

Asymmetric Price Rigidity and Inflationary Bias

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When prices adjust in response to market disturbances, they usually do so in discrete jumps. Even when market conditions are changing continuously, prices tend to remain fixed for substantial lengths of time. The commodities fitting this general pattern include most retail goods, services, and intermediate materials.¹

While it is widely recognized that this pricing pattern holds for both upward and downward adjustments, there is no consensus as to whether these are mirror images for given individual firms. Some scholars believe that upward adjustments are generally more pronounced in magnitude or frequency than downward adjustments. Robert Solow (1980), for instance, believes on the basis of casual observations of some macroeconomic evidence, that commodity prices are sticky downward.

Many others, however, view the issue as a completely open question. Phillip Cagan (1979) has documented that prices in the United States tend to rise more in response to increases in demand than they fall in response to corresponding decreases in demand; but he is careful to point out that our present knowledge does not permit us to attribute his evidence to biases in the adjustment behavior of individual firms. Arthur Okun's (1981) research, in contrast, does not point toward an upward bias in prices, yet he, too, agrees that the issue is far from closed.²

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¹The main exception is organized exchanges for raw materials.

²Cagan's hesitation stems partly from arguments that secret discounting imparts flexibility to actual transaction prices when the quoted prices are rigid. He does concede, however, that even the important empirical study of George Stigler and James Kindahl (1970), undertaken to demonstrate that prices are substantially

It is quite possible, of course, for the adjustment policies of different types of firms to be asymmetric in opposite directions, and for some firms to display perfectly symmetric behavior. It is also possible for a given firm to exhibit asymmetric pricing behavior in response to some kinds of disturbances but not others. If indeed there are firms in the economy which display asymmetric behavior in one situation or another, one ought to be able to establish this both empirically and analytically.

This paper examines the adjustment policies of one particular class of business firms: profit-maximizing monopolistic firms with nondecreasing marginal cost functions and nonincreasing elasticity demand functions. The specific disturbances considered in the analysis are changes in the general price level.

I show that firms in this class which incur fixed-price-adjustment costs are likely to change their prices less often under deflation than they would under an equivalent inflation. I also demonstrate that the price-adjustment policies of these firms can be biased upward, in the sense that under given inflationary expectations the firms raise their prices more than they would lower them were they to have symmetric deflationary expectations. Finally, I establish that inflationary uncertainty about *any* core rate of inflation can heighten the upward bias in the firms' adjustment policies.

The intuitive explanation for all these findings is that for a given firm the opportunity cost in any period of charging a suboptimal real price is not symmetric around the firm's optimal price. Money illusion is not the cause

more flexible than they appear in official statistics, fails to settle the issue. As for Okun's doubts, they appear to be linked to the administered price thesis expounded by Gardiner Means and others (1975). Robert Gordon (1981) provides a splendid summary of the macroeconomic evidence and a survey of related theoretical arguments.

of this basic asymmetry: it exists even if the firm, its consumers, and sellers of its inputs all base their decisions on real magnitudes.

In the model presented, the firm's cumulative price adjustment cost is assumed to be invariant to the direction and size of adjustment. This assumption is realistic when the cost arises entirely from the price decision process and the dissemination of price information.³ For any actual firm, though, there exist various other costs which may differ between upward and downward adjustments,⁴ or with the size of adjustment, and asymmetries could arise in the firm's price-adjustment policy for this reason alone. The rationale for assuming that the cumulative cost is fixed is not to deny that it may differ between upward and downward movements for an individual firm, but rather to demonstrate that asymmetries can exist in the firm's price-adjustment policy even when the adjustment cost is fixed.

An important simplifying assumption in the model is that the firm has a two-period planning horizon. In a more complete formulation, the horizon would depend explicitly on the costs of developing and disseminating price policies as well as on the degree of uncertainty concerning demand and the general price level.⁵ In practice, since the future is uncertain and planning is costly, firms use finite planning horizons, the lengths of which vary widely. Each firm determines the length

of its horizon according to such characteristics as market structure, the quality of information about market conditions, planning costs, and industry rules of thumb. The two-period formulation presented here should be regarded as a simplification of the finite-horizon planning model which captures the essential aspects of the problem.

