LAURENCE BALL
DAVID ROMER

Inflation and the Informativeness of Prices

This paper studies the welfare effects of the relative-price variability arising from inflation. 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.

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.

The relative-price variability arising from inflation 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 a simple means of stabilizing relative prices: they can adjust nominal prices frequently to keep up with inflation. Since the costs of such price adjustment often appear small, the amount of relative-price variability that suppliers permit must not impose large costs on them. Any major costs of price variability must fall on consumers.

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LAURENCE BALL *is affiliated with Johns Hopkins University.* DAVID ROMER *is affiliated with the University of California, Berkeley. E-mail:* dromer@econ.berkeley.edu

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In conventional economic models, however, relative-price variability does not harm consumers. If markets are Walrasian, price variability *raises* consumer welfare because indirect utility functions are quasi convex in prices (Waugh 1944). Price variability benefits consumers because it creates opportunities for substitution toward low-price goods. A similar result holds for markets in which consumers search across sellers; in this case, price variability benefits consumers by raising the returns to search (Kohn and Shavell 1974). These microeconomic principles help explain economists' difficulties in formalizing the idea that inflation is harmful.

This paper presents a model in which inflation-induced price variability reduces consumer welfare. The crucial feature of the model is that prices have a role beyond their allocational role in Walrasian markets. In our model, prices also have an informational role. Specifically, we consider consumers who enter long-term relationships with sellers. In deciding whether to enter a relationship, potential customers use a firm's current price as a signal of the prices it will charge in the future. When inflation causes relative prices to vary, it reduces the information about future prices in current prices. We find that this loss of information harms consumers substantially.

The remainder of the paper consists of five sections. Section 1 presents our basic model. Firms sell a good to consumers who participate in the market for two periods. Firms differ in their costs of production, and consumers differ in their tastes for the good. The aggregate price level rises steadily, and firms adjust nominal prices every two periods; thus, a firm's relative price alternates between a higher level when it adjusts and a lower level when it does not. When a consumer enters the market, he meets a firm, observes its current price, and chooses whether to buy the good. There is a fixed cost of establishing a customer relationship with a seller. This assumption leads to long-term relationships; in equilibrium, a consumer buys either in both periods of life or in neither, despite the fluctuations in prices.

Section 2 derives the equilibrium of the model, and Section 3 determines the welfare effects of inflation. When a consumer decides whether to buy from a firm, he uses the firm's initial price to estimate its average price over the two periods he will be in the market. Higher inflation causes larger fluctuations in a firm's relative price, increasing the noise in the initial price relative to the signal. The reduced informativeness of prices 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 4 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? To address this question, we relax the assumption that firms keep prices fixed for two periods and ask whether such rigidity arises endogenously. Once again, long-term customer relationships are crucial to the results. In their absence, relative-price variability causes costly variation in firms' sales, and so firms have a strong incentive to stabilize prices through frequent nominal adjustment. Thus, in this case, firms do not choose infrequent adjustment unless the "menu costs" of price adjustment are very large. With long-term relationships, however, a firm's sales remain steady as its price fluctuates. As a result, the losses from infrequent adjustment are small, leading firms to choose this behavior even if menu costs are small.

Finally, Section 5 discusses our results and related ideas in previous work.

1. ASSUMPTIONS AND PRELIMINARY RESULTS

This section presents the assumptions of our basic model. We also derive the behavior of the economy in the absence of inflation and in the absence of long-term customer relationships. We use these cases as benchmarks when we analyze inflation and long-term relationships in Sections 2 and 3.

1.1 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 $F(\bullet)$, which has a finite support. In addition, we allow short-run marginal cost to be increasing: when the firm's output varies over time, we assume marginal costs of $C_iH(Q_i - \bar{Q}_i)$, where $\bar{Q}_i$ is the firm's average output and $H(0) = 1$, $H'(\bullet) \geq 0$.

The model is set in discrete time. Each period, a constant measure of consumers enters the market; each consumer participates for two periods. A consumer who enters the market is randomly assigned to a single firm and has no opportunity to buy from other firms in either period of life. Each period, the consumer can buy either zero or one unit of the good. If he decides to buy, he must pay a one-time cost, *K,* to establish a relationship with his seller; this can be interpreted as the cost of ordering the right variety of the product, arranging for delivery, and so on. We assume *K* is sufficiently large that, in equilibrium, a consumer buys in both periods if he buys at all. Intuitively, a large set-up cost means the consumer can gain from buying only if he amortizes the cost over two periods.[1]

If consumer *j* buys the good from firm *i* in a given period, his utility ignoring the set-up cost is $\tilde{e}_j - P_i$, where P_i is the firm's real price and $\tilde{e}_j$ is a taste parameter. The consumer's utility net of per-period set-up costs is $e_j - P_i$, where $e_j = \tilde{e}_j - K/2$ and where we use the assumption that he buys in both periods if at all. If the consumer does not buy the good (and does not pay the set-up cost), his utility is zero. The parameter e_j varies across consumers with distribution function $G(\bullet)$. Consumers do not observe an individual firm's cost parameter, C_i, but they know the distribution of costs, $F(\bullet)$.

The aggregate price level, which is exogenous to the market under consideration, grows by a factor of $\Delta \geq 1$ every period. Firms adjust their nominal prices every two periods, with half of all firms adjusting each period. A firm's real price changes by a factor of $1/\Delta$ when it does not adjust. If $\bar{P}$ is the firm's average real price over a two-period cycle, the price is $[2\Delta/(1 + \Delta)]\bar{P}$ when the firm adjusts and $[2/(1 + \Delta)]\bar{P}$ in the following period. 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. Our assumption of free entry implies that firms' average profits are zero. Thus welfare is identical to consumers' average utility.[2]

Finally, for simplicity we ignore discounting. A firm maximizes its average profits over time, and consumers maximize average utility.

