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INFLATION AND THE INFORMATIVENESS OF PRICES

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ABSTRACT

This paper studies the welfare effects of the relative price variability arising from inflation. When agents interact in anonymous markets, with customers buying from new suppliers each period, relative price variability benefits customers and cannot harm suppliers substantially. But if customers and suppliers form long-term relationships, prices have an informational role: a potential customer uses current prices as signals of future prices. Inflation reduces the informativeness of current prices, causing customers to make costly mistakes about which relationships to enter. In addition, the reduced informativeness of prices makes demand less price-elastic, thereby increasing markups. Both effects can be quantitatively significant at moderate inflation rates.

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I. INTRODUCTION

Although inflation is widely viewed as a major economic problem, economists have yet to give a clear account of why it is costly. An appealing but vague theme in many discussions is that inflation reduces the efficiency of the price system. Relative prices are the tools with which the invisible hand guides the economy to efficient allocations. When inflation occurs, prices do not rise in tandem; instead, different nominal prices adjust at different times. Thus relative prices deviate from the levels dictated by fundamentals. As Fischer (1981) puts it, "inflation is associated with relative price variability that is unrelated to relative scarcities and hence leads to misallocations of resources." This paper asks whether this idea can explain important welfare losses from inflation.

Relative price variability potentially harms both the suppliers who set prices and sell goods and the customers who purchase the goods. It is not plausible, however, that the losses to price setters are large. Price setters have an inexpensive means of stabilizing relative prices: they can simply adjust nominal prices more frequently. Thus the amount of relative price variability that suppliers permit cannot impose significant losses on them. We therefore focus on whether relative variability arising from firms' infrequent adjustment can impose large losses on consumers.

We reach two main conclusions. First, inflation does not have significant welfare costs if agents interact in anonymous markets, with consumers searching for a new supplier each time they buy a good. Indeed, inflation raises consumer welfare in this case. With anonymous markets, prices have only an allocational role: consumers seek to buy goods at the lowest possible price. In this setting, consumers benefit from relative price variability because it creates opportunities for substitution toward low-price goods.

Second, the costs of inflation can be large if suppliers and customers form long-term relationships. In this case, prices have not only an allocational role but also an informational role: potential customers use current prices as signals of future prices during a relationship. When inflation causes relative prices to vary, the information content of prices is eroded. We find that less informative prices can reduce consumer welfare considerably.

The remainder of the paper consists of six sections. Section II presents our basic model. Firms sell a good to consumers who participate in the market for either one or two periods. Firms differ in their costs of production, and consumers differ in their tastes for the good. When a consumer enters the market, he meets a firm, observes its current price, and chooses whether to buy the good. The aggregate price level rises steadily, and firms adjust nominal prices every two periods. A firm's relative price alternates between a higher level when it adjusts and a lower level when it does not.

Section III considers the case in which consumers buy from a firm for only one period, and shows that the relative price variability arising from inflation raises consumer welfare in this situation. In Sections IV and V, consumers buy from a firm for two periods. In this case, price variability does not create opportunities for substitution, because a long-term customer cannot buy from a firm only when its price is low. More important, consumers now use a firm's price at the start of a relationship as a signal of the average price over the relationship. Greater price variability increases the noise in the initial price relative to the signal, and thus reduces the informativeness of prices. This information loss harms consumers through two channels. First, since estimates of average prices become less precise, consumers make mistakes about which long-term relationships to enter. Second, since prices become less informative, they have less influence on consumers' decisions: demand becomes less price-elastic. With less elastic demand, average markups rise, harming consumers further. We show that both of these costs of relative price variability can be quantitatively significant.

Section VI turns from the welfare costs of relative price variability to a related question: why do firms allow relative prices to vary through infrequent nominal adjustment? Once again, the distinction between one-time and long-term relationships is crucial. With one-time relationships, price variability implies variability in sales. For plausible demand and cost functions, sales variability reduces firms' profits significantly, creating a strong incentive for more frequent adjustment. Thus the model with one-time purchases fails to explain not only why price variability harms consumers, but also why firms allow variability to occur in the first place. With long-term relationships, by contrast, sales remain steady as a firm's price fluctuates. In this setting, firms may gain little or nothing from stabilizing relative prices, and thus may adjust nominal prices infrequently.

Finally, Section VII discusses our results and the related literature. The informal discussions of inflation by Okun (1975), Wachter and Williamson (1978), and Carlton (1982) emphasize long-term customer relationships and the informational role of prices. Our results capture some of their ideas. In contrast, our analysis departs from the leading formal models of inflation and relative price variability (for example, Benabou [1988, 1991], Diamond [1988], and Benabou and Gertner [1991]). These papers consider one-time purchases, and thus cannot capture the factors that are central to our analysis. A recent exception is Tommasi (1992), who considers repeat purchases and also stresses the informational role of prices.

II. THE MODEL

We consider the market for a good produced by a continuum of infinitely-lived firms. Firms' costs are heterogeneous. Firm i's long-run cost function is C_iQ_i, where Q_i is the firm's output and C_i is real marginal cost. C_i varies across firms with distribution function $F(\cdot)$. In addition, we allow short-run marginal cost to be increasing: when the firm's output varies over time, we assume marginal costs of $C_iH(Q_i - \overline{Q}_i)$, where $\overline{Q}_i$ is the firm's average output and $H(0) = 1$, $H'(\cdot) \geq 0$.

The model is set in discrete time. Each period, a constant measure of consumers enters the market; each consumer participates either for one period (in Section III) or for two periods (in Sections IV and V). Each new consumer is randomly assigned to a single firm. The consumer can buy either zero or one unit of the good; in the two-period case, he buys the good in both periods if at all. (This assumption is justified below.) If consumer j buys the good from firm i, his utility in a period is e_j-P_i, where P_i is the firm's real price and e_j is a taste parameter. The consumer's utility if he does not buy is zero. The parameter e_j varies across consumers with distribution function $G(\cdot)$. Consumers do not directly observe firms' costs, but (as described below) learn about them from prices.

The aggregate price level, which is exogenous to the market under consideration, grows by a factor of $\Delta > 1$ every period. In our basic model, we assume that firms adjust their nominal prices every two periods, with half of all firms adjusting each period. In Section VI, however, we make the frequency of adjustment endogenous. With two-period adjustment, a firm's real price changes by a factor of $1/\Delta$ when it does not adjust. If $\overline{P}$ is the firm's average real price, its price fluctuates between $[2\Delta/(1+\Delta)]\overline{P}$ when the firm adjusts and $[2/(1+\Delta)]\overline{P}$ when it does not. We denote these prices by P_H and P_L respectively.