A related simplifying assumption is that the firm's horizon is fixed, in that successive horizons do not overlap. This means that the firm cannot modify a price decision made at the beginning of a horizon. In practice, even firms which issue catalogs at pre-announced intervals reserve the right to change their prices without notice. Due to the heavy costs involved, however, they prefer to exercise this right only in the event of a great surprise. Mail-order firms, for instance, issue price catalogs at intervals which depend on their expectations about inflation.⁶ While their predictions of the price level frequently turn out to be wrong, they do not revise their prices ahead of schedule, unless the prediction error is drastically large.

Section I contains a formulation of the basic model in which the firm has a constant elasticity demand function and a constant marginal cost function, and is assumed to know with certainty the proportional change in the price level between the two periods in its planning horizon. The section proceeds to determine the range of the inflation factor for which price adjustment is unprofitable. Section II then shows that this range is generally not symmetric around one. Section III establishes that the firm's optimal price-adjustment policy is biased upward, and that uncertainty would compound the inflationary bias. The formal results are generalized considerably in Section IV to include any nonincreasing elasticity demand function and any nondecreasing marginal cost function. Section V summarizes the results and touches upon their potential macroeconomic implications.

³Decision and dissemination costs are incurred through activities such as detecting the need for a change, altering bookkeeping entries, printing and mailing new catalogs, changing price labels, and readjusting coin vending machines.

⁴For many firms, as Okun has discussed in detail, customers' need for dependability imposes costs for upward but not downward price changes. The same asymmetry exists for regulated firms which can gain approval for price increases only through costly lobbying efforts, but can lower their prices at will. An opposite asymmetry is present in oligopolistic industries where a price decrease, but not an increase, carries with it the risk of a costly price war.

⁵See Michael Intriligator and Eytan Sheshinski (1979) for a general analysis of the horizon decision in economic planning. They show that the optimal planning horizon is infinite only in the hypothetical case where the firm knows with perfect certainty demand conditions and the price level for all time periods.

⁶For some casual evidence from the United States, see the *Wall Street Journal* news briefs assembled by Sheshinski and Yoram Weiss (1977).

I. The Model

A. Profit Functions

Consider a profit-maximizing monopolist with a two-period planning horizon. This firm's demand in period 1 is given by

$$(1) \quad x_1 = ap_1^{-b}, \quad a > 0, \quad b > 1,$$

where a specifies the market size in period 1, b is the price elasticity of demand, and p denotes nominal price per unit of output. The general price level is normalized to be one in the first period, making the nominal and real prices equal. In period 2, the firm expects its demand to be

$$(2) \quad x_2 = a\theta(p_2/\mu)^{-b},$$

$$0 \leq \theta < \infty, \quad 0 < \mu < \infty,$$

where θ and μ are proportional indexes of the changes in its market size and the price level, respectively.⁷ When θ and μ are both equal to one, the firm expects neither its market size nor the price level to change relative to their values in period 1. A value of θ less than one (greater than one) implies that the firm expects its market to shrink (expand) in period 2. When μ is less than (greater than) one, the firm expects the price level to fall (rise). For the time being, it will be assumed that the firm knows θ and μ with certainty. It is important to emphasize that money illusion is absent from this demand system since the homogeneity postulate of neoclassical economics is satisfied.

For each unit of output, the firm incurs a constant positive real cost denoted by c . In nominal terms, therefore, cost per unit is c in period 1 and $c\mu$ in period 2. If the firm chooses to charge different nominal prices in each period, it also incurs a real adjustment cost, η , in period 2.⁸ Assuming there is no

capacity constraint, the firm's nominal profits in each period are given by

$$(3) \quad \Pi_1(p_1) = x_1(p_1 - c);$$

$$(4) \quad \Pi_2(p_2) = x_2(p_2 - c\mu) - \delta(\eta\mu),$$

where δ is a Kronecker *delta* which takes the value 0 if $p_1 = p_2$, and the value 1 otherwise. Note that nominal changes are assumed to be costly even when no real change is involved. This is a natural assumption since almost all firms set their prices in nominal terms. Even in high-inflation countries where wage and bond indexation are common, very few prices, wholesale or retail, are linked to the general price level.⁹

