Low Inflation, Pass-Through, and the Pricing Power of Firms

by

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Abstract. Recently there has been a significant decline in the degree to which firms "pass through" changes in costs to prices, a decline that is frequently characterized as a reduction in the "pricing power" of firms. The decline appears to be associated with the decline in inflation in many countries. The decline has important implications for monetary policy because it affects both forecasts of inflation and the effects of changes in monetary policy on inflation. Some have argued that the decline in pricing power helped keep inflation low in the face of apparently strong demand pressures in the United States in the late 1990s. This paper puts forth the view that the decline in pass-through or pricing power is due to the low inflation environment that has recently been achieved in many countries. First, a microeconomic model of price setting is used to show that lower pass-through is caused by lower perceived persistence of cost changes. Evidence is then presented showing that inflation is positively correlated with persistence of inflation, suggesting that the low inflation itself has caused the low pass-through. An economy-wide model consistent with the micro model is then presented to illustrate how such changes in pricing power affect output and inflation dynamics in favorable ways, but can disappear quickly if monetary policy and expectations change.

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Examining the causes and consequences of the period of price stability that began in many countries in the 1980s or the early 1990s is as useful for future policy making as examining the Great Depression of the 1930s or the Great Inflation of the late 1960s and 1970s. Many possible causes for the lower and more stable inflations have been offered, ranging from good luck with shocks to favorable structural changes. In my view a change in monetary policy was the primary cause (see Clarida, Gali and Gertler (1998), Judd and Trehan (1995), and Taylor (1999a) for evidence).

In this paper I examine one of the possible consequences of these low inflation regimes.[1] I examine the possibility that lower and more stable inflation is a factor behind the reduction in the degree to which firms "pass through" (to their own prices) both price increases at competing firms and cost increases due to exchange rate movements or other factors. This decline in "pass-through" can be interpreted as the decrease in "pricing power" of firms that has been cited by many observers in recent years, especially in the United States, as a reason why inflation did not pick up in the face of apparently strong demand pressure in the late 1990s. Whether or not the lower pass-through or pricing power influences the impact of demand pressures on inflation, the main point of this paper is that the lower pass-through should not be taken as exogenous to the inflationary environment.

To examine the possibility that lower inflation has led to lower pricing power, I present a very simple microeconomic model of price setting. The model is meant to capture key elements of several recent papers (such as Akerloff and Yellen (1991), Bergin and Feenstra (1998), Bhaskar (1998), Chari, Kehoe and McGrattan (1998), Erceg (1997), Goodfriend and King

[1] Another possible consequence has been an increase in output stability (see Cecchetti and Ehrmann (1999) for an analysis of the recent data on output stability and inflation stability in several countries). For the case of the United States I argue in Taylor (1998) that the increase in inflation stability was a direct cause of the increase in output stability because, by keeping inflation low, central banks have reduced the likelihood of recessions.

(1998), Gust (1997), Kiley (1997), King and Wolman (1999), Yun (1996)) that have provided a specific microeconomic justification for staggered price setting models, which frequently appear in empirical macroeconomic models with price rigidities and rational expectations. The model indicates that observed changes in pricing power are due, in part, to changes in the expectations of the *persistence* of price and cost movements. In other words, the extent to which a firm matches an increase in costs or prices at other firms by increasing its own price depends on how persistent the increase is expected to be.

I then argue that low and more stable inflation should be associated with less persistent inflation, and I present evidence showing that, in fact, the recent period of relatively low inflation in the United States has also been a period of relatively low persistence of inflation. Hence, the low inflation and the monetary policy that has delivered it have led to lower pass-through through a reduction in the expected persistence of cost and price changes.

If true, this expectations theory of reduced pass-through implies that the much-noted reduction in pricing power may be quite ephemeral and that a return to higher inflation expectations would raise the pass-through coefficients; this in turn could speed up the inflationary process again. I use an empirically estimated macroeconomic model of staggered price setting, which is consistent with the micro model, to examine how such a scenario might play out.