We assume free entry of firms subject to a fixed cost; this cost must be paid before C_i, the firm's cost parameter, is realized. Entry occurs to the point where expected profits are zero. Positive expected profits, for example, cause additional firms to enter, lowering the number of customers assigned to each firm. Since each firm has fewer customers and the same fixed cost, its profits are reduced. The assumption of free entry simplifies the analysis: since firms' average profits are zero, welfare is identical to consumers' average utility. This assumption is not essential to our results, however. As described in the introduction, firms can eliminate the relative price variability caused by inflation through frequent price adjustment. Since such adjustment is presumably inexpensive, even without free entry inflation could not affect profits significantly.

For expositional simplicity, we ignore discounting. Thus a firm maximizes its average profits over time, and consumers maximize average utility.[1] Introducing discounting would have no

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[1]More precisely, we assume a positive discount rate and consider the limiting case as this rate approaches zero.

important effect on the analysis.

It is easy to describe the behavior of the economy when there is no inflation. In this case, relative prices and output are constant despite infrequent nominal adjustment. A consumer buys the good from the firm he meets if the price, P_i, is less than his utility from the good, e_j. The demand for a firm's good is the number of its customers with $e_j > P_i$, which is $[1-G(P_i)]N$, where N is the number of consumers assigned to each firm. If $G(\cdot)$ is uniform, for example, then demand is linear; if $G(\cdot)$ is exponential, demand is isoelastic. Firm i's profits (neglecting the fixed cost of entry) are $[P_i-C_i][1-G(P_i)]N$; the firm chooses the price P_i^* that maximizes this expression.[2]

III. INFLATION WITH ONE-PERIOD RELATIONSHIPS

We now assume that inflation is positive and firms adjust prices every two periods, so that relative prices vary. We assume that customers enter the market for one period -- there are no long-term relationships -- and ask how inflation affects

[2]To obtain linear demand, we assume that G(e) equals $(e-a)/(b-a)$ for $a \le e \le b$, zero for $e < a$, and one for $e > b$. We also assume that the support of C_i is such that firms choose a price in [a,b]. To obtain isoelastic demand, we assume that G(e) equals $1-e^{-\eta}$ for $e \ge 1$ and zero for $e < 1$, and that the lower bound of the support of C_i is large enough that all firms choose a price greater than one.

In general, we assume a $G(\cdot)$ such that a unique maximum for profits exists. This is the case for both the uniform and exponential distributions, for example. A sufficient condition is $2G'(P) > -(P-C_i)G''(P)$ for all P.

welfare. For simplicity, we initially assume that inflation does not affect a firm's average price: firm i's average price is P_i^*, its profit-maximizing price in the absence of inflation. This assumption allows us to isolate the effects of the <u>variability</u> of prices induced by inflation. In this case, inflation unambiguously raises welfare. We then make average prices endogenous, and show that the results do not change significantly.

With fixed average prices, it is easy to show that inflation raises welfare. Consider a consumer who meets a firm with price P and receives utility e if he buys (we suppress the i and j subscripts for simplicity). If there is no inflation, then $P = P^*$, and the consumer's utility is $\max[e-P^*,0]$. With inflation, P varies between $P_H = [2\Delta/(1+\Delta)]P^*$ and $P_L = [2/(1+\Delta)]P^*$, with an average of P^*. The consumer has an equal chance of meeting the firm when either price is posted; thus his expected utility is $(1/2)\{\max[e-P_H,0] + \max[e-P_L,0]\}$. $\max[e-P,0]$ is convex in P. Thus the variability in P induced by inflation raises expected utility. Since firms earn zero profits, higher expected utility for consumers means higher welfare.

This result is simply a special case of the microeconomic principle that indirect utility functions are quasi-convex in prices (Waugh, 1944; Varian, 1984). When there is a mean-preserving spread in prices, consumers are equally well off if they continue to buy the same goods (since average expenditure is unchanged), and better off if they substitute toward less expensive goods. In our model, consumers with $P_L < e < P_H$ gain by buying when P is low and do not lose as much when P is high, because they substitute away from the good.[3]

In the absence of long-term relationships, the result that price variability benefits consumers appears robust. Consider, for example, Okun's (1975) argument that variability is costly because it induces consumers to devote resources to search. If consumers in our model were allowed to search, their gains from inflation would increase. Consumers could maintain the same utility as before by forgoing search and staying with their original sellers. If they search, the costs must be less than the gains from additional opportunities for substitution, in this case across sellers.

The fact that consumers gain from price variability helps explain why previous researchers have had difficulty formalizing the idea that inflation is costly. With one-period relationships, the only way that variability can be costly to consumers is through indirect effects on average prices, which our argument holds constant. As discussed below, a number of authors suggest reasons that inflation can raise average prices. However, economists' intuition about the costs of inflation arises at least partly from the direct effects of variability

[3]This result depends on the assumption that utility is linear in P if the consumer buys the good. If utility were a concave function of P, relative price variability could make consumers worse off. It is reasonable, however, to assume that consumers are risk-neutral toward the price of a single good, conditional on purchasing the good. Consumers are always risk-neutral toward small gambles, and expenditure on one good is small relative to income.

(recall Fischer's claim in the introduction). Models with one-time customer relationships cannot capture this intuition.

To complete our analysis, the Appendix determines the effects of inflation on average prices in the current model; that is, we relax the assumption that average prices are fixed at P^*. In general, a firm's profit-maximizing average price when its price varies between P_H and P_L differs from P^*, its profit-maximizing price in the absence of inflation. We find, however, that the effects of inflation on average prices are complex and ambiguous in sign. There does not appear to be any robust economic reason that the effects are positive or negative; instead, the results depend on functional forms. For example, if short-run marginal cost is constant, inflation lowers average prices if demand is linear but raises prices if demand is isoelastic. For most plausible cases, the effect on average prices is small, which implies that inflation has little effect on welfare through this channel. Thus making average prices endogenous does not alter our conclusion that this model fails to generate significant costs of inflation.[4]

[4]See Naish (1986) and Benabou and Konieczny (1991) for more detailed analyses of inflation and average prices with one-time purchases.

IV. INFLATION WITH TWO-PERIOD RELATIONSHIPS

This section and the next introduce long-term customer relationships. In this section we hold average prices constant, and show that the variability caused by inflation reduces welfare. Section V makes average prices endogenous and shows that inflation also reduces welfare through higher average prices.