The assumption that real input costs are impervious to changes in the price level has a significant bearing on the results to be presented, so it must be justified before proceeding. There are two rationales for this assumption, one involving material costs and the other labor costs. The material component of costs could conceivably fluctuate over time because the suppliers themselves incur price adjustment costs. Considering, however, that the production of almost any commodity requires multiple material inputs and that price adjustment patterns are imperfectly synchronized across suppliers, it appears that the cumulative real cost of material inputs would not in general be seriously affected by changes in the price level. The labor component of costs, on the other hand, is not affected by inflation because wages are often implicitly, and sometimes explicitly, linked to the price level.¹⁰

B. Alternative Price Policies

At the beginning of period 1, the firm must decide whether to charge the same or different nominal prices in the two periods.

⁷Implicit in this formulation is the assumption that the firm is small enough to ignore its own influence on the price level.

⁸The cost of choosing a price in period 1 is treated as a fixed cost and hence disregarded.

⁹In an economy where firms' prices were indexed, price level movements would generate automatic and costless changes in nominal prices. In such an economy, firms would incur costs only for real price changes.

¹⁰See Okun (chs. 2, 3, and 6) for an analysis of why wage indexation is so prevalent.

To determine the profit-maximizing sequence of prices, the firm calculates and then compares the present discounted value of total real profits under each of these two price policies. The real discount factor is $\rho = 1/(1+r)$, where r denotes the real interest rate.

If the firm chooses to pursue a one-price policy, the optimal nominal price is that which maximizes its total discounted real profits

$$(5) \quad \Pi(p) = \Pi_1(p) + \rho\mu^{-1}\Pi_2(p),$$

where $p = p_1 = p_2$, and $\Pi_2(p)$ is given by (4) with $\delta = 0$. Taking the first-order condition of (5) and rearranging terms gives the optimal p as

$$(6) \quad p^* = P \frac{(1 + \rho\theta\mu^b)}{(1 + \rho\theta\mu^{b-1})},$$

where $P = bc/(b-1)$. Substituting (6) into (5) yields the firm's maximum real profit as

$$(7) \quad \Pi^* = \phi \frac{(1 + \rho\theta\mu^{b-1})^b}{(1 + \rho\theta\mu^b)^{b-1}},$$

where $\phi = aP^{-b}(P-c)$.

The firm's other option is to pursue a two-price policy. In this case, its maximand takes the form

$$(8) \quad \Pi(p_1, p_2) = \Pi_1(p_1) + \rho\mu^{-1}\Pi_2(p_2),$$

where $\Pi_2(p_2)$ is given by (4) with $\delta = 1$. The first-order conditions of (8) give

$$(9) \quad p_1^{**} = P;$$

$$(10) \quad p_2^{**} = P\mu,$$

which are the monopoly prices in each period. Note that p_1 and p_2 are independent of a and θ . Whereas the optimal one-price policy almost always depends on the relative market sizes in the two periods,¹¹ here p_1 and p_2 are

invariant with respect to the market size parameters. By substituting the optimal prices into (7), we obtain the maximum level of discounted real profits as

$$(11) \quad \Pi^{**} = \phi(1 + \rho\theta) - \rho\eta.$$

C. Optimal Price Policy

Now let us define the function

$$(12) \quad G(\mu, \theta) \equiv \Pi^* - \Pi^{**}.$$

Given a pair of values for μ and θ , the sign of G determines the firm's optimal price regime. The one-price policy is optimal when $G > 0$, and the two-price policy is optimal when $G < 0$. In cases where $G = 0$, the firm is indifferent between the two regimes, but to facilitate exposition of the results, it is assumed that the firm favors the one-price policy.

To establish the properties of the function G , which is depicted in Figure 1, it is useful to begin by examining its slope as μ varies between 0 and ∞ . Differentiating G with respect to μ and rearranging terms reveals that the function G monotonically increases as μ varies between 0 and 1, reaches a maximum at $\mu = 1$, and monotonically decreases as μ increases beyond 1. By substituting $\mu = 1$ into (12), one can see that the maximum value of G is $\rho\eta$. Intuition bears this out: when $\mu = 1$ the optimal price and output levels are the same under the two alternative price policies, but real profits are lower under the two-price policy because of the adjustment cost. As μ moves away from 1 in either direction, G takes on values less than $\rho\eta$ because Π^* monotonically declines.