The subject matter of this paper—the effect of the general inflationary environment on the pricing behavior of firms—makes use of two strands of economic research: monetary theory and the theory of price setting with imperfect competition. Imperfect competition models in which firms' have some market power have long been part of theories of price adjustment (Arrow (1959)). Blanchard and Kiyotaki (1987) and Svensson (1986) have shown the

importance of such theories in macroeconomic models; the more recent research on the microeconomic foundations of staggered price setting (referred to above and reviewed in Taylor (1999b)) builds on this research, and is ideally suited for answering questions about changes in pricing power. This paper represents only one potential application of this research.

1. Changes in Pricing Power: Evidence and the Need for an Explanation

This section addresses two questions: First, what evidence do we have that there has been a change in pricing power or pass-through? Second, why is it important to have a theory that explains this change?

Evidence of Changes in Pass-Through

The most useful evidence for a decline in pricing power comes from studies of the effect of exchange rate changes on prices. There is a lot of evidence showing that there has been a reduction in pass-through of changes in exchange rates to consumer prices. In the 1990s changes in exchange rates have had surprisingly small effects on consumer prices even in small open economies where imported products are a large fraction of final consumption and intermediate inputs to production. Event studies by Cunningham and Haldane (1999) of the 1992 depreciation and 1996 appreciation in the United Kingdom, the 1992 depreciation in Sweden, and the 1999 depreciation in Brazil show a remarkable small pass-through of exchange rate changes to retail prices. In the case of the United Kingdom, neither the 20 percent depreciation in 1992 nor the 20 percent appreciation in 1996 caused retail price inflation to deviate noticeably from the 2.5 percent trend. The same is true for the 1992 depreciation in Sweden. In addition, after the depreciation in Brazil in early 1999 there was a much smaller pass through than in

earlier periods when inflation was much higher.

Research[3] at the Reserve Bank of Australia on the pass-through of exchange rate changes in Australia following the Asian financial crisis in 1997 and 1998 shows that the "price movements at the docks appear to have had little or no impact at the retail level, where prices of imported items have generally continued to decline."

Of course in each of these cases, there may have been other forces at work—such as greater competition in the Australian automobile market due to the entry of Hyundai and Daewoo, the weak economy in Britain in 1992 and in Brazil in 1999. However, the decline in pass-through in recent years seems too large and pervasive to be explained by special factors.

McCarthy (1999) provides more comprehensive evidence. McCarthy's time series estimates show a decline in exchange rate pass-through for all nine of the OECD countries examined in the period 1983 through 1998 compared with the period 1976 through 1982. According to those estimates the pass-through declined by 50 percent or more in the United States, the United Kingdom, France, and Japan, and by a smaller amount in Germany, Belgium, Netherlands, Sweden, and Switzerland. See in particular Figure 6 of McCarthy (1999).

The Need for an Explanation

A reduction in pricing power has been offered as one explanation for the absence of increases in inflation in the United States in the late 1990s in the face of what appears to have been a strong economy. During the late 1990s economic growth rose well above most estimates of the growth rate of potential GDP. As a result estimates of the percentage gap between real GDP and potential GDP increased substantially. See Figure 1. The U.S. Congressional Budget

[3] Reserve Bank of Australia Bulletin, August 1999, p. 28.

Office estimated that the gap between actual and potential GDP rose to over 3 percent by the start of 1999. At the same time the rate of unemployment declined substantially to levels well below most estimates of the natural rate of unemployment. Yet, as shown in Figure 2, the overall inflation rate declined through the late 1990s. Nor was there any evidence of increased wage inflation.

The decline in pricing power is frequently mentioned as potential explanation for this benign inflation in the face of demand pressures because it appears to have caused firms to hold back price or wage increases that might otherwise be associated with low unemployment and high capacity utilization levels. A typical line of reasoning is that[2] "Employers argue that in this low-inflation environment they can't pass on cost increases to customers and thus are pushing harder against wage demands." A similar view from the Federal Reserve System is reflected in this statement by Alan Greenspan (1999a): "In the current economic setting, businesses sense that they have lost pricing power and generally have been unwilling to raise wages any faster than they can support at current price levels. Firms have evidently concluded that if they try to increase their prices, their competitors will not follow, and they will lose market share and profits. Given the loss of pricing power, it is not surprising that individual employers resist pay increases." Continuing on the same subject, Greenspan (1999b) noted that this reduced pricing power is a change from the past: "Because neither business firms nor their competitors can currently count any longer on a general inflationary tendency to validate decisions to raise their own prices, each company feels compelled to concentrate on efforts to hold down costs.... This contrasts with our experiences through the 1970s and 1980s."