A. Assumptions and Consumer Demand

We continue to assume that a firm sets nominal prices for two periods; the firm's relative price varies between P_H and P_L, with the average fixed at P^*. A consumer who meets a firm remains in the market for two periods. Crucially, we assume that a consumer buys the good either in both periods or in neither; if he buys, he pays P_H in one period and P_L in the other. Our assumption can be justified by introducing a cost of setting up a relationship with a supplier -- a cost of getting to know the supplier, arranging for delivery, and so on. If the set-up cost is sufficiently large, then a consumer gains from buying only if the cost is amortized over two periods. This idea can be introduced formally by interpreting the utility e_j from a good as net of per-period set-up costs.[5]

[5]To formalize this idea, let e' be the gross utility gain from the good, let $K > 0$ be the one-time set-up cost, and let P' and P'' be a firm's price in the first and second periods that it sells to the consumer. When the consumer observes P' in the first period, the most optimistic scenario is that this is the

Equal numbers of consumers meet a firm when it is charging each of its two prices. The consumer observes the current price, but does not know whether this price is P_H or P_L; that is, the consumer does not observe P^*. He does know the distribution of P^* across firms, which is determined by the distribution of the cost parameter C_i.

If a consumer buys the good, his utility is $e-P_H$ in one period and $e-P_L$ in the other, for an average of $e-P^*$. Thus the consumer gains overall from buying if $e > P^*$. Since the consumer does not observe P^*, he bases his behavior on its expected value given his information: he buys if $e > E[P^*]$. The consumer knows that the price P that he observes is either a first-period price $[2\Delta/(1+\Delta)]P^*$ or a second-period price $[2/(1+\Delta)]P^*$. Thus P^* is either $P_1 = [(1+\Delta)/2\Delta]P$ or $P_2 = [(1+\Delta)/2]P$. $E[P^*]$ is an average of these two prices, weighted by the density of P^*:[6]

firm's high price, in which case $P'' = P'/\Delta$. A necessary condition for the consumer to buy in the first period is that he gains under this scenario. This requires that $(e'-P'-K) + (e'-P'/\Delta) > 0$, or $e' - P'(1+\Delta)/(2\Delta) - K/2 > 0$.

If the consumer buys in the first period, the condition for buying in the second period is $e' - P'' > 0$. $e' - P''$ is at least $e' - \Delta P'$. Thus buying in the first period always implies buying in the second if $e' - P'(1+\Delta)/(2\Delta) - K/2 > 0$ implies $e' - \Delta P' > 0$. This condition holds if $K > (2\Delta^2 - \Delta - 1)P'/\Delta$. A sufficient condition is $K > 3(\Delta - 1)P^*_{max}$, where P^*_{max} is the average price of the highest-cost firm. Thus a sufficiently large set-up cost implies that the consumer buys in both periods if at all.

[6]The $2\Delta/(1+\Delta)$ and $2/(1+\Delta)$ terms in the first line of (1) reflect the fact that inflation changes prices by a fixed percentage amount, not a fixed absolute amount. This effect compresses the distribution of prices at low levels and spreads out the distribution at high levels.

$$(1) \qquad E[P^*|P] = \frac{[\hat{f}(P_1)/\frac{2\Delta}{1+\Delta}]P_1 + [\hat{f}(P_2)/\frac{2}{1+\Delta}]P_2}{\hat{f}(P_1)/\frac{2\Delta}{1+\Delta} + \hat{f}(P_2)/\frac{2}{1+\Delta}}$$

$$= \frac{\hat{f}(P_1)P_1 + \Delta\hat{f}(P_2)P_2}{\hat{f}(P_1) + \Delta\hat{f}(P_2)},$$

where $\hat{f}$ is the density of P^* (a transformation of the density $f(\cdot)$ of C_i). Equation (1) implies that $E[P^*]$ exceeds P^* when the observed price P is P_H: observing a firm's high price causes consumers to overestimate its average price. Similarly, $E[P^*] < P^*$ when the consumer observes P_L.

B. Welfare

It is straightforward to show that inflation reduces consumer welfare in this model. With no inflation, $P_H = P_L = P^*$, so the consumer observes P^* by observing an initial price. He buys whenever $e > P^*$. With inflation, the consumer does not observe P^* perfectly, so $E[P^*]$ differs from P^*. Thus the consumer sometimes buys when $e < P^*$ and fails to buy when $e > P^*$. These deviations from the consumer's no-inflation choices reduce his utility.

To understand this result, note first that the benefit from inflation in the previous model is not present here. A consumer in a long-term relationship pays both a firm's high price and its low price, and thus cannot substitute toward buying at the low price. In addition, there is now a cost to price variability: current prices become noisy signals of average prices. Since average prices determine whether consumers should buy, this noise leads to mistakes.

Our result that inflation adds noise to estimates of P* captures the common argument that inflation reduces the usefulness of prices as signals of economic fundamentals. Carlton (1982), for example, argues that "inflation degrades the information content of price[s]." In our model, long-term relationships are crucial to this idea: only when customers attempt to infer future prices, because they are entering long-term relationships, do they care about the quality of signals.

C. Quantitative Results

We now ask whether the welfare losses from realistic levels of inflation are significant. The Appendix derives an expression for the welfare loss and takes a second-order approximation in the inflation rate, $\pi \equiv \Delta - 1$. We find that, as long as inflation is not too high relative to the variation in P*, the loss as a fraction of total spending in the market is approximately $\pi^2/8$ times a weighted average of the elasticity of demand at different points on the demand curve. For the case of a constant elasticity η, the loss is simply $\eta\pi^2/8$.

For our calculations, we assume a constant demand elasticity of 8. This implies that prices exceed marginal cost by 14%, a markup consistent with microeconomic evidence for typical industries (Scherer, 1980). Recall that π is inflation per period, and that prices are fixed for two periods; thus π should be interpreted as inflation over half the life of a price. As a base case, we choose $\pi = 5\%$, which is consistent with inflation of 10% per year and price adjustment once per year (i.e., periods that last six months). One year is the median interval between price adjustments in Blinder's (1991) survey of firms. There appears to be considerable variation, however, in the frequency of price adjustment; there are a number of examples of prices that fall 25% in real terms between adjustments, such as magazine prices (Cecchetti, 1986) and prices in retail catalogs (Kashyap, 1991). For these cases, π is 12.5%.

For the base case of $\eta = 8$ and $\pi = 5\%$, the cost of inflation is 0.25% of total spending. If every market in the economy were described by our model, the welfare loss from inflation would be 0.25% of GNP. Although this loss is not huge, it is not negligible. With a discount factor of 0.95, it would be worth sacrificing 20(0.25) = 5 percentage points of annual output to eliminate inflation. That is, our results justify a significant recession to disinflate. For the case of 25% price adjustments ($\pi = 12.5\%$), the flow cost of inflation is 1.6% of revenue, for a present value of 31% of annual revenue. Thus the losses from inflation appear quite significant in industries with infrequent adjustment. Our model is too stylized to take these results literally, but they do suggest that the losses from less informative prices are non-trivial.