It follows that the equation $G(\mu, \theta) = 0$ has a maximum of two roots in μ . These critical values, when they exist, will be denoted by $\underline{\mu}(\theta)$ and $\bar{\mu}(\theta)$, designating, respectively, the lowest and highest values of μ for which the one-price policy is optimal. Only if μ falls outside this closed interval is it optimal to charge different nominal prices in each period.

¹¹The optimal one-price policy is independent of θ only when $\mu = 1$. In this special case, the vector of optimal prices is the same under each policy, but profits

are lower by the amount $\rho\eta$ under the one- than the two-price policy.

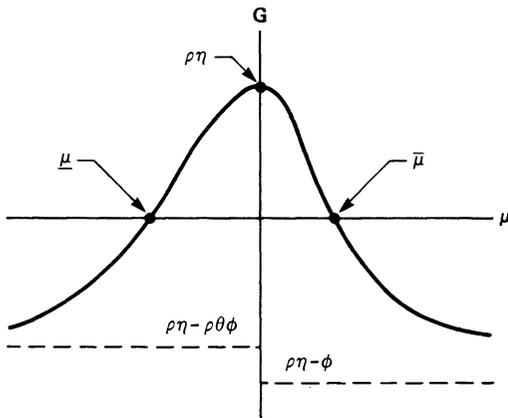


FIGURE 1. THE FUNCTION G AND ITS ASYMPTOTES FOR GIVEN θ (SEMILOGARITHMIC SCALE)

II. Analysis of the Critical Values

A. Existence

The conditions under which $\underline{\mu}$ and $\bar{\mu}$ exist can be determined by examining the behavior of G as μ approaches 0 and ∞ . The limit of G as μ approaches 0 is $\rho\eta - \rho\phi\theta$, implying that $\underline{\mu}$ exists if and only if $\eta \leq \phi\theta$. The limit as μ approaches ∞ is $\rho\eta - \phi$, implying that $\bar{\mu}$ exists if and only if $\eta \leq \phi/\rho$. Thus, a sufficient condition for the existence of both critical values is that η fall short of the minimum of $\phi\theta$ and ϕ/ρ . Since the firm is likely to have chosen its pricing period sufficiently long to make this condition hold, it shall be assumed in the following analysis that $\underline{\mu}$ and $\bar{\mu}$ do exist.

B. Asymmetry

Let us begin by examining the properties of the set which consists of the ordered pairs (μ, θ) satisfying the equation $G(\mu, \theta) = 0$. This equation implicitly defines $\underline{\mu}$ and $\bar{\mu}$ as a function of θ . An important initial question is whether $\underline{\mu}(\theta)$ and $\bar{\mu}(\theta)$ are generally symmetric around 1. The relevant concept of symmetry is, of course, the geometric one, since μ represents *proportional* changes in the price level. By definition, $\underline{\mu}$ and $\bar{\mu}$ are symmetric if and only if their geometric mean $\hat{\mu}$

is equal to 1. The following proposition establishes the magnitude of $\hat{\mu}$ in relation to 1:¹²

PROPOSITION 1: $\hat{\mu}(\theta) \geq 1$ if and only if $\theta \geq 1/\rho$.

It follows from this proposition, since $1/\rho = 1 + r$, that $\underline{\mu}$ and $\bar{\mu}$ are symmetric around 1 when $\theta - 1 = r$, where $\theta - 1$ can be interpreted as the growth rate of the size of the market.¹³ When the market growth rate exceeds the interest rate, the one-price policy remains optimal for proportionally larger increases in the price level than decreases. In contrast, when the growth rate is lower than the interest rate, the one-price policy stays optimal for larger decreases than increases.