[2] "Pace of wage growth declines in U.S. during the first quarter," by Alejandro Bodipo-Memba, *Wall Street Journal*, April 30, 1999.

The view that changes in the pricing power of firms can affect the relationship between output and inflation is actually an old one in macroeconomics. During the period when inflation was increasing in the late 1960s and 1970s, an *increasing* degree of pricing power of firms in concentrated industries was blamed. See Cagan (1978). Such a view was part of the rationale for price and wage guidelines introduced in the 1960s as a way to hold back inflation as the unemployment rate declined. When inflation appeared difficult to reduce in the 1970s, the resistance of firms in concentrated industries to reduce prices in the face of slack markets was frequently cited as a reason. In retrospect, the reluctance of firms to lower the rate of price increases at that time seems more related to expectations of increasing inflation than to increases in pricing power, and that is probably why this older view of increased pricing power making inflation harder to reduce is infrequently mentioned to today. Nevertheless, the current view—stated in reverse as lower pricing power holding back inflation—is similar.

To be sure, there are other good explanations for the behavior of inflation. Research by Gordon (1998) and by Shimmer (1998) has shown that a decrease in the natural rate of unemployment due to demographic factors and/or an increase in potential GDP due to higher productivity growth can explain this shift in the inflation-unemployment relationship. Nevertheless, the empirical relationship between inflation and unemployment has never been a particularly stable one, and this creates uncertainty about any single explanation of the recent shift. Hence, an alternative, but not mutually exclusive, explanation that a change in pricing power or pass-through may have caused inflation to be tamer cannot be ruled out a priori, and a theory for the increased pass-through is needed.

The degree of pass-through is also important for forecasting inflation and for deciding how much to tighten monetary policy in response to an increase in inflation that can be identified

with something specific, such as an exchange rate change. For example Ball (1999) shows that the coefficients in the monetary policy rule depend on the degree of pass-through. The same is true for monetary policy operating procedures that depend explicitly on the forecast of inflation.

2. A Simple Staggered Pricing Model with Market Power

The decision process that the managers of a firm go through in setting a price of a good—whether the price of orange juice at a grocery store chain or the price of a new car or truck at a car dealer—is complex and time consuming. See Levy et al (1997) and Blinder et al (1998) for empirical evidence on the decision process. Firms usually perceive that they have some market power as they set their price, so that the price becomes a decision variable for the firm unlike in a perfectly competitive market where the firms take the price as given. Of course, from a modeling perspective, if the price is to be a decision variable of a firm, then the price must be in the firm's control, requiring some degree of market power. The amount of market power that firms perceive depends on the degree that the product is differentiated from other products, on the substitutability of that product with other products, and on the likely reaction of other firms in the market. In other words, market power depends both on the utility function of consumers and the reaction of other firms in the market.

In order to examine the hypothesis that pricing power has changed, we need a model that incorporates the effects of three changes on a firm's price decision: a change in costs, a change in the price set by other firms, and a change in demand. The extent to which a firm matches an increase in costs or an increase in other firm's prices is a measure of pricing power, and corresponds exactly with the concept of pass-through.

Consider a firm selling a product that is differentiated in some dimensions from the other goods, and the consumers' utility functions value this difference. To be specific suppose that the demand curve facing each firm is linear in the difference between the firm's own price for its product and the average price for the other differentiated products. Such a linear demand curve can be derived from models of consumer utility maximization where product differentiation is due to spatial separation (Solow, 1998) and is an analytically convenient alternative to the nonlinear demand curves that arise from CES utility functions.

Suppose that this linear demand curve is written as

$$y_t = \varepsilon_t - \beta(x_t - p_t) \qquad (1)$$

where y_t is production, x_t is the price of the good, and p_t is the average price of other (differentiated) goods. The term ε_t is a random shift to demand.

