey of firms, Blinder (1991) finds the mean interval between adjustments to be as long as one year.

But why are prices costly to change ? Taken literally, adjustment costs are the resources required to print new menus and catalogues, post new price lists and so on. But it is hard to believe that such apparently minor costs could have significant effects. Therefore it is often informally argued that these costs should be interpreted more metaphorically to include the time it takes consumers to become informed about inflation, and the customer annoyance caused by frequent price changes (e.g., Okun, 1975).

The objective of this paper is to develop an information theoretic model in which an *endogenously* determined cost keeps some prices from responding to general inflation. The theme of the model is inspired by the following tale. Consider a consumer who is in the market for a widget but is uncertain about the rate of inflation. Upon visiting the local widget shop, she finds the price to be rather high but is assured by the seller that its own price has merely increased to keep up with inflation. In other words, it would have the buyer believe that only its nominal price, not its relative price, has increased. A rational buyer should be sceptical about the veracity of this claim, recognizing that it is in the seller's interest for her to believe this. A natural reaction to this scepticism is to sample other widget sellers to determine whether the observed price hike does indeed reflect general inflation or is specific to that seller. Such a tendency towards more intensive consumer search under uncertain inflation intensifies competition for consumers and may lead firms to absorb inflationary cost increases without raising prices.

This model formalizes this idea. Consumers divide their income between a competitively supplied good and a "search" good. In the market for the latter, consumers must invest in costly search to learn about individual sellers' prices. As is well known, this market friction can endow sellers with substantive market power (*e.g.*, Diamond, 1971). Consumers face additional uncertainty with respect to general inflation so that the observed nominal price of the search good only imperfectly reveals its real price. In these circumstances, there generally exists a plethora of "pooling" equilibria in which the price of the search good is independent of actual inflation.

However, it turns out that the addition of the following feature produces a *unique, "sticky price"* equilibrium. Suppose that although consumers are imperfectly informed about inflation *ex ante*, there exists an independent reliable source of information (*e.g.*, published economic data) which consumers may consult at a cost to become perfectly informed, before buying. When this cost is sufficiently small, the nominal price of the search good is unaffected by inflation. This is the case even if consumers become perfectly informed in advance of trade. Thus even a *potential* informational friction may cause price inertia.

It is shown that this result is related to a potentially novel role of search in this setting. In conventional search models, the only reason for consumer search is to discover cheaper prices. In other words, the purpose of search is to discover *differences* between sellers. In the context of this paper, however search may confer an additional benefit: If sellers are privately informed about the aggregate state, their prices may *collectively* reveal information about the the *real* price of the search good. In other words, in this context, search may be of value in learning more about what sellers have in *common*. The resulting increased propensity to search leads firms to vie for customers by absorbing cost increases without raising prices.

By emphasizing the informational role of prices, this paper links to other recent papers on the real effects of inflation with a related perspective, especially Benabou and Gertner (1992), Dana (1992) and Fishman (1992), who analyze the responsiveness of prices to costs in search markets wherein individual prices are affected by both general inflation and idiosyncratic shocks which consumers cannot perfectly unravel. While those papers build upon an assumed relationship between aggregate and idiosyncratic shocks, this essay shows that even a "pure" inflationary episode, which affects all agents symmetrically, may, because of informational frictions, have important real consequences

2 PRELIMINARIES

An economy produces two consumption goods which consumers regard as imperfect substitutes. The first good is produced competitively, i.e., is sold at cost. The other good is sold in a "search market" in which consumers are imperfectly informed about prices. Specifically, in this market, a consumer must bear a search cost of $c > 0$ to learn the price of any individual seller. The search "technology" is sequential; each search reveals exactly one (randomly selected) price at a time.[1] As is well known, and as shall be elaborated upon at length below, this market friction generally endows firms with substantive market power. The product sold in the search market is referred to as the "search good". For simplicity, assume there are only two firms in the search market.

The government controls the economy's sole factor of production and sets the nominal price at which it is sold to producers. Both the competitive good and the search good are produced by an identical constant returns to scale technology, in which one unit of input produces one unit of output.

Consumers receive endowments of fiat money at each period, which they allocate between the two consumption goods.

The state of the economy is described by a random variable θ which can assume one of two values: $\theta = l$ (*low*) with probability β and $\theta = h$ (*high*) with probability $1-\beta$, $h > l$.

The state θ determines both the consumers' nominal income and the cost of production as follows. The consumers' endowment is determined as θm, $m > 0$, and the cost of hiring a unit of the factor of production is θw, $w > 0$. Thus, the price of the competitive is "linked" to nominal income.

There are two periods. At the first period, $\theta = l$ and all market participants are perfectly informed. At the second period, as is more fully specified below, consumers are uncertain if θ is unchanged or has increased to h. A low realization ($\theta = l$) at the second period corresponds to zero inflation and a high realization ($\theta = h$) to positive inflation.