The functions $\underline{\mu}(\theta)$, $\bar{\mu}(\theta)$, and $\hat{\mu}(\theta)$ are illustrated in Figure 2. In this figure the region bounded by and including the functions $\underline{\mu}(\theta)$ and $\bar{\mu}(\theta)$ is the locus of ordered pairs (μ, θ) for which the one-price policy is optimal. The limits of $\underline{\mu}(\theta)$ and $\bar{\mu}(\theta)$ as θ tends to infinity are denoted by $\underline{\mu}\infty$ and $\bar{\mu}\infty$, and their geometric mean, which by Proposition 1 is necessarily greater than one, is denoted by $\hat{\mu}\infty$.¹⁴

The intuitive explanation for the proposition centers around two properties of the model: 1) the growth rate and the interest rate affect the valuation of first- vs. second-period profits in opposite ways. This valuation is an increasing function of the interest rate, but a decreasing function of the growth rate. The two effects balance each other out only when $\theta = 1/\rho$. 2) The firm's profits in any given period are greater for an upward displacement from the monopoly

¹² The proof contains two major steps. First, it must be shown that $G(\mu, \theta) \geq G(1/\mu, \theta)$ as $\theta \geq 1/\rho$, which implies, since $G(\bar{\mu}, \theta) = 0$ by the definition of $\bar{\mu}$, that $G(1/\bar{\mu}, \theta) \leq 0$ as $\theta \geq 1/\rho$. Application of some of the properties of G outlined in Section I is then sufficient to establish the proposition.

¹³ In aggregative growth theory, this condition describes the Golden Rule path along which consumption per capita is maximized; but the Golden Rule and the symmetry condition in the present model arise from two entirely different sets of economic assumptions.

¹⁴ Figures 1 and 2 are complementary. While the former indicates the value of G as a function of μ for fixed θ , the latter shows μ as a function of θ for one particular level curve of G , namely that where $G = 0$.

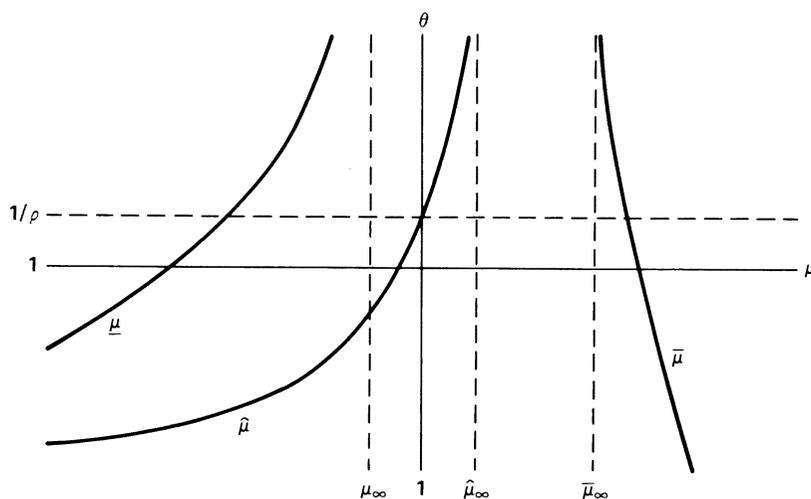


FIGURE 2. CRITICAL VALUES OF μ AS A FUNCTION OF θ
(LOGARITHMIC SCALE)

price than for a proportionally equivalent downward displacement.¹⁵ The source of this asymmetry can be traced (as discussed more fully in Section IV) to the facts that the price elasticity of demand is nonincreasing, and that real marginal cost is nondecreasing.

Of the two asymmetric cases, the one where the growth rate is less than the interest rate is more likely to be observed in any actual economy, so let us examine it in some detail. In this case, the valuation of first-period profits exceeds that of second-period profits. Under inflation, therefore, when the firm is pursuing a one-price policy, its real price is too high in the period weighted more heavily and too low in the other period. Under deflation, in contrast, its real price is too low in the period weighted more heavily and too high in the other period. Thus, if the profit function were symmetric, the firm would want, under inflation, to charge a price closer to the lower of the two monopoly prices. Under deflation, on the other hand, it would want to charge a price closer to the higher of the two monopoly prices.

But the profit function is *not* symmetric, and this requires the firm to charge a price

closer to the higher of the two monopoly prices. Under inflation the asymmetry pulls the optimal price toward the period weighted less heavily, while under deflation the pull is toward the period weighted more heavily. So the reason why the firm switches to a two-price policy more readily under inflation is that the two forces, one due to discounted growth and the other to the asymmetry in the profit function, are counteracting.

Naturally, if the growth rate were greater than the interest rate the forces denoted above would be counteracting under deflation and reinforcing under inflation. The firm would then switch to a two-price policy more readily under deflation.