Let c_t be the marginal cost of production of this good. Suppose that the firm sets its price to last for four periods, and that its sets its price every fourth period. Other firms set their price for four periods, but at different points in time. These timing assumptions correspond to the simplest version of the staggered price setting model (Taylor (1980)). A generalization of this stylized model would be for some firms to set prices for longer periods, or to assume a distribution of firms, each setting price for different, possibly random lengths of time, but the simple four period case is sufficient for the theoretical analysis in this paper.[4] Under these assumptions the price level p_t is a four-period average of the recent prices x_t set by the four groups of firms:

$$p_t = (x_t + x_{t-1} + x_{t-2} + x_{t-3})/4.$$

[4] The interpretation of the emprical model below is that there is a distribution of firms with price setting intervals of different lengths.

Under these assumptions, the firm's expected profit for the four periods when the price set in period t applies is given by:

$$\sum_{i=0}^{3} E_t(x_t y_{t+i} - c_{t+i} y_{t+i}) \qquad (2)$$

where x_t applies in period t through t+3 so that y_{t+i} depends on x_t rather than x_{t+i}, for i = 1,2, and 3. The term E_t represents the conditional expectations operator based on information at period t. Firms maximize profits taking marginal cost and average price at other firms as given[5].

Substituting equation (1) into equation (2) and differentiating with respect to x_t results in the solution for the optimal price

$$x_t = .125 \sum_{i=0}^{3} (E_t c_{t+i} + E_t p_{t+i} + E_t \varepsilon_{t+i}/\beta) \qquad (3).$$

Note that the coefficient of .125 implies that a unit increase in the price at other firms (p_t through p_{t+3}) and in marginal cost (c_t through c_{t+3}) results in the same unit increase in the representative firm's price x_t. If only c_t through Ec_{t+3} rise by one unit, then the price x_t will rise by .5 units. Note that equation (3) has the from of the price setting equation in a standard staggered price setting model (Taylor (1980)). The derivation of equation (3) is directly analogous to several recent derivations of similar staggered price setting equations (see Chari, Kehoe, and McGrattan (1998) or King and Wolman (1999), for example) except that the functional form is linear. That the equation is derived from firm's profit maximization makes it very useful for addressing the questions of pass-through and pricing power in this paper.

Several points relating to market power and inflation emerge from equation (3). First, note that the amount by which a firm matches an increase in marginal cost with an increase in its

own price depends on how permanent that marginal cost increase is. Similarly, the extent to which an increase in the price at other firms will lead to an increase in the firm's own price will depend on how permanent that increase in other firms' prices is expected to be. However, in neither case does the extent of this pass-through depend on the slope of the linear demand curve (which depends on β).

To see the how the effect of an increase in marginal costs on the price depends on how permanent the increase in marginal costs is, suppose that marginal cost follows a simple first order autoregression:

$$c_t = \rho c_{t-1} + u_t. \qquad (4)$$

In this case the matching or pass-through coefficient will be $.125(1+\rho + \rho^2 + \rho^3)$. Thus, less persistence of costs (lower ρ) reduces the size of the pass-through coefficient. Firms, or at least an economist observing the firms, would likely refer to this smaller amount of matching as a loss of pricing power. But in fact it is in reality a reduction in the persistence of cost increases.

Note that there are similar persistence differences for the price of other firms. Less persistence of an increase in the price at other firms leads to less pass-through, again a characteristic of reduced pricing power on the part of firms.

These results indicate that observed market or pricing power depends greatly on expectations of future cost and price movements. We have assumed rational expectations in order to relate the actual time series of costs to people's expectations, but the more general point

[5] I have assumed for simplicity that the discount factor is 1, which is a close approximation for price setting intervals of a year or less.

is that if an increase in costs is expected to last then the increase will be matched to a greater extent. Hence, measured pricing power is heavily dependent on expectations.

For a firm that imports inputs to production, cost c_t will depend on the exchange rate. For a retail firm that imports its merchandise, the import is an intermediate input to which the firm ads its value in the form of retail services. A depreciation will raise the costs of the imports evaluated in domestic currency units. Now, according to equation (3), if the depreciation is viewed as temporary (relative to the underlying inflation rate), the firm will pass through less of the depreciation in the form of a higher price x_t. Hence, less persistent exchange rate fluctuations will lead to smaller exchange rate pass-through coefficients.