Let η be the posterior probability a consumer assigns to $\theta = h$ when purchasing the search good. The greater η, the greater the consumer's nominal income and the higher the expected nominal price of the competitive good. Accordingly, for a given nominal price,

[1]It is immaterial for the analysis whether search is with recall (consumers can costlessly return to buy from a previously sampled store after sampling other prices) or not.

demand for the search good is increasing in η. More specifically, let $q_\eta(p)$ be the quantity of the search good demanded by a consumer who believes that $\theta = h$ with probability η when the lowest available price is p and assume that $q_\eta(p)$ is continuous and differentiable in p and η. Then for $\eta \in [0,1]$, $\partial q_\eta(p)/\partial p < 0$ and $\partial q_\eta(p)/\partial \eta > 0$.

I make the following additional assumptions about the demand function $q_\eta()$. Let $\pi_\theta(p,\eta) = (p - \theta w)q_\eta(p)$, $\theta = l,\ h$. $\pi_\theta(\cdot,\cdot)$ is the profit function of a monopoly firm with marginal cost θw, facing the demand curve $q_\eta(\cdot)$. It is assumed that for each θ and η, $\pi_\theta(\cdot,\eta)$ is concave, attaining a unique maximum at $p^*(\eta,\theta)$ with $\partial p^*/\partial\eta > 0$, and $p^*(\eta,h) > p^*(\eta,l)$.

Note that since marginal costs are constant, the optimal (monopoly) price is independent of the number of buyers.

For notational convenience let

$p_l = p^*(0,l)$, $q_l = q_0(p_l)$

$p_h = p^*(1,h)$, $q_h = q_1(p_h)$

p_l and p_h are the complete information monopoly prices corresponding to $\theta = l$ and $\theta = h$ respectively, and q_l and q_h are the corresponding quantities (per consumer) demanded at these prices, $p_h > p_l$. We shall also assume that $p_l \geq hw$. That is, p_l covers production costs and is therefore a viable price for any realization of θ. I frequently refer to a firm in the state $\theta = l$ ($\theta = h$) as a low cost (high cost) firm.

2.1 Neutrality:

Under conditions of complete information, nominal changes should not affect demand for the search good if all prices and incomes are increased by the same proportion. Specifically, let $\delta = h/l$. Then for all $p : q_0(p) = q_1(\delta p)$.

2.2 The Value of Information

Information about θ is valuable to a consumer because it enables her to determine the "correct" quantity of the search good to buy. Specifically, a consumer who believes that $\theta = h$ with probability η, $0 < \eta < 1$, is certain to demand the "wrong" amount of the search good. This is because, were she perfectly informed, she would demand $q_0(p) < q_\eta(p)$ when $\theta = l$ and $q_1(p) > q_\eta(p)$ when $\theta = h$. Therefore, additional information about θ is of value to her in determining how much of the search good to buy at the lowest available price. Accordingly, denote by $V(\eta, p)$ the value of perfect information about θ to the consumer whose beliefs are described by $0 < \eta < 1$ when the lowest available price is p. It is assumed that $V(\eta, p) > 0$ for $0 < \eta < 1$, and goes to zero as $\eta \to 0$ or $\eta \to 1$.

2.3 The Sequence of Events

All market participants are costlessly informed that $\theta = l$ at the beginning of the first period. Events then transpire as follows. Firms selling the search good simultaneously set prices. Then each consumer costlessly observes the price of one firm at random. At this point she may either buy at this price or search to learn the other seller's price.

At the second period, only firms are informed about the realization of θ; consumers are imperfectly informed and put the prior probability β on $\theta = h$. It is shown in the appendix that this assumption, that firms are better informed than consumers, is inessential for the main results. Otherwise, the order of events at the second period are the same as in the first period. Consumer demands for the search good at the two periods are independent.

I solve for the Bayesian perfect equilibrium prices at the two periods, restricting attention to symmetric, pure strategy equilibria.

3 Equilibrium Under Complete Information

To appreciate the role of uncertainty about θ, it is important to understand the equilibrium that obtains under complete information. As is well known, (Diamond, 1971), under conditions of complete aggregate information, the only equilibrium price is the monopoly price: p_l if $\theta = l$ and p_h if $\theta = h$. Because of its importance for the analysis of the next sections, I review the proof of this result. The following arguments apply to the case $\theta = h$; entirely analogues arguments apply if $\theta = l$.

The first step is to show that the monopoly price is indeed an equilibrium. Suppose that p_h is the equilibrium price. Since consumers are perfectly informed about θ, their only motive for search can be to buy at a lower price (they cannot expect to learn more about the state by sampling a second price). A buyer who is charged p_h expects the other firm's (as yet unobserved) price to be p_h as well. Thus her expected cost saving from search is zero. Since search is costly, she optimally accepts the first price without further search. Conversely, since p_h is the best possible price from the sellers' perspective and since consumers accept this price without further search, it is individually optimal for each firm. Thus p_h is an equilibrium.