1.2 The Economy with Stable Prices

If there is no inflation ($\Delta = 1$), relative prices are constant despite infrequent nominal adjustment. With each firm charging a constant price, a consumer clearly buys in both periods of life or in neither. A consumer buys if the price at his firm, P_i, is less than his net utility from buying, e_j. The demand for a firm's output is the number of its customers with $e_j > P_i$; this number is $2N[1 - G(P_i)]$, where N is the number of consumers assigned to each firm each period. The firm's per-period profits (neglecting the fixed cost of entry) are $[P_i - C_i]2N[1 - G(P_i)]$; the firm chooses the price, P_i^*, that maximizes this expression. We assume a $G(\bullet)$ such that a unique maximum for profits exists.

Specific functional forms for the distribution $G(\bullet)$ yield convenient special cases of the model. If $G(\bullet)$ is exponential, demand is isoelastic. The profit-maximizing price, P_i^*, is $[\eta/(\eta - 1)]C_i$, where η is the elasticity of demand. If $G(\bullet)$ is uniform, demand is linear. P_i^* is $(B + C_i)/2$, where B is the upper bound of the support of the distribution.

1.3 The Economy without Set-up Costs

We now assume positive inflation but set K, the fixed cost of establishing a customer relationship, to zero. In this case, a consumer makes independent choices of whether to buy in his two periods of life: in each period, he buys if $e_j > P_i$, where P_i is the current relative price at his firm. Since P_i fluctuates under inflation, a consumer may buy in one period but not the other. Since demand is not linked across periods, the behavior of the economy is essentially the same as if consumers participated in the market for only one period.

The Appendix derives the equilibrium of the economy when $K = 0$ and determines the welfare effects of inflation. To summarize, inflation affects welfare through two channels. First, inflation induces variability in a firm's relative price, which *increases* the welfare of its customers. As discussed in the introduction, this is a standard microeconomic result. A customer gains by buying when the firm's price is low and substituting away from the good when the price is high.

Second, inflation affects the average level of firms' prices. That is, a firm's profit-maximizing average price when its price varies over two periods differs from its profit-maximizing price in the absence of inflation. There is not, however, any robust reason that inflation either raises or lowers average prices; instead, the effect is ambiguous and depends on functional forms. For example, inflation reduces average prices if demand is linear but raises them if demand is isoelastic. In addition, for most plausible cases the effect of inflation on average prices is small.[3]

Thus inflation has one positive welfare effect and one that is ambiguous and small. This version of the model does not support the view that inflation has substantial costs.

2. EQUILIBRIUM

We now determine the equilibrium of the model with inflation and costs of setting up a customer relationship. We first derive consumer demand and then firms' profit-maximizing prices.

2.1 Consumer Inference and Demand

As discussed above, we assume that the cost of setting up a relationship is sufficiently large that a consumer buys in both periods of life or in neither.[4] We therefore focus on the choice between these two options. If a consumer buys in both periods, his utility is $e - P_H$ in one period and $e - P_L$ in the other, for an average of $e - \bar{P}$; again, e is the utility from buying net of per-period set-up costs. (We suppress the i and j subscripts for simplicity.) If the consumer does not buy, his average utility is zero. The consumer must decide whether to buy in his first period when he observes an initial price P'. Since the consumer does not observe his firm's cost parameter, C, he does not know the average price, $\bar{P}$; that is, he does not know whether P' is P_H or P_L. He bases his behavior on an estimate of $\bar{P}$: he buys if $e > \hat{P}(P')$, where $\hat{P}(P')$ is his estimate of $\bar{P}$ given P'.

How do consumers estimate $\bar{P}$? For simplicity, we assume that consumers use the optimal *linear* function of P'. That is, we restrict attention to inference rules of the form

$$\hat{P} = a + bP' . \tag{1}$$

This assumption is not essential: one can show that the results are similar when consumers use optimal inference without the linearity restriction.

With linear inference, the consumer faces a standard signal-extraction problem. Inflation makes an observed price, P', a noisy signal of a firm's average price, $\bar{P}$. If a consumer observes a high P', for example, this might reflect a high average price, or it might reflect the fact that the firm is charging P_H instead of P_L. Writing $P' = \bar{P} + (P' - \bar{P})$, the average price, $\bar{P}$, is uncorrelated with the noise term,

$P' - \bar{P}$. Thus the optimal a and b in Equation (1) are

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

and

$$a = (1 - b)\mu\,, \tag{3}$$

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.

To determine the parameters a and b, recall that a firm's initial price, P', equals either $P_H = [2\Delta/(1 + \Delta)]\bar{P}$ or $P_L = [2/(1 + \Delta)]\bar{P}$. This implies $\sigma^2_{P'-\bar{P}} = [(\Delta - 1)/(1 + \Delta)]^2 E[\bar{P}^2] = [(\Delta - 1)/(1 + \Delta)]^2[\mu^2 + \sigma^2_{\bar{P}}]$. Substituting this expression into Equation (2) yields

$$b = \frac{\nu^2}{\nu^2 + [(\Delta - 1)/(1 + \Delta)]^2[1 + \nu^2]}\,, \tag{4}$$

where $\nu = \sigma_{\bar{P}}/\mu$ is the coefficient of variation of average prices, $\bar{P}$, across firms. The parameter ν is determined by the distribution of costs, C_i, which the consumer knows, and by firms' optimal markups, derived below.