A shift in the demand curve will lead to a change in the price, which depends on the slope of the demand curve—a factor determining the market power that the firm has in its own market. Higher values of β represent less market power, with $\beta = \infty$ representing perfect competition. Thus, as β increases the impact of a change in demand on price decreases. Less market power would leads to a smaller increase in the firm's price when there is a change in demand. Hence, if markets became more competitive—say because of an increase in international competition—one would expect to see smaller price increases in response to a change in demand in that particular market. As in the case of changes in marginal costs or the price at other firms, the size of the price response to a demand shift depends on how permanent the increase in demand is.

3. Empirical evidence of changes in persistence

Though the above model is very stylized compared to the great variety of firms and market structures in the modern economy, changes in the two parameters β and ρ are symbolic of the types of changes that could affect the market power of firms. First consider β. What

evidence is there of a change over time—and especially in the 1990s—in the slope of the demand curve facing the typical firm? Does the empirical industrial organization literature provide any evidence?

Bresnahan (1989) focused on empirical measures of a "perceived demand curve," in different industries, which comes close the demand curve in equation (2). The perceived demand curve includes the conjectural variations of both the price actions of a firm's rivals in response to its own price and the purchase decisions of consumers. Bresnahan (1989) provided estimates of the elasticity of the "perceived" demand curve and the resulting price cost margin for a number of industries in the United States. The price elasticity of the perceived demand curve ranges widely across industries (from 2 in food processing to 14 in textiles, for example).

The elasticity does change over time when there are changes in the competitive nature of the market. For example, Bresnahan showed that the elasticity of the perceived demand curve for railroad transportation increased substantially when the railroad cartel ended. Unfortunately, Bresnahan's studies have not been continued, so we do not have evidence of how the elasticity of perceived demand might have changed in the 1990s. Surprisingly, I have not been able to uncover any empirical work documenting whether the elasticity has changed in recent years. In the absence of such evidence we have little to go on besides anecdotes that competition has increased.

One type of anecdotal evidence that has received considerable attention is the observation that there has been an increase in international competition in the 1990s compared with earlier periods. While there is little doubt that international competition has increased in many industries, the reduction in trade barriers and transportation costs that are behind the greater competition have been an ongoing process for many years, while the change in pass-through and

pricing power seem to be a more recent phenomenon. In any case, additional empirical work on different industries that would update Bresnahan's (1989) earlier work and give it a time series dimension would be at least as useful for the macroeconomics as it would be for industrial organization.

What evidence do we have on the persistence of cost changes or price changes? The perceived persistence of such changes is likely to be related to the persistence of aggregate inflation. For example, in a macroeconomic environment with a great deal of price stability, an increase in (nominal) marginal cost will have less persistence than in an environment with little aggregate price stability. The same is true for price increases due to depreciations. An economy with an inflation rate as low as the average of its trading partners will be very unlikely to experience a persistent nominal depreciation because it would bring the real exchange rate out of line for an extended period. Hence, low inflation economies should have less pass-through or less matching of prices changes than economies with high and persistent inflation. In other words, firms in low inflation economies will appear to have less pricing power than firms in high inflation economies. And small open economies that trade with countries which have the same inflation rate as they do, will tend to have less persistent changes in nominal exchange rates than countries with high inflation differentials with their trading partners.

But is there any econometric evidence of a reduction in the persistence of aggregate inflation as the inflation rate has been reduced? Table 1 provides two autoregressions for the quarterly inflation rate in the United States measured with the GDP deflator. One autoregression starts in 1960 and goes through the beginning of 1979, a period that includes the Great Inflation. The other is for the period of greater price stability starting after the disinflation at the end of 1982 and continuing until the third quarter of 1999 (the latest available observation as of this

writing). The 95 percent confidence interval for the largest root of the autoregression proposed by Stock (1991) is a good way to compare the persistence of inflation in the two periods. This confidence interval for the largest root falls from (.939, 1.049) in the earlier period to (.503, .864) in the later period; this represents a large decline in persistence. The sum of the coefficeints on the lagged dependent variables is .94 in the earlier period and .74 in the later period. Hence, persistence has been lower when the inflation rate has been lower in the United States. To the extent that expectations are rational, people would therefore expect a deviation of inflation to be less persistent. Other things equal, firms would expect a change in costs or prices to be less persistent, and would therefore pass on less of this increase, according to this expectations theory of pass-through.[4]

Such a relationship between the persistence of cost and price changes and the level of inflation creates a connection between low inflation and low pricing power, much as has been suggested by the observations of low pricing power in the current low inflation countries. However, this low pricing power would disappear as soon as it was clear that the low inflation environment was ending and cost and price increases therefore became more persistent again.