The next step is to show that no other price is an equilibrium. Let $U(p)$ denote the consumer's utility from buying the search good at price p, where $U(\cdot)$ is continuous and decreasing in p. Suppose the equilibrium price is $p' < p_h$ and a firm unilaterally deviates to $p' + \epsilon$, $\epsilon > 0$, $p' + \epsilon \leq p_h$. Before observing any prices, a consumer expects each firm's price to be p'. If the first price she observes is $p' + \epsilon$, her expected value of search depends on how her beliefs about the other firm's price are affected by the deviation. If she continues to believe that the other firms price is p', her expected return form search is $U(p') - U(p' + \epsilon)$. If ϵ is chosen sufficiently small that $U(p') - U(p' + \epsilon) \leq c$, it is optimal for this consumer to accept $p' + \epsilon$ rather than search. Thus the deviant to $p' + \epsilon$ loses no customers. Since profits per customer are concave in the price, and the number of customers is undiminished, the deviation is profitable. Another possibility is that the observed deviation to a higher price by one firm leads the consumer to revise her beliefs and expect the other seller's price to also be greater than p'. If so, the preceding argument holds a fortiori.[2] To summarize:

Proposition 1: Under conditions of complete aggregate information, the only equilibrium price is p_l if $\theta = l$ and p_h if $\theta = h$.

Thus, in particular, the price of the search good at the first period is p_l.

4 Equilibrium Under Incomplete Information

The equilibrium of proposition 1 does not obtain at the second period, when information is incomplete. If it did, the price of the search good would fully reveal the state; that is, if the price is p_l , consumers would infer that $\theta = l$ and demand q_l, and if the price is p_h, they would infer that $\theta = h$ and demand q_h. By neutrality $q_h = q_\ell$.[3] Thus the profit (per

[2]The only instance in which this argument fails is if an observed deviation to a higher than equilibrium price by one seller leads the consumer to expect that the other firm's price is significantly less than p_ℓ. Such "perverse" equilibria are excluded by restricting out-of-equilibrium beliefs so that a consumer who observes a deviation to a higher than equilibrium price by one seller cannot expect a lower price at the other seller. It should also be noted that the consistency criterion of sequential equilibrium (Kreps and Wilson, 1982) requires that an observed deviation by one seller not affect consumers' beliefs about the other seller's price. Therefore the monopoly price is the only sequential equilibrium.

[3]By definition, $p_\ell = \arg\max\{(p - \ell\bar{w})q_0(p)\}$. Thus p_ℓ must satisfy the first-order condition: (i) $q_0(p_\ell) + q_0'(p_\ell)(p_\ell - \ell\bar{w}) = 0$. Similarly, $p_h = \arg\max\{(p - h\bar{w})q_1(p)\}$ and must satisfy (ii) $q_1(p_h) + q_1'(p_h)(p_h - h\bar{w}) = 0$. Neutrality implies that if p_ℓ satisfies (i), then $p_h = \delta p_\ell$ must satisfy (ii). Since p_ℓ and p_h are unique, this

customer) from charging p_h is $p_h q_h$ while the profit from charging p_l is only $p_l q_h < p_h q_h$. It would therefore be profitable for the firms to charge p_h in each state. Indeed, an analogous argument shows that *no* separating equilibrium in which the high state price is less than or equal to p_h can exist (see proposition 5). Thus there are two possibilities. Either there exists an alternative separating equilibrium in which the high state price is greater than p_h or the equilibrium price is invariant with respect to θ and hence reveals nothing about it - a pooling equilibrium. I discuss the former possibility below. Here I focus on pooling equilibria.

Unfortunately, a plethora of such equilibria exist.

Proposition 1 *There exists $c^* > 0$ such that for $c < c^*$, any price $\tilde{p} \in [p_l,\ p^*(\beta, l)]$ is a pooling equilibrium (recall that $p^*(\beta, l)$ is the monopoly price in the low state when consumers assign the prior probability β to the high state)*