V. AVERAGE MARKUPS WITH TWO-PERIOD RELATIONSHIPS

A. Overview

This section relaxes the assumption that average prices are invariant to inflation in our model with long-term relationships. In contrast to the case of one-time purchases, average prices are likely to respond substantially to inflation. The source of this result is again the reduced informativeness of prices. When inflation adds noise to prices, consumers' estimates of average prices rise less than one-for-one with observed prices. Since consumer demand depends on average prices, this effect makes demand less elastic with respect to observed prices. Less elastic demand causes firms to raise their markups over marginal cost, and this distortion reduces welfare. Our numerical results suggest that this effect can be substantial.

The general effects of inflation on average prices are complex. We therefore make two simplifying assumptions in the text. First, we assume a constant elasticity of demand with respect to estimated average prices (that is, we assume that $G(\cdot)$ is exponential). Second, we assume that consumers estimate average prices using the optimal <u>linear</u> function of observed prices. That is, we restrict attention to inference rules of the form

$$(2) \qquad \hat{P} = a + bP ,$$

where $\hat{P} \equiv E[\overline{P}|P]$, the estimated average price. The Appendix shows that our results do not change when we relax this linearity restriction or when we consider more general demand functions.

A final complication is that, in principle, inflation affects average prices through two channels. First, as emphasized here, inflation affects firms' profit-maximizing prices by changing the elasticity of demand. Second, as in the case of one-time purchases, the mere fact that a firm's relative price becomes variable can cause its profit-maximizing average price to deviate from its profit-maximizing price when prices are constant. The Appendix shows, however, that this second effect disappears with constant-elasticity demand. Thus we simply derive a firm's profit-maximizing price; the result in the Appendix implies that this is also the profit-maximizing average price under inflation.[7]

B. Consumer Inference

The first step in deriving firms' profit-maximizing prices is to consider consumer inference. Inflation makes an observed price P a noisy signal of a firm's average price $\overline{P}$; if a consumer observes a high price, for example, this might reflect a high average price or simply the fact that the firm is charging P_H instead of P_L. Writing $P = \overline{P} + (P-\overline{P})$, $P-\overline{P}$ is uncorrelated with

[7]We assume that the firm chooses the same average price for each two-period cycle. In principle, the firm might gain from varying its average price, but such strategies can be ruled out with reasonable restrictions on parameters (e.g., a mild lower bound on the slope of short-run marginal cost and an upper bound on the set-up cost K in note 5).

$\bar{P}$. Thus, assuming linear inference, consumers face a standard signal extraction problem. The optimal b and a in (2) are

(3) $$b = \sigma^2_{\bar{P}}/(\sigma^2_{\bar{P}} + \sigma^2_{P-\bar{P}}) \ ,$$

(4) $$a = (1-b)\mu \ ,$$

where $\sigma^2_{\bar{P}}$ and $\sigma^2_{P-\bar{P}}$ are the variances of $\bar{P}$ and $P-\bar{P}$, and μ is the mean of $\bar{P}$ across firms. A firm's price alternates between $P_H = [2\Delta/(1+\Delta)]\bar{P}$ and $P_L = [2/(1+\Delta)]\bar{P}$; thus $\sigma^2_{P-\bar{P}} = [(\Delta-1)/(1+\Delta)]^2 E[\bar{P}^2] = [(\Delta-1)/(1+\Delta)]^2[\mu^2 + \sigma^2_{\bar{P}}]$. Substituting this expression into (3) yields

(5) $$b = \frac{c^2}{c^2 + [(\Delta-1)/(1+\Delta)]^2[1 + c^2]} \ ,$$

where $c = \sigma_{\bar{P}}/\mu$ is the coefficient of variation of average prices $\bar{P}$ across firms.

When inflation is zero ($\Delta = 1$), b is one: prices are constant, so estimated average prices move one-for-one with observed prices. When inflation is positive, b is less than one, because consumers attribute part of price variation to inflation rather than to differences in average prices. We focus on the case of $c = 0.1$, which means that the standard deviation of average prices across firms is 10% of the mean price. When $c = 0.1$ and π is at its base value of 5%, b is 0.94. When

$c = 0.1$ and $\pi = 12.5\%$, b is 0.74.

C. Prices and Welfare

The demand function facing a firm is $2[1-G(\hat{P}(P))]N$, where $[1-G(\cdot)]N$ is the demand function of the basic model and $\hat{P}(P)$ is consumers' estimate of the firm's average price. (The factor of two reflects the fact that customers stay in the market for two periods.) The firm's profits are $2(P-C)[1-G(\hat{P}(P))]N$. Differentiating with respect to P and using the assumption that $G(\cdot)$ is exponential, one can show that the profit-maximizing price is

$$(6) \qquad P = \frac{\eta}{\eta-1}C + \frac{1-b}{b(\eta-1)}\mu ,$$

where η is the elasticity of demand. In this equation, the first term on the right is the profit-maximizing price in the absence of inflation. The second is a positive constant that is the same for all firms. Thus inflation raises every firm's price by the same absolute amount. Again, since $\hat{P}'(P) < 1$, inflation makes demand less responsive to actual prices, raising firms' optimal markups.

When prices rise, welfare falls. The loss in welfare for a consumer who purchases the good is simply the increase in the amount that he pays. Consumers who substitute away from the good lose less, but the difference is zero to second order, because inflation has no first-order effect on average prices and consumers who are initially on the margin for purchasing the good receive no surplus. Thus consumers' losses as a fraction of total spending in the market are (to second order) simply the percentage increase in the average price faced by consumers who initially purchased the good.

For plausible parameter values, the effects of inflation on prices and welfare are large. Consider the case of $\pi = 5\%$, $\eta = 8$, and $c = 0.1$ (implying $b = 0.94$). In this case, (6) implies that inflation raises the price of a firm initially charging the mean price μ by 0.9%. The resulting welfare loss of 0.9% of revenue is more than three times the loss from inflation for given average prices, derived in Section IV.[8] With a discount factor of 0.95, the present value of the loss is 17% of annual revenue. If π is raised to 12.5% (so b falls to 0.74), the welfare loss is a huge 5.0% of revenue. Thus the costs of inflation through higher markups appear quite important quantitatively.[9]

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[8]Since demand is higher at low-price firms, the average price paid by consumers is less than the average price μ. Consequently, our calculations understate the welfare loss as a fraction of spending. For reasonable cases this effect is small, however.