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 still positive: a higher observed price implies a higher estimate of the average price. But b is less than one because consumers attribute part of price variation to inflation rather than to differences in average prices.

2.2 *Profit-Maximizing Prices*

We now determine firms' pricing behavior. Recall that a customer buys the good if $e > \hat{P}(P')$, where P' is the price he initially observes. The number of new customers attracted by a firm charging a price P is $N[1 - G(\hat{P}(P))]$. In each period, the firm sells to customers who were attracted at P_H and to customers who were attracted at P_L; the total sales to these two cohorts are $N[1 - G(\hat{P}(P_H))] + N[1 - G(\hat{P}(P_L))]$. Since P_H and P_L are determined by $\bar{P}$ and Δ, we can write this total demand as $D(\bar{P},\Delta)$. The firm's average price is $\bar{P}$ and its unit cost is C; thus its average profits are $(\bar{P} - C)D(\bar{P},\Delta)$. The firm chooses the average price $\bar{P}$ that maximizes this expression.

The Appendix derives an expression defining the profit-maximizing average price. In general, the expression is complex. For the case of linear demand, however, the expression simplifies to

$$\bar{P} = \frac{C + B}{2} + \frac{(1 - b)(B - \mu)}{2b}\,. \tag{5}$$

For constant-elasticity demand, the result is

$$\bar{P} \simeq \frac{\eta}{\eta - 1} C + \frac{1 - b}{\eta - 1} \mu \, , \tag{6}$$

where we use a second-order Taylor approximation in inflation around $\Delta = 1$. In both these cases, the first term on the right is the profit-maximizing price in the absence of inflation, and the second term is positive. Thus, inflation leads to higher average prices. We interpret this result below.

We have analyzed a firm's pricing decision taking costs and consumer demand as given. Demand depends on consumers' inference rules, Equations (1)–(4), which in turn depend on the mean and variance of average prices across firms. Thus, we have implicitly solved for a firm's price as a function of its cost parameter, C, and the distribution of average prices. This solution defines the equilibrium distribution of average prices in terms of the distribution of C.[5]

3. INFLATION AND WELFARE

3.1 Overview

We now determine the welfare effects of inflation. Recall that entry drives firms' average profits to zero. We therefore focus on how inflation affects consumers' utility.

Consider a consumer with a taste parameter e who meets a firm with an average price $\bar{P}$. The consumer receives utility $e - \bar{P}$ if he buys the good and zero otherwise. He buys the good if $\hat{P}(P') < e$; P′ equals P_H or P_L, depending on when the consumer meets the firm. These facts imply that, for a given e, the consumer's expected utility is determined by $\bar{P}$ and the values of $\hat{P}$ corresponding to P_L and P_H. Equivalently, utility is determined by $\bar{P}$ and the two values of $\hat{P} - \bar{P}$, the error in estimating $\bar{P}$. We write utility as $u(\bar{P},\mathbf{E})$, where $\mathbf{E}$ is a vector with elements $\hat{P}(P_H) - \bar{P}$ and $\hat{P}(P_L) - \bar{P}$.

$u(\bar{P},\mathbf{E})$ is the expected utility of a particular consumer conditional on meeting a particular firm. A consumer's unconditional expected utility is the average of $u(\bar{P},\mathbf{E})$ across firms with different prices. Aggregate welfare is obtained by averaging across consumers with different taste parameters e.

Inflation affects both average prices, $\bar{P}$, and consumers' errors in estimating $\bar{P}$. We therefore write a consumer's utility as $u(\bar{P}(\Delta),\mathbf{E}(\Delta))$. If there is no inflation ($\Delta = 1$) then $\bar{P}$ is the no-inflation price, P^*, derived in Section 1.2. And since prices are constant in this case, consumers estimate average prices perfectly: $\mathbf{E} \equiv 0$. Thus the effect of inflation on utility is

$$u(\bar{P}(\Delta),\mathbf{E}(\Delta)) - u(P^*,0) \, . \tag{7}$$

The effect of inflation on aggregate welfare is Expression (7) averaged across all firms and consumers.

To understand the effects of inflation, we decompose Expression (7) into two terms:

$$u(\bar{P}(\Delta),\mathbf{E}(\Delta)) - u(P^*,0) = [u(\bar{P}(\Delta),\mathbf{E}(\Delta)) - u(\bar{P}(\Delta),0)] + [u(\bar{P}(\Delta),0) - u(P^*,0)] \,. \tag{8}$$

The two terms capture two channels through which inflation affects a consumer's utility. The first is the effect of inflation on the consumer's errors in estimating a firm's average price, holding constant the price itself. The second is the effect on the average price. The following parts of this section analyze these two effects. To preview the results, the first effect unambiguously reduces welfare. The second is in principle ambiguous, but it reduces welfare in most reasonable cases. And both negative effects can be substantial at moderate inflation rates.

3.2 *Relative-Price Variability and Consumer Inference*

The first term in Equation (8) gives the effect of inflation on consumer welfare holding constant a firm's average price, $\bar{P}$. It is easy to show that this effect is negative. When there is no inflation, and hence no errors in estimating $\bar{P}$, a consumer buys if and only if $e > \bar{P}$. His utility, $u(\bar{P},0)$, is $\text{Max}[e - \bar{P},0]$. With inflation, a consumer's estimate, $\hat{P}$, differs from the true $\bar{P}$; therefore, he may buy when $e < \bar{P}$ or fail to buy when $e > \bar{P}$. These deviations from his no-inflation behavior reduce his utility below $\text{Max}[e - \bar{P},0]$.

The intuition for this result is simple. A consumer uses a firm's initial price to estimate its average price, which determines whether he should buy. Inflation causes the firm's relative price to vary, making an initial price a noisy signal of the average price. With less accurate information, the consumer makes mistakes about whether to buy.