Proof: Suppose $\tilde{p}$ is the equilibrium price. Since $\tilde{p}$ is independent of the state, a consumer who observes $\tilde{p}$ must maintain her prior beliefs. Therefore the profit of a low cost (high cost) seller is $\pi_l(\tilde{p}, \beta)(\pi_h(\tilde{p}, \beta))$ if its price is $\tilde{p}$. Let consumers' out of equilibrium beliefs be that $\theta = l$ with probability 1(or high enough probability) if the price is greater than $\tilde{p}$. If such a consumer observes a price greater than $\tilde{p}$, she expects to receive $U(\tilde{p}, l)$ by searching (assuming the other firm adheres to the equilibrium price). Let Δ satisfy: $U(\tilde{p}, l) - U(\tilde{p} + \Delta, l) = c$. Δ is increasing in c and goes to zero as c goes to zero. A firm whose price is greater than $\tilde{p} + \Delta$ earns zero profit. The profit of a low cost seller whose price is p', $\tilde{p} + \Delta > p' > \tilde{p}$ earns $\pi_l(\tilde{p} + \Delta, l)$, which, by continuity, must be less than $\pi_l(\tilde{p}, \beta)$, for small enough Δ (i.e., small enough c). The profit from $p < \tilde{p}$ is at most $\pi_l(p, \beta) < \pi_l(\tilde{p}, \beta)$, by concavity of the profit function (since $\tilde{p}$ is nearer to $p^*(\beta, l)$ than p). An analogous argument applies to a high cost seller. ■

proves that $p_h = \delta p_l$.

The objective of the following section is to modify the model in a way which eliminates the multiplicity of pooling equilibria.

5 Exogenous Information

Suppose that although consumers are uninformed ex ante, there exists an independent reliable source of information which consumers can consult at a cost of $s > 0$ to become perfectly informed about θ. This seems like an appropriate description of a modern economy in which statistics about the economy are available. I thus modify the (extensive form) game as follows. After observing her first price, a consumer chooses between three options: to buy at that price without becoming informed, to search, or to become informed before deciding whether to search, buy or leave the market. Consumers can also become informed after observing both prices.

The following proposition states that if the cost of information is sufficiently small, p_l is the only possible pooled price.

Proposition 2 *There exists $s^* > 0$ such that if $s < s^*$, p_l is the only possible pooled price.*

Proof: Let $\bar{p} > p_l$ satisfy: $\pi_\ell(\bar{p}, \beta) = \pi_\ell(p_l, 0)$. Similarly, let $\underline{p} < p_l$ satisfy: $\pi_\ell(\underline{p}, \beta) = \pi_\ell(p_l, 0)$. Then, for $p > \bar{p}$ and $p < \underline{p}$, concavity of the profit function implies $\pi_\ell(p, \beta) < \pi_\ell(p_l, 0)$. Suppose there exists a pooled equilibrium price, $p' \neq p_l$, $p' > \bar{p}$ or $p' < \underline{p}$. The profit from charging p' when $\theta = \ell$ is $\pi_\ell(p', \beta)$, if consumers do not become informed and $\pi_\ell(p', 0) < \pi_\ell(p', \beta)$ if they do. Since the profit from deviating to p_l when $\theta = \ell$ is at least $\pi_\ell(p_l, 0)$, such a price cannot be an equilibrium price for any s. Thus only $p \in [\underline{p}, \bar{p}]$ are equilibrium candidates. Corresponding to such p, there exists s^* such that: $V(p, \beta) > s^*$ for all $p \in [\underline{p}, \bar{p}]$. Consider a pooled price $p'' \in [\underline{p}, \bar{p}]$. Consumers who observe p'' must retain their priors and, consequently, become informed about θ before buying. Thus, the profit from p'' when $\theta = l$ is $\pi_\ell(p'', 0)$. But the profit from charging p_l when $\theta = l$ is at least $\pi_\ell(p_l, 0) > \pi_\ell(p'', 0)$. This proves that if $s < s^*$, the only possible pooled price is p_l. ■

The preceding proposition has only excluded prices other than p_l. It remains to see whether and under what conditions p_l *is* an equilibrium.

Proposition 3 *There exists c^* such that for $c < c^*$, p_l is an equilibrium price for any $s >$ 0.*

Proof: The proof is similar to the proof of proposition 2. Suppose that a consumer who observes a price greater than p_l believes that $\theta = l$ with probability 1 (or sufficiently high probability). If such a consumer is charged more than p_l, she will not pay for costly information (since she considers herself to be informed) and consequently demands $q_0(p_l)$. If she observes p_l, on the other hand, she retains her prior beliefs and, consequently, either becomes informed, demanding $q_h(p_l)$ in the high state and $q_0(p_l)$ in the low state, or does not become informed and demands $q_\beta(p_l)$ in each state. Thus a high cost seller's profit from p_l is either $\pi_h(p_l, 1)$ or $\pi_h(p_l, \beta)$, while a low cost sellers profit is either $\pi_l(p_l, 0)$ or $\pi_l(p_l, \beta)$. Let $p(c)$ be the highest price that can be charged without triggering search, where by already familiar arguments (cf. the proof of proposition 2), $p(c)$ is an increasing function of c that goes to p_l as c goes to zero. For small enough c, $\pi_h(p_l, 1), \pi_h(p_l, \beta) > \pi_h(p, 0)$, and $\pi_l(p_l, 1), \pi_l(p_l, \beta) > \pi_l(p, 0)$ for $p \leq p(c)$. ■

Combining propositions 3 and 4 gives p_l as the *unique* pooled equilibrium, if the informational frictions c and s are sufficiently small. Although p_l has been shown to be the unique outcome only if s is small, a robustness argument may be used to justify its selection even if s is large. Specifically, suppose it is required that the equilibrium be invariant to perturbations in the cost of information. Since p_l is the only price which is an equilibrium for *any* s, it is the only price that satisfies this criterion, and should therefore be selected as "the" equilibrium even when s is large enough to admit other equilibria.