[9]Equations (3)-(6) define a firm's price P in terms of the mean and variance of P across firms. To close the model, one can derive P in terms of the underlying distribution of P*, the no-inflation price (which is determined by the distribution of the cost parameter C). Equation (6) implies $\sigma^2_{\bar{P}} = \sigma^2_{P*}$ and $\mu = B\mu*$, where $\mu*$ and σ^2_{P*} are the mean and variance of P* and $B = 1/[1 - (1-b)/(\eta-1)b]$. It follows that $\sigma^2_{P-\bar{P}} = [(\Delta-1)/(1+\Delta)]^2[B^2\mu*^2 + \sigma^2_{P*}]$. Substituting these results into (3) yields

$$(5') \qquad b = \frac{c*^2}{c*^2 + [(\Delta-1)/(1+\Delta)]^2[B^2 + c*^2]},$$

VI. THE FREQUENCY OF PRICE ADJUSTMENT

A. Motivation and Overview

So far we have assumed that firms adjust nominal prices every two periods. Here, we make the frequency of adjustment endogenous: firms choose between adjusting every period and every two periods, given a "menu" cost. This exercise allows us to address another issue concerning the costs of inflation: why do firms adjust prices so infrequently? As described above, a typical U.S. firm adjusts prices once a year, and some firms adjust even less frequently. This behavior is essential to our argument that inflation creates relative price variability with significant costs. Infrequent adjustment is puzzling in light of the fact, stressed in the menu cost literature, that price adjustment appears inexpensive. Surely it would be easy for magazine publishers to adjust prices every two years rather than every four, as found by Cecchetti. Since price setters adjust to inflation infrequently, their gains from stabilizing relative prices must be very small (even though consumers might benefit considerably). We now ask whether our models of relative price variability are consistent with this observation.

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where c^* is the coefficient of variation of P^*. This expression defines b implicitly, since B depends on b; along with (6), the solution for b determines a firm's price P. For $c^* = 0.1$ and $\eta = 8$, the firm with $P^* = \mu^*$ raises its average price by 0.9% if $\pi = 5\%$, and by 5.9% if $\pi = 12.5\%$.

Once again, the answer turns on whether firms and customers establish long-term relationships. With one-time purchases, firms' losses from relative price variability are fairly large, because price variability causes costly fluctuations in sales. In this case, it is implausible that firms would endure variability rather than adjust every period. With long-term relationships, by contrast, firms' losses from variability can be small; indeed, it is possible that profits are <u>higher</u> when prices are adjusted less frequently. This result arises because long-term relationships keep a firm's sales stable despite fluctuations in its price.

These results complement those of previous sections in establishing the importance of long-term relationships for the costs of inflation. Long-term relationships are needed to explain not only why price variability harms consumers, but also why firms allow variability to occur through infrequent adjustment.

B. One-Time Purchases

We first consider the case of one-time purchases. We compute a firm's profits when it adjusts its price every two periods and when it adjusts every period. For two-period adjustment to be an equilibrium, the difference in profits in the two cases must be less than the added menu costs of adjusting every period.[10]

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[10]In computing profits, we hold constant the number of firms, and hence each firm's number of customers N. That is, we ignore the fact that entry drives profits to zero in either case.

If the firm adjusts its price every period, its price is constant at P^*. If it adjusts every other period, its price alternates between P_H and P_L.[11] In either case, profits in a period are the difference between revenue, $P[1-G(P)]N$, and costs. Here the relevant cost function is the short-run function, $CH(\cdot)$, since output fluctuates between even and odd periods if relative prices fluctuate. We compute the difference between profits with one- and two-period adjustment and take a second-order approximation in Δ; for constant-elasticity demand, this difference as a share of revenue is

$$(7) \qquad \frac{(1 + \alpha\eta)(\eta - 1)}{8} \pi^2 ,$$

where η is the elasticity of demand and $\alpha = H'(0)/H(0)$ is the elasticity of short-run marginal cost. (If the curvature of demand is less sharp than the constant-elasticity case, the loss is larger.)

To calculate the loss from two-period adjustment, we focus on a base case of $\eta = 8$ and $\alpha = 1$, which means moderately increasing marginal cost. When $\pi = 5\%$ (that is, prices change 10% per adjustment in the two-period case), the loss from two-

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This is appropriate because a firm takes the number of other firms as given in determining its own behavior.

[11]As discussed in Section III, inflation can cause the firm to change its average price. One can show, however, that (to second order) this change has no effect on the incentives for more frequent adjustment. We therefore hold average prices constant.

period adjustment is 2.0% of revenue and 15.8% of profits. These costs seem quite large relative to menu costs. For π = 12.5%, the losses from infrequent adjustment are huge: 12.3% of revenue and 98% of profits. Intuitively, the relative price variability arising from infrequent adjustment causes variability in sales, which raises total costs if the cost function is convex. The large losses from infrequent adjustment suggest strongly that firms would pay the additional menu costs of adjusting every period. That is, our model with one-time purchases is inconsistent with the infrequent adjustment of actual price setters.[12]

C. Two-Period Relationships

We now assume long-term customer relationships. To see whether infrequent price adjustment is an equilibrium, we assume that all firms but firm i adjust every two periods, and consider firm i's incentive to deviate by adjusting every period. Regardless of whether the firm deviates, customers estimate its average price using the inference rule $\hat{P}(P)$, which is correct with two-period adjustment. That is, customers do not know that they are facing the single firm that may adjust every period.

The number of customers that firm i attracts in a period is

[12]Although upward-sloping marginal cost greatly increases the loss from infrequent adjustment, it is not essential for our argument. Even if α is set to zero, implying flat marginal cost, the loss is 1.3% of revenue for π = 12.5%. It appears unlikely that menu costs exceed one percent of revenue; thus, even for flat marginal cost, the model appears inconsistent with the behavior of some firms.

$[1-G(\hat{P}(P))]N$. If the firm adjusts every period, its relative price is constant at its average price $\overline{P}$; its sales are $2[1-G(\hat{P}(\overline{P}))]N$ each period. If the firm adjusts every two periods, its relative price alternates between P_H and P_L, and its number of new customers alternates between $[1-G(\hat{P}(P_H))]N$ and $[1-G(\hat{P}(P_L))]N$.[13] Crucially, since customers remain for two periods, total sales are constant at $[2-G(\hat{P}(P_H))-G(\hat{P}(P_L))]N$. Since sales are constant, marginal cost is constant at C. Finally, the average price charged each customer is $\overline{P}$. Combining these results, the difference in profits per period with one- and two-period adjustment is

$$(8) \quad (\overline{P} - C)2[1 - G(\hat{P}(\overline{P}))]N - (\overline{P} - C)[2 - G(\hat{P}(P_H)) - G(\hat{P}(P_L))]N.$$

To see whether more frequent adjustment raises profits, note that profit per unit, $\overline{P}$-C, is the same with one- and two-period adjustment. Thus the firm gains from adjusting every period if and only if its sales rise -- that is, if $2[1-G(\hat{P}(\overline{P}))]N$ exceeds the sum of $[1-G(\hat{P}(P_H))]N$ and $[1-G(\hat{P}(P_L))]N$. Whether this condition holds depends on the shapes of $G(\cdot)$ and $\hat{P}(\cdot)$. The Appendix shows that the sign of (8) is ambiguous. There is no presumption that it is positive; indeed, it is negative for constant-elasticity demand and low inflation rates. Thus there

[13] As in Part B of this section, we ignore the effect of inflation on a firm's average price. Once again, this simplification does not affect our results.

are reasonable cases in which profits <u>fall</u> if the firm adjusts more frequently. In other cases, profits rise, but by tiny amounts.