Our model therefore captures the idea that inflation is costly because it "degrades the information content of price[s]" (Carlton 1982). In our model, this result arises because consumers form long-term relationships with suppliers. The desire to estimate future prices during a relationship creates an informational role for current prices. This role does not exist in spot markets, where consumers' optimal behavior depends only on current prices.

3.3 *Inflation and Average Prices*

The second term in Equation (8) gives the effect of inflation on welfare that arises because inflation affects a firm's average price. This effect is evaluated when $\mathbf{E} = 0$—when consumers observe average prices perfectly. As discussed above, a consumer's utility when $\mathbf{E} = 0$ is $\text{Max}[e - \bar{P},0]$, which is decreasing in $\bar{P}$. Thus, the second term in Equation (8) is negative if $\bar{P}(\Delta)$ exceeds P^*. That is, inflation harms consumers through this channel if it raises a firm's average price.

As discussed in Section 2.2, one cannot obtain general results about the effect of inflation on average prices in our model. But for standard cases such as linear or constant-elasticity demand, inflation raises average prices. Thus, our presumption is that inflation harms consumers through this channel.

The increases in average prices are caused by the reduced informativeness of prices. When relative-price variability adds noise to prices, consumers put less weight on them in estimating average prices. Specifically, inflation reduces b, the effect of an observed price on the estimated average price, $\hat{P}$, below one. Consumer demand depends on estimated average prices; thus, a lower effect of observed prices on $\hat{P}$ makes demand less elastic with respect to observed prices. Specifically, demand from customers who observe a price P is proportional to $1 - G(\hat{P}(P))$. The slope of demand is proportional to $G'(\cdot)\hat{P}'(\cdot) = G'(\cdot)b$, and so reducing b makes demand flatter. This decline in the elasticity of demand raises average prices.[6]

3.4 Quantitative Results

Our model is too stylized to yield precise estimates of the welfare costs of inflation. Nonetheless, we would like to know whether inflation at levels experienced in developed countries can plausibly have costs that are quantitatively important. To gain some insight into this question, we calculate the losses from inflation for realistic values of the model's parameters.

We calculate the losses arising from each of the two terms in Equation (8). For each term, the Appendix derives a second-order Taylor approximation in the inflation rate, $\pi \equiv \Delta - 1$. We average the loss for a given consumer over all customers of all firms. As a fraction of total spending in the market, the first term in Equation (8) is approximately $\pi^2/8$ times a weighted average of the elasticity of demand at different points on a firm's demand curve. If there is a constant elasticity η, the loss is simply $\eta\pi^2/8$. This is the loss from consumers' errors in estimating average prices.

As a fraction of spending in the market, the second term in Equation (8)—the loss from higher average prices—is approximately the percentage increase in the mean of the prices faced by consumers who initially purchased the good. For linear and constant-elasticity demand, this increase can be calculated using Equations (5) and (6) for the case of a firm with $\bar{P} = \mu$.[7]

For simplicity, we assume constant-elasticity demand in our numerical calculations. We set the elasticity, η, equal to 8; this implies that prices exceed marginal cost by 14%, a markup consistent with microeconomic evidence for typical industries (Scherer and Ross 1990). In considering consumers' signal-extraction problem, we set the parameter ν equal to 0.1. This means that the standard deviation of average prices across firms is 10% of the mean price.

The final relevant parameter is the inflation rate, π. 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 (that is, periods that last six months). One year is the median interval between price adjustments in Blinder et al.'s (1998) survey of firms. There is 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 1995). For these cases, π is 12.5%.

For our base case of $\eta = 8$, $\nu = 0.1$, and $\pi = 5\%$, the first term in Equation (8)—the loss from inflation-induced estimation errors—is approximately 0.25% of total spending in the market. The second term—the loss from higher average prices—is 0.82% of total spending. This reflects a value of b, the effect of an initial price on the estimated average price, of 0.94 [see Equation (4)]. The total welfare loss from inflation is 1.07% of spending.

Thus, our model suggests that inflation has substantial costs. If every market in the economy were described by the model, the welfare loss from inflation would be 1.07% of GDP. With a discount factor of 0.95, it would be worth sacrificing 20(1.07%) = 21% of annual output to eliminate inflation. Disinflation would raise welfare even if it required a major recession.

For the case of $\pi = 12.5\%$ (that is, 25% price adjustments), the results are dramatic. The coefficient b is only 0.74. The first term in Equation (8) is approximately 1.6% of spending in the market, and the second term is approximately 3.8%, for a total loss of 5.4%. Our model suggests that inflation has major costs in the markets with the least frequent price adjustment.

4. THE FREQUENCY OF PRICE ADJUSTMENT

4.1 Motivation and Overview

In our basic model, we take infrequent price adjustment as given: we assume that firms adjust their nominal prices every two periods. Here we relax this assumption and allow firms to choose between adjusting every period and every two periods, given a menu cost. We show that firms choose two-period adjustment under plausible conditions, justifying our earlier assumption.

The results of this section help to explain an important empirical phenomenon: the infrequency of price adjustment. 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. One possible explanation is simply that there are large costs of price adjustment. As suggested by Levy et al. (1997) and Zbaracki et al. (2000), firms in some industries expend substantial resources changing prices. For such firms, it may not be puzzling that adjustment is infrequent. Yet, as stressed in the menu-cost literature, there are also cases where adjustment is infrequent even though it appears inexpensive. Many barber shops keep the price of a haircut fixed for several years, even though it would be easy to adjust every year or every several months to keep up with inflation. The failure of such firms to adjust frequently implies that their gains from stabilizing relative prices must be small (even though consumers might benefit considerably). Is this plausible?