The proof of proposition 4 supports p_l as an equilibrium by requiring that consumers associate higher prices with a lower expected realization of θ. Specifically, even if the cost of information is small enough that consumers become informed in equilibrium, a high cost seller is unable to charge more than p_l, lest its customers conclude that the state is low with sufficient confidence to obviate their demand for information. Is this plausible? To be sure, these beliefs satisfy popular "refinements", such as the "intuitive criterion" (Cho and Kreps, 1987)[4]. And note that our purpose in examining beliefs is not for the conventional one of equilibrium selection, since, in any case, proposition 2 establishes p_l as the only possible pooling equilibrium.

Nevertheless, requiring that buyers associate higher prices with lower general inflation seems perverse. If anything, a higher price should be taken as evidence of higher, not lower, inflation.

Therefore the goal of the following subsection is to explore whether p_l may be sustained by more natural beliefs, in which higher prices are associated with *higher* θ. I again emphasize that, since p_l is unique, this is only for the purpose of rendering the equilibrium more intuitive, and not for the purpose of equilibrium selection,

[4]That criterion requires of the pooling equilibrium that there exist no other price which is more profitable for the high cost seller but is unprofitable for the low quality seller under *any* beliefs. Such is clearly the case here.

5.1 FLEXIBLE BELIEFS

Suppose that the pooled price is p_l. Before having observed any prices, a consumer expects the price of the search good to be independent of θ and hence uninformative. Suppose the first price she observes is, contrary to expectation, $p' > p_l$. Might she not then reasonably question her original opinion, that prices are uninformative, and put some weight on the alternative hypothesis, that prices of the search good *are* in fact responsive to the state. In particular, it would be reasonable to update beliefs by assigning some probability, but less than 1, to the "separating hypothesis", that $p' > p_l$ is the price in the high state and p_l in the low state (for both firms) (particularly as, under complete information p_l is "naturally" associated with the low state)[5]. In the same vein, the observation of p' at *each* seller should increase the belief that prices are informative. This idea motivates the following definition:

Flexible Beliefs: Beliefs are said to be flexible if the following obtains. As long as she has not observed any deviations from p_l, a consumer believes that the price of the search good at either seller is independent of θ. In the wake of a **single** observed deviation to $p' > p_l$, she assigns the probability λ, $0 < \lambda < 1$, to the hypothesis that both firms charge p' iff $\theta = h$ (and p_l otherwise). If she observes p' at **both** firms she adopts this hypothesis with probability 1.

Thus, if the equilibrium price is pooled at p_l, a consumer with flexible beliefs who observes $p' > p_l$ increases her belief in the high state to $\lambda + (1-\lambda)\beta > \beta$ (by Baye's rule). And if she observes p' at both firms, she concludes that $\theta = h$ with probability 1. (It is not necessary for the following results that a "double deviation" increase the probability to 1,

[5]The consistency condition of sequential equilibrium (Kreps and Wilson, 1982) requires that a deviation by one seller not affect beliefs about the unobserved price. So the equilibrium based on flexible beliefs is not sequential.

only to a "sufficiently" high level).

Consider a consumer with flexible beliefs whose first price observation is $p' > p_l$. Having observed a single deviation, she expects an additional search to resolve her remaining uncertainty about θ with probability λ. This is because a second observation of p', which she expects with probability λ, will lead to the inference that $\theta = h$. Thus by charging more than p_l, a firm triggers a demand for additional price observations; not for the purpose of finding a lower price, but as corroborative evidence about the state. As the following proposition states, this can effectively deter unilateral price increases.