Thus long-term relationships provide a simple explanation for why firms adjust prices infrequently even though the costs of adjustment are small. Long-term relationships break the link between short-run fluctuations in relative prices and variation in sales. Since sales remain stable, firms can keep nominal prices fixed for substantial periods without significant profit losses.[14]

VII. DISCUSSION AND CONCLUSIONS

A. Comparison to Recent Literature

Here we compare our model to other recent models of inflation that emphasize the effects of relative price variability.

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[14]Throughout this analysis, we have assumed that current prices are consumers' only source of information about firms' average prices. If the model were extended to allow firms to convey information in other ways, for example by posting past as well as current prices, low-cost firms would wish to take advantage of these opportunities. Such extensions would raise complicated issues, such as the problem of verifying that announcements of past prices were accurate. At least since Adam Smith, economists have argued that prices' role in transmitting information cannot be easily replaced. We therefore focus on inflation's effects on the information transmitted through prices, and leave other means of conveying information to future work.

Benabou (1988, 1991); Diamond (1988): These papers focus on the case of one-time purchases, and thus do not capture the informational role of prices, which is central in our model. Instead, the papers study the effects of inflation on average markups when consumers engage in non-trivial search. In Benabou (1988), inflation reduces markups and thus raises welfare; intuitively, greater price dispersion encourages greater search, making markets more competitive. Diamond (1988) and Benabou (1991) extend this model to include several channels through which inflation potentially reduces welfare. They emphasize two channels in particular. The first is exit: inflation-induced price variability can lower firms' profits, which reduces the equilibrium number of firms and thus makes search more difficult. The second is that (as in our model with one-time purchases) a firm's profit-maximizing average price generally depends on the variability of its price. Competition among firms can magnify this effect.

Since Benabou's and Diamond's models and ours focus on different effects of inflation, they are complementary. One important difference is that Benabou and Diamond do not identify any robust reason that inflation reduces welfare; that is, in our view they do not succeed in capturing the common intuition that inflation is harmful. For inflation to induce exit by a significant number of firms, the costs of price adjustment must be large. If these costs are small, as is more plausible, then firms facing costly price variability would simply eliminate it through frequent adjustment rather than exit. And, as we discuss in Section III, the direct impact of variability on profit-maximizing average prices can be either positive or negative, depending on functional forms. Large adverse effects of variability arise only when demand curves are sharply curved.

Benabou and Gertner (1991): Building on Lucas (1973), this paper assumes that variability in inflation creates confusion between nominal and relative prices. Consumers' decreased ability to estimate relative prices influences welfare through its effects on search and competitiveness; the net welfare effect is ambiguous. This paper is similar to ours in emphasizing the effects of inflation on consumers' information about prices. The nature of the information problem is quite different, however. The uncertainty in Benabou and Gertner concerns the aggregate price level, and hence the relative prices corresponding to observed nominal prices. In our model, the price level is observable, but there is microeconomic uncertainty concerning firms' average prices. A related difference is that in Benabou and Gertner (as in Lucas), only the variance of inflation influences welfare; in our model, trend inflation reduces welfare by increasing microeconomic variability. It appears that our model may be more relevant for moderate-inflation countries such as the United States, where accurate information about the price level is released with a short lag. The Benabou-Gertner model appears relevant to high-inflation countries, where there can be considerable uncertainty about the current price level.

Tommasi (1992): This paper follows the previous literature in emphasizing search behavior and the effects of inflation on average markups. However, some of Tommasi's analysis is close in spirit to ours. As in our model, customers make repeat purchases. Variability in a firm's relative price reduces the informativeness of current prices about future prices, reducing buyers' sensitivity to prices and thus increasing average markups. Our analysis differs from Tommasi's in emphasizing the direct effects of variability as well as its effects on average prices, and in deriving rather than simply assuming a link between inflation and relative price variability. In addition, by suppressing search and other features of Tommasi's model, our analysis captures the effects of inflation on the informativeness of prices more simply.

B. The Informational Role of Prices

In our model with two-period relationships, inflation reduces welfare because it erodes the information in current prices about future prices. The core feature of our model is that prices have an informational role: a consumer cares about a price not only because it determines how much he currently pays, but also because it is a signal of another variable. In emphasizing the informational role of prices, we follow some older, informal discussions of the costs of inflation, such as Okun (1975), Wachter and Williamson (1978), and especially Carlton (1982).

Future prices, which matter to consumers in long-term relationships, are a natural example of a variable for which current prices are a signal. Long-term relationships are not, however, the only reason that prices have an informational role. Carlton emphasizes that agents who operate outside of thick markets use the information contained in market prices. For example, sellers of a customized product use the prices of similar standardized products to guide their own price setting. Vertically integrated firms compare the costs of internal input suppliers to market prices for the inputs to determine whether production is efficient. When inflation adds noise to prices, they become less useful signals in these settings.

Okun, Wachter and Williamson, and Carlton argue that inflation's disruption of the price system is most harmful in markets where agents rely <u>less</u> on prices to allocate resources. Our results support this counterintuitive argument. Inflation cannot have large costs in anonymous markets, where allocations are determined solely by prices. But it <u>can</u> have significant costs with long-term relationships, in which buyers overlook small period-to-period price movements in determining their purchases.

When inflation reduces the informativeness of prices in our model, the results are simply higher markups and more mistakes about which goods to purchase. If market structure is endogenous, the reduced informativeness of prices can have more wide-ranging effects. Carlton argues that inflation leads to less vertical integration and greater reliance on standardized rather than customized products. In Tommasi's model, the fact that consumers are willing to buy at higher prices allows high-cost producers to remain in operation, reducing the average efficiency of production. The effects of inflation on the informativeness of prices have rich implications that future research should examine both theoretically and empirically.