Once again, long-term customer relationships are crucial to the answer. If demand is not linked across periods, then relative-price variability induces variability in sales that reduces firms' profits substantially. But if customers buy repeatedly or not at all, firms' sales remain steady as their prices fluctuate. In this case, a firm may lose little or nothing from relative-price variation. Thus, it adjusts its nominal price infrequently even if the cost of price adjustment is small.

4.2 The Model without Set-up Costs

To see the importance of long-term relationships, we first consider the case in which the cost, K, of setting up a relationship is zero. In this case, as discussed in Section 1.3, consumers make independent decisions about whether to buy in each period. We compute a firm's profits when it adjusts its nominal price every period and when it adjusts every two periods. Infrequent adjustment is an equilibrium if the difference in profits in the two cases is less than the added menu costs of adjusting every period.

If a firm adjusts its price every period, its relative price is constant at P^*, the no-inflation price. If the firm adjusts every two periods, its price alternates between P_H and P_L with an average level that maximizes average profits. In either case, the firm's sales each period are $2N[1 - G(P)]$, where P is the current price. The firm's cost function is the short-run function, $CH(Q - \bar{Q})$, since output fluctuates if P fluctuates. Using these facts, we compute the difference between average profits with one- and two-period adjustment and take a second-order approximation in the inflation rate. For constant-elasticity demand, the difference as a share of the firm's revenue is

$$\frac{(1 + \alpha\eta)(\eta - 1)}{8}\pi^2 , \tag{9}$$

where η the is 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 in the constant-elasticity case, the loss is larger.)

To calculate the loss from two-period adjustment, we set $\eta = 8$ and $\alpha = 1$, which means moderately increasing marginal cost. If $\pi = 5\%$ (that is, prices change 10% per adjustment in the two-period case), the loss from two-period adjustment is substantial: 2.0% of revenue and 15.8% of profits. For $\pi = 12.5\%$, the loss is huge: 12.3% of revenue and 98% of profits. These losses stem from the variability in sales with two-period adjustment, which reduces profits through both lower revenues (since sales are low when price is high) and higher costs (since the cost function is convex).

These losses from nominal rigidity appear large compared with the costs of price adjustment in many industries. We therefore conclude that firms would choose to adjust every period.

4.3 Long-Term Relationships

We now reintroduce the cost of setting up a relationship, which causes consumers to buy in both periods of life or in neither. 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 face the single firm that may adjust every period.

The number of customers that firm i attracts in a period is $1 - G(\hat{P}(P))$. If the firm adjusts its price every period, its relative price is constant. Its profits each period as a function of its price, $\bar{P}$, are

$$(\bar{P} - C)[2 - 2G(\hat{P}(\bar{P}))]N\,. \tag{10}$$

If the firm adjusts every two periods, its price alternates between $P_H = [2\Delta/(1 + \Delta)]\bar{P}$ and $P_L = [2/(1 + \Delta)]\bar{P}$, where $\bar{P}$ is its average price. Its number of new customers alternates between $[1 - G(\hat{P}(P_H))]N$ and $[1 - G(\hat{P}(P_L))]N$. Crucially, since customers remain for two periods, total sales are constant at $[2 - G(\hat{P}(P_H)) - G(\hat{P}(P_L))]N$ and marginal cost is constant at C. The firm's average profits are

$$(\bar{P} - C)[2 - G(\hat{P}(P_H)) - G(\hat{P}(P_L))]N\,. \tag{11}$$

Firm i chooses to adjust every two periods if the gain in profits from more frequent adjustment is less than the added menu costs. The gain in profits is the difference between Expressions (10) and (11), with $\bar{P}$ set at the profit-maximizing level in each case.

It is straightforward to show that two-period adjustment is an equilibrium under plausible conditions. In particular, a sufficient condition is that demand is weakly convex, which means $G''(\bullet) \leq 0$. This case is the standard one: it covers linear demand ($G''(\bullet) = 0$), constant-elasticity demand, and demand with curvature between these two cases.

To see that $G''(\bullet) \leq 0$ is sufficient for two-period adjustment, we compare Expressions (10) and (11) with the same $\bar{P}$. The difference between these expressions has the same sign as the difference between $2 - 2G(\hat{P}(\bar{P}))$ and $2 - G(\hat{P}(P_H)) - G(\hat{P}(P_L))$. Note that $\bar{P}$ is the average of P_H and P_L, and that $\hat{P}(\cdot)$ is linear. These facts imply that $\hat{P}(\bar{P})$ is the average of $\hat{P}(P_H)$ and $\hat{P}(P_L)$. Thus, by Jensen's inequality, the assumption that $G''(\bullet) \leq 0$ implies that the value of Expression (11) is greater than or equal to that of Expression (10): for a given $\bar{P}$, the gain from adjusting more frequently is nonpositive. Since the gain is nonpositive for any $\bar{P}$, the maximum value of Expression (11) over $\bar{P}$ is at least as large as the maximum value of Expression (10). Thus, the gain in profits from more frequent adjustment, ignoring the menu cost, is nonpositive. This implies that any positive menu cost, no matter how small, is sufficient to make two-period adjustment an equilibrium.