Proposition 4 *There exists $s^* > 0$, $c^* > 0$ and $\delta > 0$ such that if $c < c^*$, $s < s^*$ and $c/s < \delta$, then p_l is a pooled equilibrium price if consumers have flexible beliefs.*

Proof: If p_l is the equilibrium price, consumers accept this price without search (because they believe the other price is p_l as well). Suppose a firm unilaterally deviates to $p' > p_l$. That leads its customers to anticipate that by searching, and learning that the other firm's price is also p', they will become perfectly informed (and conclude that $\theta = h$). The probability with which they expect this to occur is λ. And with probability 1- λ, they expect the other seller's price to be p_l, lowering the purchasing cost from by p' - p_l. Thus, the value of search to the deviant's customers is at least[6]:

$$\Delta(p') = \lambda \cdot V(p', \lambda + (1-\lambda)\beta) + (1-\lambda)[U(p_l,\beta) - U(p',\beta)] - c,$$

where $\lambda + (1-\lambda)\beta > \beta$ is the posterior probability (by Baye's rule) a consumer assigns to $\theta = h$ after observing p' at one firm (before observing a second price). The first term on the RHS of the preceding equation is the expected value of search if it generates a second observation of p', the second its value if it does not. Let $p'' \in \arg\ \inf\{\Delta(p)\}$ for

[6]The value is exactly $\Delta(p')$ if a consumer who observes p_l at one store and p' at the other reverts to her prior beliefs. Otherwise the value is greater than $\Delta(p')$.

$p > p_l$ and let $\Delta(p'') = c^*$. Then if $c < c^*$, a consumer who observes $p > p_l$ will either search or become informed (from the external source) before buying. The utility from the latter option is $V(p', \lambda + (1-\lambda)\beta) - s$. Thus search is optimal if:

$$\Delta(p) > \max\{V(p, \beta) - s, 0\}.$$

If $c < c^*$ and s/c is sufficiently large, this inequality holds for every $p > p_l$. Then, a deviation to any $p > p_l$ triggers search and leads to zero profit. ■

Thus it is precisely because consumers with flexible beliefs *do* associate higher prices with higher inflation that sellers do not increase prices. Those consumers' response to a price increase is to sample a second price, to become better informed about θ. In particular, this motivation for search may be present even when the conventional one (of finding a cheaper price) is not, *i.e.* even when the cost of search exceeds the expected price difference between the sellers. Put differently, in our incomplete information environment, search may be perceived to be of value in discovering what the firms have in *common* — namely, the aggregate stimulus to which their prices respond- in addition to its conventional role of uncovering (possible) price differences. This dual role of search increases its value to consumers. In the face of this increased propensity to search, firms must absorb increased costs without raising prices.

5.2 ADDING A FRICTION ON THE SUPPLY SIDE

The previous section described out of equilibrium beliefs that can sustain p_l as an equilibrium price in each state. The purpose of this subsection is describe an alternative way of rationalizing p_l as an equilibrium, which does not depend on out of equilibrium beliefs. Specifically, it will be shown that p_l can be an equilibrium price even if deviations have no effect on consumers' beliefs, i.e., even if, regardless of what price is charged, consumers always maintain their prior beliefs about the state. Under these conditions, it cannot be a concern with the effect on consumers' beliefs that keep prices from increasing above p_l in the high state.

The new ingredient is a friction on the *seller's* side (in addition to the existing informational frictions on the buyers side); it is assumed that whenever its second period price differs from its first period price, a firm incurs a lump sum cost of k > 0 (which is independent of the price difference), such as the cost of printing new price tags, etc. This, of course, is the assumption underlying the menu cost literature (see the references in the introduction). The difference is that I consider *small* adjustment costs, which on their own - i.e., under complete information - would be inconsequential.

As above, assume that s is sufficiently small that no price but p_l can be a pooled price (it is easy to check that this result is unaffected by the inclusion of the menu cost). Thus, (since we're assuming that posterior beliefs always coincide with priors), consumers always become fully informed before buying. Let $p^l(c)$ and $p^h(c)$ be the highest price that consumers accept without search in the low and high states respectively: $U(p_l, \beta) - U(p^i(c), \beta) = c, i = l, h$. No firm will charge more than $p^i(c)$. Suppose the firms' first period price was p_l and its second period price is p, $p_l < p < p^i(c)$. Since consumers become informed before buying, the profit from p is: $\pi_l(p, 0) - \pi_l(p_l, 0)$ if $\theta = l$ and $\pi_h(p, 1) - \pi_h(p_l, 1)$ if $\theta = h$. Thus a low cost firm will not deviate from p_l even if k = 0. Consider a high cost seller. Let $\overline{k}$ be given by: $\pi_h(p_h, 1) - \pi_h(p_l, 1) = \overline{k}$. Then for $k < \overline{k}$, the second period price would be p_h under complete information. That is, under complete information only menu costs *larger* than $\overline{k}$ matter. Let $k(c)$ satisfy: $\pi_h(p^h(c), 1) - \pi_h(p_l, 1) = k(c)$. The left hand side of the preceding equation represents the most by which the high cost seller can increase its profit by changing its price from p_l, net of the menu cost (higher prices would trigger search). Then for $k < k(c)$, the optimal second period price is p_l. Since $k(c)$ is increasing in c and goes to zero as c goes to zero, even an arbitrarily small menu cost will prevent a price increase if the search cost is sufficiently small. Thus we have the following proposition:

Proposition 5 *To every $k > 0$, however small, there corresponds $c(k) > 0$, such that for $c < c(k)$, the second period price is p_l in each state, even if consumers' beliefs about the state are unaffected by observed prices.*

It is worth reemphasizing that this result depends on incomplete information. Under complete information, the firms retain full monopoly power as long as $k < \overline{k}$.[7]

5.3 THE REAL EFFECTS OF PRICE INERTIA

At any rate, whichever of the preceding explanations are adopted, p_l is the unique pooling equilibrium when s is sufficiently small, (i.e., $V(p_l, \beta) > s$). But that is not all. Since this price is uninformative and does not affect the consumers' beliefs, consumers actually become perfectly informed before buying, in equilibrium. Therefore, since p_l is a higher relative price in the low state than in the high state, output of the search good in the high state is greater than in the low state (as long as uncertainty persists). In spite of the fact that all aggregate uncertainty is resolved in advance of trade, the buyers' credible "threat" to search in response to a higher price keeps the price "sticky" at p_l in each state. Thus even a small amount of *potential* uncertainty, which consumers resolve in equilibrium, can produce price

[7]The preceding assumes that the first period price was p_l. When price changes are costly, the optimal first period price must take future pricing into account. Let $p' \in \arg\max(\beta\pi_h(p,1) + (1-\beta)\pi_h(p,0),\ p < p(c)$. Then, given that the second period equilibrium price is p_l,the optimal first period price is either p_l or p'. If β (and/or the discount factor) is sufficiently small, p_l is the optimal first period price under these conditions.

inertia.[8]

6 SEPARATING EQUILIBRIA

The preceding analysis has only been concerned with pooling equilibria. Separating equilibrium also exist. Those are characterized by the following proposition.

Proposition 6 *Separating equilibria exist. In any separating equilibrium, the price corresponding to $\theta = l$ is p_l and the price corresponding to $\theta = h$ is greater than p_h.*

Proof: I shall first prove the first statement- that the price corresponding to $\theta = l$ is p_l.

Let p' be the price in the low state, $\theta = l$. Suppose $p' > p_l$. Then, since p' is perfectly revealing, the seller's profit per customer from adhering to p' is $\pi_l(p', 0)$. A deviant to p_l loses no customers whether or not its customers search because $p_l < p'$. Therefore, if the deviation does not affect its customer's posterior beliefs about θ, its profit per customer is increased to $\pi_\ell(p_l, 0) > \pi_\ell(p', 0)$, where the inequality follows from the definition of p_l. If the deviation affects the consumers' posterior beliefs about θ, the posterior probability assigned to $\theta = h$ must be positive, say $\eta' > 0$. In that case, the profit per customer is increased even further to $\pi(p_l, \eta') > \pi(p_l, 0)$. Thus $p' \leq p_l$. Suppose $p' < p_l$. There exists $\epsilon > 0$ sufficiently small that a unilateral deviation to $p' + \epsilon \leq p_l$ does not trigger search and thus does not lead to the loss of any customers. If the deviation to $p' + \epsilon$ does not affect buyer's beliefs

[8] It is interesting to consider this result in light of the popular trend to dismiss the importance of the nominal misperceptions model (Lucas 1972). According to that view, with the amount of detailed aggregate data that is available in modern economies, informational frictions cannot have significant real effects. This model suggests to the contrary that even an apparently insignificant informational friction can be important.

about θ, then, the deviant's profit per customer is increased to $\pi_\ell(p' + \epsilon, 0) > \pi_\ell(p', 0)$ by the concavity of $\pi_\ell(\cdot, 0)$. If posterior beliefs are affected, profit per customer is raised even further. Thus $p' = p_l$. This completes the proof of the first statement.

Let $\hat{p}$ be the price that corresponds to $\theta = h$ in the separating equilibrium. Then in the symmetric separating equilibrium, both firms charge $\hat{p}$ if $\theta = h$ and p_l if $\theta = l$. Therefore if the first price a consumer observes is $\hat{p}$, she must infer that $\theta = l$ and that the other firm's price is identical. Similarly, she must infer that $\theta = l$ if her first price is p_l. Thus if $\theta = l$, profit per customer from p_l is $\pi_\ell(p_l, 0)$ in the low state and $\pi_h(p_l, 0)$ in the high state. Similarly its profit from charging $\hat{p}$ in the high state is $\pi_h(\hat{p}, 1)$ and $\pi_\ell(\hat{p}, 1)$ in the low state. In equilibrium it must be individually optimal for the sellers to charge the appropriate price in each state. That is, it is required that

(i) $\pi_\ell(p_l, 0) \geq \pi_\ell(\hat{p}, 1)$

(ii) $\pi_h(\hat{p}, 1) \geq \pi_h(p_l, 0)$.