C. Conclusion

This paper studies the welfare effects of the relative price variability arising from inflation. With one-time customer relationships, inflation raises consumer welfare by creating opportunities for substitution toward low-price goods. In addition, relative price variability causes costly variability in firms' sales, giving firms a strong incentive to reduce variability through more frequent price adjustment. With long-term relationships, in contrast, inflation reduces consumer welfare by reducing the informativeness of prices. Inflation has little effect on firms because sales remain stable. Thus long-term relationships explain both why relative price variability reduces welfare and why firms allow variability to occur through infrequent adjustment.

The costs of inflation identified by our model do not appear easy to overcome. Many frequently cited costs of inflation arise from nominal features of the tax system, of loan arrangements, and of other institutions. These distortions can be (and in some countries are) overcome through fairly straightforward indexation. It is unlikely, however, that adoption of these reforms would eliminate concern about inflation -- policymakers and the public appear to believe that inflation harms the economy in a fundamental way that does not depend on institutions. The relative price variability arising from staggered price adjustment is a fundamental non-neutrality that arises from inflation even if loans and taxes are indexed. This non-neutrality could be eliminated only through perfect indexation of all prices, which would amount to abandoning money's role as the unit of account.

Our numerical results -- while admittedly arising from a highly stylized model -- suggest that the welfare costs that we identify are significant at moderate inflation rates. More broadly, relative price variability appears potentially important because of the central role of the price system in market economies. The ability of prices to guide the economy to efficient allocations is commonly cited as the main benefit of free markets. To the extent that inflation disrupts this mechanism, it strikes at the heart of the economy.

APPENDIX

This Appendix addresses several complications that we ignore in the text, and shows that our results do not change significantly. We also present derivations omitted from the text.

<u>Average Prices with One-Period Relationships</u>: In Section III, we derive the welfare effect of inflation under the assumption that a firm's average price is invariant to inflation. Here we relax this assumption and allow firms to choose average prices optimally. For simplicity, we focus on the case in which short-run marginal cost is constant.

With one-period relationships and constant marginal cost, a firm's profits are a function only of its current price. In particular, profits equal $[P-C][1-G(P)]N \equiv R(P)$. For a given inflation rate, the firm's choice of an average price $\overline{P}$ determines its two prices, $P_H = [2\Delta/(1+\Delta)]\overline{P}$ and $P_L = [2/(1+\Delta)]\overline{P}$. The firm's profits over two periods are $R(P_H) + R(P_L)$. The first-order condition for $\overline{P}$ is thus

$$\text{(A-1)} \qquad \Delta R'(P_H) + R'(P_L) = 0 .$$

Taking a second-order approximation of (A-1) in the inflation rate, one can show that a firm's average price is

$$(A\text{-}2) \qquad \overline{P} \approx P^* - \left[\frac{P^{*2}R'''(P^*)}{2R''(P^*)} + P^*\right]\frac{\pi^2}{4} ,$$

where P* is the profit-maximizing price in the absence of inflation. The second term in this expression is the effect of inflation on the firm's average price.

In (A-2), the first term inside the brackets is a familiar third-derivative effect: when objective functions are not quadratic, variability affects average behavior. The second term in the brackets arises because inflation changes the firm's price by a fixed percentage amount, not a fixed absolute amount. By choosing a lower average price, the firm can reduce its absolute price variability.

The sum of these two effects is ambiguous. For the case of linear demand, one can show that inflation lowers a firm's average price by a proportion $\pi^2/4$. Thus inflation of 5% per period reduces average prices by approximately 0.06%. For constant-elasticity demand, average prices rise by $\eta\pi^2/4$, where η is the demand elasticity; for η=8 and π=5%, $\overline{P}$ rises by 0.5%. Thus the effect in this case is positive and larger than before. The size of the effect arises, however, from the fact that a constant-elasticity demand curve with a substantial elasticity is sharply curved. In the absence of such curvature, inflation has only a small effect on average prices.[15]

[15]If marginal cost is upward-sloping, the effect remains ambiguous but becomes larger. If the elasticity of short-run marginal cost, H'(0)/H(0), is one, then inflation lowers average prices by 0.3% with linear demand and raises them by 4.5% with constant-elasticity demand. As we discuss in Section VI,

Welfare with Two-Period Relationships: Here we derive the approximation to the welfare loss from inflation that we use for the quantitative analysis in Section IV. As described in the text, a consumer enters a relationship if $e > E[P^*|P]$, where P is the price the consumer observes and $E[P^*|P]$ is given by equation (1). We assume that $E[P^*|P]$ is strictly increasing in P; in the neighborhood of zero inflation, this assumption is correct for any continuous distribution of P^*.[16]

Suppose that a consumer meets a firm that is currently charging its high price, $[2\Delta/(1+\Delta)]P^*$. In this case, the consumer's estimate of the firm's average price is $E[P^*|[2\Delta/(1+\Delta)]P^*]$. Defining P_0 by $E[P^*|[2\Delta/(1+\Delta)]P_0] = e$, and using the assumption that $E[P^*|P]$ is increasing in P, the consumer buys from the firm if the firm's average price is less than P_0. Similarly, define P_0' by $E[P^*|[2/(1+\Delta)]P_0'] = e$. If the consumer meets a firm charging its low price, he buys if the firm's average price is less than P_0'.

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however, if marginal cost is significantly upward-sloping, firms have very large incentives to adjust their prices every period, and so infrequent price adjustment could not be an equilibrium.

[16] Our assumption is false if inflation is large relative to the variation in average prices. For reasonable cases, however, the assumption holds over the range of inflation rates that we consider. For example, if the distribution of P^* is lognormal, $E[P^*|P]$ is strictly increasing in P as long as the inflation rate is less than twice the coefficient of variation in P^*. Thus if the coefficient of variation is 10%, $E[P^*|P]$ is increasing in P for $\pi < 20\%$. Similar results hold when the distribution of P^* is truncated normal.

If the consumer buys from a firm with an average price of P, his average utility over the two-period relationship is e-P. The consumer meets a firm charging P_H and P_L with equal probability. Thus the consumer's expected utility is

$$\text{(A-3)} \quad E[U(e)] = \frac{1}{2}\Big[\int_{P=0}^{P_o} (e-P)\hat{f}(P)dP + \int_{P=0}^{P_o'} (e-P)\hat{f}(P)dP\Big],$$

where again $\hat{f}$ is the density of average prices across firms.