This result arises because long-term relationships break the link between short-run fluctuations in relative prices and variation in sales. Since frequent nominal adjustment is not needed to stabilize sales, its effect on profits depends on its effect on the constant *level* of sales. For most natural demand functions, this effect is nonpositive.[8]

5. DISCUSSION AND CONCLUSIONS

5.1 Comparison with Recent Literature

A number of recent papers study the welfare effects of relative-price variability arising from inflation, including those of Bénabou (1988, 1992), Bénabou and Gertner (1993), Fishman (1992), and Diamond (1993). By introducing such phenomena as consumer search and imperfect information about the aggregate price level, these papers identify a number of channels through which inflation might affect welfare. Generally, however, this literature suggests that the welfare effects of inflation are ambiguous: the models do not robustly capture the common intuition that inflation is harmful. A basic explanation is that these papers consider consumers who purchase a good a single time—there are no long-term relationships. Without long-term relationships, the models lack the informational role of prices that we argue is central to the costs of inflation.

The previous model that is closest to ours is that of Tommasi (1994). Tommasi emphasizes the effects of inflation on consumer search across firms, which is absent from our model. As in our model, however, 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 assuming a link between inflation and relative-price variability. In addition, by suppressing search and other features of Tommasi's model, we capture the basic effects of inflation more simply.

5.2 The Informational Role of Prices

In our model, 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 those of 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 with 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 *less* on prices to allocate resources. Our results support this counterintuitive argument. If there are no long-term relationships, so demand depends only on current prices, then inflation does not have large costs (recall Section 1.3). Inflation *does* have significant costs with long-term relationships in which sales do not respond to period-to-period price movements.

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 higher markups arising from inflation allow 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.

In his Nobel Lecture, Friedman (1977) argues that inflation reduces the ability of the price system to "transmit information." His ideas are complementary to ours, but the argument is quite different. In Friedman's view, which builds on the work of Lucas (1973), fluctuations in inflation make it difficult to determine relative prices from the nominal prices that agents observe (see also Bénabou and Gertner 1993). The story depends on the assumption that the current price level is unobservable. In our model, by contrast, the price level is observable, so agents know current relative prices; the uncertainty concerns future price movements. A related difference is that only the *variance* of inflation affects information in Friedman's story, while we find that even steady inflation reduces information by increasing microeconomic variability. Our model appears more relevant to moderate-inflation countries such as the U.S., where accurate information about the price level is released with a short lag. Friedman's story appears relevant to high-inflation countries, where there can be considerable uncertainty about the current price level.

5.3 Conclusions

This paper studies the welfare effects of the relative-price variability arising from inflation. If demand is not linked across periods, relative-price variability *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 customer 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 nonneutrality that arises from inflation even if loans and taxes are indexed. This nonneutrality 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 presents details of our analysis that are omitted from the text.

The Model without Set-up Costs

Here we derive the welfare effects of inflation in the absence of set-up costs (that is, with $K = 0$). These effects are summarized in Section 1.3 of the text.

Consider a consumer who meets a given firm. When $K = 0$, the consumer buys each period if and only if $e > P$, where P is the firm's current price (we suppress the i and j subscripts). The consumer's utility is $\text{Max}[e - P, 0]$. The consumer participates in the market for two periods; if the firm's average price is $\bar{P}$, the consumer faces $P_H = [2\Delta/(1 + \Delta)]\bar{P}$ in one period and $P_L = [2/(1 + \Delta)]\bar{P}$ in the other. The consumer's total utility is

$$U(\bar{P},\Delta) = \text{Max}\left[e - \frac{2\Delta}{1 + \Delta}\bar{P},0\right] + \text{Max}\left[e - \frac{2}{1 + \Delta}\bar{P},0\right]. \tag{A1}$$

The gross inflation rate Δ affects utility through two channels: it affects utility directly for a given $\bar{P}$, and it affects $\bar{P}$. To analyze the direct effect, note that an increase in Δ raises the variance of P across the two terms in Equation (A1) and does not change the mean. $\text{Max}[e - P, 0]$ is convex in P. Thus, the higher variance of P raises utility.

To analyze the effect of inflation that works through $\bar{P}$, we consider a firm's profit-maximization problem. For simplicity, we focus on the case in which short-run marginal cost is constant.

With constant marginal cost and no set-up costs, a firm's profits in a given period are $[P - C]2N[1 - G(P)] \equiv R(P)$. The firm's profits over two periods are $R(P_H) + R(P_L)$. For a given Δ, the firm's choice of $\bar{P}$ determines P_H and P_L. The first-order condition for $\bar{P}$ is

$$R'(P_H)\frac{\partial P_H}{\partial \bar{P}} + R'(P_L)\frac{\partial P_L}{\partial \bar{P}} = 0\,, \tag{A2}$$

which simplifies to

$$\Delta R'(P_H) + R'(P_L) = 0\,. \tag{A3}$$

A second-order approximation of Equation (A3) in the inflation rate yields

$$\bar{P} \simeq P^* - \left[\frac{P^{*2}R'''(P^*)}{2R''(P^*)} + P^*\right]\frac{\pi^2}{4}\,, \tag{A4}$$

where P^* is the profit-maximizing price in the absence of inflation and $\pi = \Delta - 1$. The second term in this expression is the effect of inflation on a firm's average price.

The effect of inflation on $\bar{P}$, and hence on welfare, is ambiguous. For the case of linear demand, one can show that inflation lowers $\bar{P}$ 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 elasticity of demand; for $\eta = 8$ and $\pi = 5\%$, $\bar{P}$ rises by 0.5%. Thus, the effect on average prices 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 small effects on average prices.[9]

The Effect of Inflation on Average Prices

Section 2.2 gives an expression for a firm's average profits. Using the inference rule of Equation (1), this expression can be written as $(\bar{P} - C)N[2 - G(a + bP_H) - G(a + bP_L)]$, where $P_H = [2\Delta/(1 + \Delta)]\bar{P}$ and $P_L = [2/(1 + \Delta)]\bar{P}$. The first-order condition for the firm's choice of $\bar{P}$ is

$$\begin{aligned}&\frac{2}{1+\Delta}b(\bar{P} - C)[\Delta g(a + bP_H) + g(a + bP_L)]\\ &\quad = 2 - G(a + bP_H) - G(a + bP_L)\,.\end{aligned} \tag{A5}$$

If e is uniform on $[A, B]$—so demand is linear—$g(a + bP_H) = g(a + bP_L) = g(\bar{P})/(B - A)$ and $G(a + bP_H) + G(a + bP_L) = 2G(a + b\bar{P}) = 2(a + b\bar{P} - A)/(B - A)$. Substituting these facts into Equation (A5) yields Equation (5) in the text.