Neutrality implies (see footnote 2) that (i) cannot obtain if $p_l < \hat{p} \leq p_h$. Therefore either $\hat{p} > p_h$ or $\hat{p} < p_l$. The latter possibility may be ruled out with the aid of figure 1. There $\pi_\ell(p_l, 0)$ is represented by the sum of the areas of the rectangles A, B and D, $\pi_h(p_l, 0)$ by A and B, $\pi_\ell(\hat{p}, 1)$ by B, C, D and E and $\pi_h(\hat{p}, 1)$ by B and C. Thus $\pi_h(\hat{p}, 1) \geq \pi_h(p_l, 0)$ implies that $C \geq A$, while $\pi_\ell(p_l, 0) \geq \pi_\ell(\hat{p}, 1)$ implies that $C + E \leq A$, a contradiction. Thus $\hat{p} > \hat{p}_h$. This completes the proof. ∎

- Figure 1 here -

So in separating equilibria, the price of the search good "overshoots" the rate at which the rest of the economy is inflating, in the high state (recall that the "neutral" price of the search good in the high state is p_h). That is, in this equilibrium, output of the search good is decreased in the high state (compare with proposition 4 in the case of the pooling equilibrium). Thus inflation is not neutral in either the pooled or the separating equilibrium.

The separating equilibrium may be criticized on the grounds that, since the high state separating price is greater than p_h, *both* sides of the market would prefer a lower price in the high state. In other words, once the high price "reveals" the state, a firm could offer a mutually beneficial price reduction to p_h. This argument does not apply to the "sticky" price, pooled outcome, since consumers would not agree to a higher price.

Remark: Equilibrium "refinements", such as the "intuitive criterion" (Cho and Kreps) argue in favor of separating equilibria if there exists a price which is not optimal for the low cost seller under *any* consumer beliefs. Thus the high cost seller could convincingly "separate" out of the pooling price, p_l, by charging a price, such as $\widehat{p} > p_h$, defined in the proof of proposition 7, which is unprofitable for the low cost seller to mimic under any circumstances. The reason this argument does not work against the sticky price equilibrium in this model is that, while such a deviation might be persuasive about the state, it triggers search if the search cost is small enough. Thus, given the sticky price equilibrium, a high cost seller has no incentive to "break out" of it.

7 CONCLUSION

I have presented a model of nominal price inertia in a market characterized by dual frictions. At the individual firm level, it is costly to learn the nominal price of any specific seller. At the aggregate level, there is ex ante uncertainty about inflation, so that knowledge of a seller's nominal price only imperfectly imparts its relative price. Buyers may resolve this uncertainty by purchasing additional information from an external source. And, if this cost is sufficiently small, all market participants are perfectly informed at the time of trade. Nevertheless the price of the search good is unresponsive to an increase in the general price level. This result was rationalized in two ways. The first appeals to the way price increases affect the consumers' demand for additional price observations as a possible source of information about general inflation. This constitutes a credible threat which discourages price increases even when warranted by increased production costs.

The second way in which the sticky price outcome was rationalized was by showing that even arbitrarily small costs of changing prices prevent price increases for correspondingly small search costs.

8 APPENDIX

The purpose of this appendix is to show that the main result of this paper holds even if the initial information available to firms and consumers is identical. Suppose that sellers are initially uninformed but, like buyers, have the option of becoming informed at a cost of s. This adds the following stage to the extensive game. Before posting prices, the sellers decide whether to become informed. Subsequently, events unfold as described in the text. Now suppose the pooled price is $\widetilde{p} > p_l$ and s is sufficiently small that buyers become informed in equilibrium (*i.e.* $V(\widetilde{p}, \beta) > s$). By adhering to $\widetilde{p}$, the seller's profit per customer is $\pi_\ell(\widetilde{p}, 0)$ if $\theta = l$ and $\pi_h(\widetilde{p}, 1)$ if $\theta = h$. Suppose that a seller learns that $\theta = l$. By already familiar arguments, it is optimal for this seller to reduce its price to p_l. Thus, if there are N consumers, the expected value to the seller of learning the state (and deviating to p_l if the state turns out to be low) is at least:

$$Y(\widetilde{p}, s) = \tfrac{N}{2}(1-\beta)\{\pi_\ell(p_l, 0) - \pi_\ell(\widetilde{p}, 0)\} - s.$$

Therefore $\widetilde{p}$ can only be an equilibrium price if sellers optimally choose not to become informed, i.e., if $Y(\widetilde{p}, s) \leq 0$. Clearly, $Y(\widetilde{p}, s) \leq 0$ implies that $\widetilde{p} \rightarrow p_l$ as $s \rightarrow 0$. Thus, the unique limit equilibrium price as $s \rightarrow 0$ is p_l.

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