Taking a second-order Taylor expansion of E[U(e)] in the inflation rate, one can show that inflation reduces a consumer's expected utility by approximately $e^2\hat{f}(e)\pi^2/8$. Integrating over consumers, the average welfare loss per consumer is

$$\text{(A-4)} \quad \int_e e^2\hat{f}(e)g(e)de \, \frac{\pi^2}{8} .$$

This expression can be rewritten as

$$\text{(A-5)} \quad \int_P P[1-G(P)]\hat{f}(P)\eta(P)dP \, \frac{\pi^2}{8} ,$$

where $\eta(P) \equiv g(P)P/[1-G(P)]$ is the elasticity of demand at price P. Average spending per consumer in this market is $\int_P P[1-G(P)]\hat{f}(P)dP$; thus the welfare loss as a fraction of spending is

$$(A-6)\qquad \frac{\int_P P[1-G(P)]\hat{f}(P)\eta(P)dP}{\int_P P[1-G(P)]\hat{f}(P)dP}\frac{\pi^2}{8}\ .$$

As claimed in the text, this expression is $\pi^2/8$ times a weighted average of the demand elasticity at different points on the demand curve.

Average Prices with Two-Period Relationships: Our analysis in Section V employs three simplifying assumptions: we assume constant-elasticity demand; we restrict attention to linear inference rules; and we ignore the distinction between a firm's profit-maximizing price and its profit-maximizing average price when it adjusts every two periods. Here we show that none of these assumptions is important for our results.

We first relax the assumption of constant-elasticity demand. For a general demand function, we derive the first-order condition for a firm's profit-maximizing price and then take a second-order approximation. This yields

$$(A-7)\qquad P \simeq P^* + [\frac{1-(\phi-\eta)[(P^*-\mu)/P^*]}{2\eta-\phi}P^*][\frac{1+c^2}{4c^2}\pi^2]\ ,$$

where $\phi \equiv -PG''(P)/G'(P)$ measures the curvature of the demand curve. For an average-price firm (one with $P^*=\mu$), this expression reduces to

$$(A-8)\qquad P \simeq P^* + \frac{P^*}{2\eta-\phi}\frac{1+c^2}{4c^2}\pi^2\ .$$

A smaller curvature of demand weakens the impact of inflation on average prices. For the constant-elasticity case in the text, ϕ equals $\eta+1$, and so the denominator of (A-8) is $\eta-1$. If demand is linear, ϕ is zero, and so the denominator is 2η. Thus assuming linear rather than constant-elasticity demand cuts the impact of inflation on average prices roughly in half; nonetheless, the effect is still substantial. For demand with curvature between the constant-elasticity and linear cases, the effect of inflation falls by less than half.

We next relax the assumption that consumers use linear inference rules. As before, a firm's profits are $2(P-C)[1-G(\hat{P}(P))]N$, where $\hat{P}(P)$ gives consumers' estimate of the firm's average price. We now assume that $\hat{P}(P)$ is given by the optimal inference rule (1), which is in general non-linear.

A second-order approximation to a firm's first-order condition yields

$$\text{(A-9)} \qquad P \simeq P^* - \frac{1}{4}\frac{1}{2\eta-\phi}\left[\frac{P^{*2}\hat{f}''(P^*)}{\hat{f}(P^*)} + (\eta+2-\phi)\frac{P^*\hat{f}'(P^*)}{\hat{f}(P^*)} + 2(\eta+1-\phi) - \left(\frac{P^*\hat{f}'(P^*)}{\hat{f}(P^*)}\right)^2\right] P^*\pi^2 .$$

This expression is difficult to interpret. For a variety of special cases, however, the effects of inflation on average prices are close to the effects with linear inference. For example, if the distribution of average prices, $\hat{f}$, is lognormal,[17] (A-9) simplifies to

$$\text{(A-10)} \quad P \simeq P^* + \frac{1}{4}\frac{1}{2\eta-\phi}\left[\frac{1}{\sigma^2} - (\eta+1-\phi)\left[1 - \frac{\ln P^*-\mu'}{\sigma^2}\right]\right]P^*\pi^2 ,$$

where μ' and σ are the mean and standard deviation of $\ln P^*$. A firm with $\ln P^* = \mu'$ raises its price by proportion $\pi^2[(1/\sigma^2) - (\eta+1-\phi)]/[4(2\eta - \phi)]$. For either constant-elasticity or linear demand, the implied changes in prices for reasonable cases are similar to those with linear inference. For $\sigma = 0.1$, $\eta = 8$, and constant-elasticity demand, the firm raises its price by 0.9% if $\pi = 5\%$, and by 5.6% if $\pi = 12.5\%$. The corresponding figures with linear inference are 0.9% and 5.0%.

Finally, we consider the effect of inflation on average prices arising because a firm does not charge the same price every period. To focus solely on this effect, consider a firm that adjusts its price every two periods while all other firms adjust every period; this approach eliminates the impact of inflation on consumer inference that we analyze in the text. (Up to second order, there is no interaction between these two effects of inflation on average prices. Thus they can be analyzed separately.)

With all but one firm adjusting prices continually, consumers assume that the price they observe is a firm's average price. For the single firm that adjusts every two periods, sales

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[17] Results for the case of $\hat{f}$ normal are very similar.

each period are $[1-G(P_H)]N + [1-G(P_L)]N$, and profits are $(\overline{P} - C)$ times sales. With constant-elasticity demand, profits are

$$\text{(A-11)} \qquad [P_H^{-\eta} + P_L^{-\eta}]N(\overline{P} - C)$$

$$= (\frac{2}{1+\Delta})^{-\eta}[1 + \Delta^{-\eta}]\overline{P}^{-\eta}N(\overline{P}-C) \ .$$

In (A-11), inflation affects profits only through a multiplicative term. Thus it has no impact on the profit-maximizing average price through this channel. Similarly, if demand is linear, sales depend only on a firm's average price; thus inflation again has no impact on average prices.[18]

<u>Incentives for Price Adjustment with Two-Period Relationships</u>: Here we investigate the sign of expression (8), which gives a firm's incentive to adjust prices every period with long-term relationships. After a second-order approximation in the inflation rate, (8) reduces to

$$\text{(A-12)} \qquad [P^* - C]P^{*2}g'(P^*)N\pi^2/8 \ .$$

[18]For a general demand function, the effect of inflation on an average price is approximately

$$\frac{2 + \eta - \psi}{8[2\eta - \phi]}\phi\pi^2 P^* \ ,$$

where $\psi \equiv -PG'''/G''$. Given the results for constant-elasticity and linear demand, it appears unlikely that there are plausible cases for which this effect is substantial.

Intuitively, the gain from adjusting every period is the change in the number of customers times the markup, P*-C. When g'(P*) > 0, more customers are lost when the firm charges more than P* than are gained when the firm charges less than P*; thus frequent nominal adjustment raises profits. If g'(P*) < 0, the reverse occurs, and frequent adjustment reduces profits. If $G(P) = 1 - P^{-\eta}$, so the demand curve has constant elasticity, then $g'(P) = G''(P) < 0$, and frequent adjustment reduces profits.

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