If $G(e) = 1 - e^{-\eta}$ for $e \geq 1$—so demand is isoelastic—Equation (A5) simplifies to

$$\begin{aligned}&\frac{2}{1+\Delta}b(\bar{P} - C)[\Delta\eta[a + bP_H]^{-\eta-1} + \eta[a + bP_L]^{-\eta-1}]\\ &\quad = [a + bP_H]^{-\eta} + [a + bP_L]^{-\eta}\,.\end{aligned} \tag{A6}$$

Taking a second-order approximation of this expression around $\pi = 0$ yields Equation (6) in the text.

Welfare with Two-Period Relationships

Here we derive a second-order approximation to Equation (8)—the welfare loss from inflation—that we use for the quantitative analysis in Section 3.4. We start with the second term in Equation (8), which is the loss arising from higher average prices. The loss from higher prices to 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, as claimed in the text, consumers' losses as a fraction of total spending are the percentage increase in the average price faced by consumers who initially purchased the good.

We next consider the first term in Equation (8)—the welfare loss from inflation for a given average price. As described in the text, a consumer enters a relationship if $e > a + bP$, where P is the price the consumer observes. Suppose that a consumer meets a firm that is currently charging its high price, $[2\Delta/(1 + \Delta)]\bar{P}$. In this case, the consumer buys from the firm if its average price is less than P_o, where P_o is defined by $a + b[2\Delta/(1 + \Delta)]P_o = e$. Similarly, define P'_o by $a + b[2/(1 + \Delta)]P'_o = e$. If the consumer meets a firm charging its low price, he buys if the firm's average price is less than P'_o.

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

$$\mathbf{E}[U(e)] = \frac{1}{2}\left[\int_{\bar{P}=0}^{P_o}(e - \bar{P})\hat{f}(\bar{P})\mathrm{d}\bar{P} + \int_{\bar{P}=0}^{P'_o}(e - \bar{P})\hat{f}(\bar{P})\mathrm{d}\bar{P}\right], \tag{A7}$$

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

Taking a second-order Taylor expansion of $\mathbf{E}[U(e)]$, 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

$$\int_e e^2\hat{f}(e)g(e)\mathrm{d}e\frac{\pi^2}{8}\,. \tag{A8}$$

This expression can be rewritten as

$$\int_P P[1 - G(P)]\hat{f}(P)\eta(P)\mathrm{d}P\frac{\pi^2}{8}\,, \tag{A9}$$

where $\eta(P) \equiv g(P)P/[1 - G(P)]$ is the elasticity of demand at price P in the absence of inflation. Average spending per consumer in this market is $\int_P P[1 - G(P)]$

$\hat{f}(P)\mathrm{d}P$; thus, the welfare loss as a fraction of spending is

$$\frac{\int_P P[1 - G(P)]\hat{f}(P)\eta(P)\mathrm{d}P}{\int_P P[1 - G(P)]\hat{f}(P)\mathrm{d}P}\frac{\pi^2}{8}. \tag{A10}$$

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.

NOTES

1. Our working paper (Ball and Romer 1998) presents an extension of our model that relaxes the assumption that a consumer can buy only from a single firm. Specifically, we assume that consumers can visit additional firms by paying a search cost. We find that the main welfare effects of inflation are robust to allowing search. Indeed, this modification of the model strengthens our argument by providing a foundation for long-term customer relationships: even in the absence of set-up costs, customers form long-term attachments with firms to economize on search costs.

2. Our assumption of free entry means that our estimates of the costs of inflation are conservative. If we relaxed this assumption, so entry did not drive firms' profits to zero, then relative-price variability caused by inflation would reduce profits (Samuelson 1972). As a result, the total welfare loss from inflation would exceed the cost to consumers that we derive here. However, the effect of relaxing the free-entry assumption is unlikely to be large. As described in the introduction, firms can eliminate the relative-price variability caused by inflation through frequent price adjustment. Since such adjustment appears inexpensive, firms would presumably use it to eliminate any substantial profit losses.

3. See Naish (1986) and Bénabou and Konieczny (1994) for more detailed analyses of inflation and average prices.

4. A sufficient condition is that the fixed cost of setting up a relationship, K, exceeds $3(\Delta - 1)\bar{P}_{\max}$, where $\bar{P}_{\max}$ is the average price of the highest-cost firm. To see this, consider first a consumer who faces the low price, P_L, in the first period. A necessary condition for him to buy in the first period is that he gains in the optimistic scenario that the price he faces is the firm's high price; this condition is $(\tilde{e} - P_L - K) + (\tilde{e} - [P_L/\Delta]) > 0$. If the consumer buys in the first period, he buys in the second if $\tilde{e} - P_H > 0$. Straightforward algebra shows that if $K > 3(\Delta - 1)\bar{P}_{\max}$, then $(\tilde{e} - P_L - K) + (\tilde{e} - P_L/\Delta) > 0$ implies $\tilde{e} - P_H > 0$. A similar analysis shows that $K > 3(\Delta - 1)\bar{P}_{\max}$ also ensures that a consumer who faces P_H in the first period and chooses not to buy will also choose not to buy in the second period.