These results show that in the presence of an adjustment cost price rigidity can be greater in one direction than the other. In the case where the interest rate exceeds the growth rate, for instance, prices would change more often under inflation than deflation.

III. Inflationary Bias

A. Comparison of Responses to Downward and Upward Price Level Changes

While the discussion thus far has analyzed the conditions under which each of the firm's alternative pricing policies is optimal, it is necessary to examine now whether the firm

¹⁵The asymmetry is most easily seen by comparing the two extreme displacements, $p = \infty$ and $p = 0$. Raising the firm's price to ∞ reduces profits to 0, but lowering it to 0 reduces profits to $-\infty$.

responds differently to equivalent doses of inflation and deflation in its price-setting strategy. The analysis involves comparing \bar{p} , the geometric average of the first- and second-period nominal prices, for proportionally equal price level changes in either direction.¹⁶ Note that if μ were sufficiently high or low to make the firm pursue a two-price policy, \bar{p} would equal $P\mu^{1/2}$.

If the firm's price is more responsive to a rise in the price level than to a proportionally equal fall, we shall say that its price adjustment policy exhibits inflationary bias. Thus, for a given $\mu > 1$ the firm's price-adjustment policy is biased toward inflation if $\hat{p}(\mu)$, the geometric average of $\bar{p}(\mu)$ and $\bar{p}(1/\mu)$, exceeds P . The firm's adjustment policy is unbiased if $\bar{p}(\mu)$ and $\bar{p}(1/\mu)$ differ from P in the same proportion, that is, if $\hat{p}(\mu)$ equals P . The following proposition establishes how \hat{p} varies according to the level of μ .¹⁷

PROPOSITION 2: *If $1 < \mu \leq \max[\bar{\mu}, 1/\bar{\mu}]$, then $\hat{p}(\mu) > P$. Otherwise, $\hat{p}(\mu) = P$.*

This proposition indicates that the firm's responses to inflation and deflation are symmetric if $\mu > \bar{\mu}$ and $1/\mu < \bar{\mu}$. The firm is more responsive to a rise in the price level than to a fall if either μ or $1/\mu$ (or both) are located in the one-price adjustment zone. Note that the proposition holds irrespective of the size of θ in relation to $1/\rho$. In particular, when the growth rate and the interest rate are equal, so that μ and $\bar{\mu}$ are symmetric, $\hat{p}(\mu)$ still exceeds P , provided μ or $1/\mu$ is in the one-price adjustment zone.

The source of inflationary bias is the already discussed asymmetry in the profit function. The firm pursues an asymmetric pricing policy to compensate for the asymmetry in profit losses from charging too high or too low a real price.

B. Response to Price Level Uncertainty

Another possible manifestation of inflationary bias is the firm's response to uncer-

tainty. Since the firm's profit function under a one-price policy is nonlinear in the logarithm of its real price, two equiprobable values of μ that are symmetric in logarithms around a given core value of μ need not exert mutually offsetting gravitational pulls on p^* , the optimal price. So I shall now explore whether an appropriately defined change in the degree of uncertainty about an arbitrary core rate of inflation can impart an upward bias to an individual firm's price adjustment policy.

To begin, let us drop the assumption that the firm knows μ with certainty, and postulate instead that only the distribution of μ is known. With this generalization, the first-order condition of (5) takes the form

$$(13) \quad p^*P^{-1} = \frac{1 + \rho\theta E(\mu^b)}{1 + \rho\theta E(\mu^{b-1})},$$

where E is the expectation operator. How a change in any given distribution affects p^* depends, of course, on the nature of the change. Since μ is a proportional parameter, and more importantly, since arithmetic distributions of prices are in general heavily skewed to the right, it is meaningful to consider geometric-mean-preserving spreads (*GMPS*).¹⁸

The effect of a *GMPS* on p^* can be measured by its effect on the ratio on the right-hand side of (13), denoted by R . If R were to rise in response to a *GMPS*, then, if the first-order condition is to be maintained, p^* would have to rise, too. How R is affected by a *GMPS* can be deduced from the curvature of R , considered as a function of $\log \mu$, in the range of the spread. A sufficient condition for R to rise in response to a *GMPS* is that R be strictly convex with respect to $\log \mu$ throughout the range of the spread. Unfortunately, the second derivative of R with respect to $\log \mu$ is too complex to be evaluated analytically. Numerical analysis strongly suggests, however, that any *GMPS* would

and $1/\mu < \bar{\mu}$, (iii) $\mu > \bar{\mu}$ and $1/\mu \geq \bar{\mu}$, and (iv) $\mu > \bar{\mu}$ and $1/\mu < \bar{\mu}$.