5. Recall that we assume each firm has a unique profit-maximizing price in the absence of inflation. The behavior of prices is continuous in the inflation rate. Thus equilibrium prices are unique when inflation is positive but sufficiently small.

6. Inflation also affects average prices through a conventional third-derivative effect: since profit functions are not quadratic, variability in a firm's price affects its optimal average price. This effect has an ambiguous sign, and in principle it can be larger than the effect of less-elastic demand. This explains why inflation does not raise average prices in general, even though it does for standard demand functions.

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

8. We have assumed that if a firm adjusts every period, it keeps its real price constant. In models with long-term relationships, a firm can sometimes gain by attracting customers at a low price and then raising its price greatly once customers are attached (Klemperer, 1987, and Farrell and Shapiro, 1988). Our working paper (Ball and Romer 1998) shows, however, that such strategies are unprofitable in our model under plausible conditions. We also show that $G''(\bullet) \leq 0$ implies not only that infrequent adjustment is an equilibrium, but also that the equilibrium is unique.

9. 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 4.2, however, if there are no long-term relationships and marginal cost is significantly upward sloping, firms have very large incentives to adjust their prices every period, and so infrequent price adjustment cannot be an equilibrium.

LITERATURE CITED

Ball, Laurence, and David Romer (1998). "Inflation and the Informativeness of Prices." Paper, Johns Hopkins University and University of California, Berkeley.

Bénabou, Roland (1988). "Search, Price Setting, and Inflation." *Review of Economic Studies* 55, 353–373.

Bénabou, Roland (1992). "Inflation and Efficiency in Search Markets." *Review of Economic Studies* 59, 299–329.

Bénabou, Roland, and Robert Gertner (1993). "The Informativeness of Prices: Search with Learning and Cost Uncertainty." *Review of Economic Studies* 60, 69–93.

Bénabou, Roland, and Jerzy D. Konieczny (1994). "On Inflation and Output with Costly Price Changes: A Simple Unifying Result." *American Economic Review* 84, 290–297.

Blinder, Alan S., Elie R. D. Canetti, David E. Lebow, and Jeremy B. Rudd (1998). *Asking about Prices: A New Approach to Understanding Price Stickiness*. New York: Russell Sage Foundation.

Carlton, Dennis (1982). "The Disruptive Effects of Inflation on the Organization of Markets." In *Inflation: Causes and Effects*, edited by Robert E. Hall, pp. 139–152. Chicago: University of Chicago Press.

Cecchetti, Stephen G (1986). "The Frequency of Price Adjustment: A Study of the Newsstand Price of Magazines." *Journal of Econometrics* 31, 255–274.

Diamond, Peter A. (1993). "Search, Sticky Prices, and Inflation." *Review of Economic Studies* 60, 53–68.

Farrell, Joseph, and Carl Shapiro (1988). "Dynamic Competition with Switching Costs." *Rand Journal of Economics* 19, 123–137.

Fischer, Stanley (1981). "Relative Shocks, Relative Price Variability, and Inflation." *Brookings Papers on Economic Activity* 2, 381–431.

Fishman, Arthur (1992). "Search Technology, Staggered Price-Setting, and Price Dispersion." *American Economic Review* 82, 287–298.

Friedman, Milton (1977). "Nobel Lecture: Inflation and Unemployment." *Journal of Political Economy* 85, 451–472.

Kashyap, Anil K. (1995). "Sticky Prices: New Evidence from Retail Catalogs." *Quarterly Journal of Economics* 110, 245–274.

Klemperer, Paul (1987). "Markets with Consumer Switching Costs." *Quarterly Journal of Economics* 102, 375–394.

Kohn, Meir G., and Steven Shavell (1974). "The Theory of Search." *Journal of Economic Theory* 9, 93–123.

Levy, Daniel, Mark Bergen, Shantanu Dutta, and Robert Venable (1997). "The Magnitude of Menu Costs: Direct Evidence from Large U.S. Supermarket Chains." *Quarterly Journal of Economics* 112, 791–825.

Lucas, Robert E., Jr. (1973). "Some International Evidence on Output-Inflation Tradeoffs." *American Economic Review* 63, 326–334.

Naish, Howard F. (1986). "Price Adjustment Costs and the Output-Inflation Tradeoff." *Economica* 53, 219–230.

Okun, Arthur M. (1975). "Inflation: Its Mechanics and Welfare Costs." *Brookings Papers on Economic Activity* 2, 351–390.

Samuelson, Paul A. (1972). "The Consumer Does Benefit from Feasible Price Stability." *Quarterly Journal of Economics* 86, 476–493.

Scherer, F. M., and David Ross (1990). *Industrial Market Structure and Economic Performance*, 3rd edition. Boston: Houghton Mifflin.

Tommasi, Mariano (1994). "The Consequences of Price Instability on Search Markets: Toward Understanding the Effects of Inflation." *American Economic Review* 84, 1385–1396.

Wachter, Michael L., and Oliver E. Williamson (1978). "Obligational Markets and the Mechanics of Inflation." *Bell Journal of Economics* 9, 549–571.

Waugh, Frederick V. (1944). "Does the Consumer Benefit from Price Instability?" *Quarterly Journal of Economics* 58, 602–614.

Zbaracki, Mark J., Mark Ritson, Daniel Levy, Shantanu Dutta, and Mark Bergen (2000). "The Managerial and Customer Costs of Price Adjustment: Direct Evidence from Industrial Markets." Paper, Emory University.