¹⁸A *GMPS* of a given distribution is obtained by performing an arithmetic-mean-preserving spread on the logarithm of the distribution. See Michael Rothschild and Joseph Stiglitz (1970) for a detailed theoretical analysis of mean-preserving spreads.

¹⁶The appropriate comparison involves geometric averages because μ is a proportional parameter.

¹⁷The proof involves straightforward computation of the four possible cases: (i) $\mu \leq \bar{\mu}$ and $1/\mu \geq \bar{\mu}$, (ii) $\mu \leq \bar{\mu}$

TABLE 1—COMPARISON OF OPTIMAL PRICES UNDER UNCERTAINTY

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Log Mean	1.25	1.25	2.00	2.00	1.25	1.25	2.00	2.00
Log Variance	0.006	0.006	0.006	0.006	0.033	0.033	0.033	0.033
$\rho\theta$	0.8	1.0	0.8	1.0	0.8	1.0	0.8	1.0
$b = 2$	0.5	0.6	0.7	0.7	2.9	3.1	4.0	4.2
$b = 5$	2.1	2.2	2.7	2.7	12.3	12.8	15.0	14.9
$b = 10$	5.8	5.8	5.7	5.7	27.5	27.3	26.3	26.3
$b = 20$	11.8	11.7	11.6	11.6	35.7	35.6	35.2	35.2

Note: The entries stand for percentage differences: columns (1)–(4) are based on the same *GMPS*; a second spread was performed on the resulting distribution to obtain the distribution underlying columns (5)–(8).

raise R and hence p^* ; a few examples will be presented later.

There is one type of geometric-mean-preserving spread for which the argument can be substantiated analytically. This is a uniform expansion of the *log* of the distribution around its geometric mean μ^* . An expansion of degree α can be written as

(14)

$$\log \mu(\alpha) = \log \mu^* + (1 + \alpha)(\log \mu - \log \mu^*).$$

The following proposition is concerned with the effect of such an expansion.

PROPOSITION 3: *A geometric-mean-preserving uniform expansion of the distribution of μ raises the firm's optimal price under a one-price policy. The price rise increases with the degree of expansion.*¹⁹

This proposition demonstrates that uncertainty about the price level is a source of inflationary bias in that it leads the firm to charge higher prices. The explanation is again that the profit function is asymmetric in the real price: effective cost indexation, coupled with the fact that the price elasticity of demand is nonincreasing, causes the firm to be penalized more severely for underestimating the second-period price level than for overestimating it.

¹⁹The crux of the proof is showing, through repeated use of Tchebychev's rearrangement inequality, that $R'(\alpha) > 0$ in the neighborhood of 0. Once this relationship is established, it is sufficient to demonstrate through a continuity argument that $R(\alpha_2) > R(\alpha_1)$ for $\alpha_2 > \alpha_1$.

Some numerical examples of the effect of uncertainty on the firm's optimal price are presented in Table 1. The entries in this table show, for various parameter values and distributional assumptions, the extent to which uncertainty causes the optimal price under a one-price policy to rise above the certainty price. There are four values of b shown which correspond to widely different levels of market power. At one extreme, when $b = 2$, the firm's monopoly price is 100 percent higher than marginal cost; at the other, it is only about 5 percent higher.²⁰

The results in Table 1 suggest that the more elastic the firm's demand, the greater the effect of uncertainty on its optimal price.²¹ The explanation for this relationship is that the higher the responsiveness of demand, the more the firm stands to lose if it is caught with too low a price in the second period. Since costs are effectively indexed, a low nominal price can entail a loss which increases with the elasticity of demand. Caution should be exercised, however, in interpreting the relationship, because any firm can always pursue a two-price policy. High-elasticity firms are likely to exercise this option more readily than low-elasticity firms, both because the one-price policy is more risky for them and because they usually have lower adjustment costs. As the variability of the price level rises, one would generally

²⁰Recall that the real monopoly price is given by $bc/(b-1)$.

²¹This appears to be true not only in terms of percentage, but also in absolute terms.

expect many high-elasticity firms to switch from one- to two-price policies, but low-elasticity firms to continue pursuing one-price policies, albeit at higher prices.

IV. Sensitivity of Propositions to Functional Forms in the Model

At this point it is useful to explain how the foregoing propositions depend on specific functional forms used in the analysis. Two assumptions require attention: constant price elasticity of demand and constant marginal cost.

The assumption that the price elasticity of demand is constant ensures that demand approaches infinity as price tends to zero, and as such is directly responsible for the asymmetry in the profit function between upward and downward displacements from the monopoly price. If elasticity were not constant but decreasing in price, the asymmetry would be even greater. If, however, elasticity were increasing, as is the case for the linear demand function, the asymmetry in the profit function could go either way.

The other functional form assumption, that real marginal cost is invariant to the scale of production, also plays a role in the observed asymmetry in the profit function. But if marginal cost were an increasing function of scale, the observed asymmetry in the profit function would be even greater. This is so because the opportunity cost from charging a price below the monopoly price would then exceed the opportunity cost from charging a price above the monopoly price to a greater extent than if marginal cost were constant. In contrast, if marginal cost were a decreasing function of scale, a counteracting asymmetry would be present. In this case, the asymmetry in the profit function could go either way.

In sum, the three propositions herein hold with any nonincreasing elasticity demand function and any nondecreasing marginal cost function. They do not necessarily hold, however, if over some range elasticity is increasing or marginal cost decreasing. In this case, the firm may exhibit deflationary bias, and its pattern of price rigidity may be fundamentally different.

V. Summary

This paper has demonstrated that the prices of monopolistic firms with nonincreasing price elasticity of demand and nonincreasing marginal cost can be relatively more rigid downward than upward. It has also shown that such firms raise their prices to a greater extent when they expect inflation than they lower them when they expect equivalent deflation. Furthermore, it has established that they raise their prices in response to an increase in the degree of price level uncertainty, defined in terms of a geometric-mean-preserving spread. These findings are all attributable to the property that profit functions are asymmetric with respect to price, in the sense that the loss from charging a price below the monopoly price is greater than the loss from charging a price above it by a proportionally equivalent amount.

Of the three findings, the first two would be very difficult to test empirically if only because deflations almost never occur in modern economies. On the other hand, the last finding can, in principle, be tested, if one is able first to determine the particular sectors of the economy for which the model herein represents a reasonable abstraction. The available macroeconomic studies based on highly aggregated data indicate that the variability and rate of inflation are positively correlated,²² and the third finding may point to one possible explanation for this empirical relationship. In periods when the time path of the price level is relatively uncertain, say, because of ongoing institutional changes or political instability, the asymmetry in some firms' profit functions would cause them to raise their prices, thereby putting upward pressure on the aggregate price level.

As stated earlier, however, other firms' adjustment policies might exhibit biases in opposite directions from those found in this paper. So it is impossible to say, at the present time, what cumulative effects the biases generated by asymmetries in firms' profit functions would have on the course of the general price level. But one can reason-

²²For some cross-country evidence, see, for example, Dennis Logue and Thomas Willett (1976).

ably expect that, since conditions for perfect symmetry in profit functions are very stringent, the general price level would be influenced by individual firms, both directly through the actual prices they generate and indirectly through the effects of price adjustments on expectations. Given the vital importance of these effects for macroeconomic policy, it would be useful to examine the biases in the price-adjustment policies of various other types of business firms found in the economy.

In a perfectly competitive economy, where prices determined by impersonal market forces clear markets at each instant, biases of the kind discussed herein would not exist. Nor would they in an economy with a monopolistic sector composed of firms which can adjust their prices at no cost; firms would passively respond to changes in the price level, exerting no influence on it themselves. In actual economies, however, most firms set their own prices, often with the intention of keeping them fixed for substantial lengths of time. Here not only do price level movements affect individual price adjustments, but these adjustments influence the course of the price level.

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