4. Economy-Wide Interactions and Policy Implications

The above model illustrates how expectations of the persistence of cost and price increases affect the pass-through of these cost and price increases, or the apparent pricing power of firms. Low inflation in the 1990s has been associated with less persistence and higher inflation in the 1960s and 1970s has been associated with more persistence. Hence, the model explains decrease in pass-through as inflation has declined.

[4]The 95 percent confidence interval for the largest root in the later period appears to be sensitive to whether the first three years of the period of price stability are included in the sample. I thank Jim Stock for calculating these

Because the above model not an economy- wide model it cannot illustrate the quantitative importance of these expectation effects as firms with different degrees of pass-through interact and affect the dynamics of inflation. In this section I examine how a change in pass-through, which apparently has been associated with the lower inflation, can affect the short-term relationship between aggregate prices and output. In particular, I examine whether reduced pricing power can explain the unusually small response of aggregate prices to increases in real GDP in the late 1990s in the United States. I examine these macro effects using an empirical model of the U.S. economy, which corresponds to the stylized model derived from optimal pricing behavior. The model of price setting I use was originally estimated as part of the price and wage sector of a multicountry model in Taylor (1993). The model of price setting consists of the following three equations:

$$x_t = .3270p_t + .2744E_tp_{t+1} + .1993E_t\, p_{t+2} + .1993E_t\, p_{t+3} + .0298(.3270y_t + .2744E_ty_{t+1} + .1993E_ty_{t+2} + .1993E_ty_{t+3}) \quad (5)$$

$$p_t = .3270x_t + .2744x_{t-1} + .1993x_{t-2} + .1993x_{t-3} \quad (6)$$

$$y_t = m_t - p_t \quad (7)$$

All variables are measured in percentage deviations from trend. The time interval for the estimated parameters is quarterly. As in the stylized model x_t is the price set by firms setting prices in period t, p_t is the average price in period t, and y_t is production in period t; however, the

estimates of the confidence interval for the largest root using the procedure he proposed in his 1991 paper and for noting this sensitivity.

variables now refer to economy-wide aggregates. The coefficients of equations (5) and (6) were originally estimated using aggregate data on wages rather than prices. I interpret the equation as referring directly to prices here so as to abstract from the dynamic interaction between nominal wages and prices. (The full model has lagged responses from wages to prices rather than the instantaneous relation that is implicit in equations (5) and (6)). Equation (7) is a simple way to relate economy-wide production to a monetary policy instrument, the money supply m_t, which I treat as exogenous.

Note the similarity between the theoretical equation (3) and the empirical equation (5). If one substitutes the wage w for marginal cost c, assumes that the wage is indexed to the price (w = p), and replaces the shock to demand ε with aggregate demand term y, then equation (3) begins to closely resemble equation (5). Under this interpretation of equation (5), the coefficient on output is inversely related to the slope of the demand curve facing firms.

One difference between equation (3) and equation (5) is that the stylized assumption that all firms set prices for four periods used in equation (3) has been dropped to allow for firms to set prices for different lengths of time (though still with a maximum of four quarters). Thus, the coefficients on the leads and the lags in equation (5) are not all equal as in equation (3) of the stylized model The estimated coefficients of equation (5) imply a distribution of price setting intervals: one can show that they imply 80 percent for four quarter intervals, 15 percent for two quarter intervals, and 5 percent for one quarter intervals (perfectly flexible in a quarterly model.). The estimates here pertain to the United States; separate estimates for Germany give coefficients with 42 percent for four quarters, 37 percent for two quarters, and 21 percent for one quarter. Equation (6) is a definition of the average price with the U.S. assumptions on the distribution of price setting intervals.

By adding equation (6) to equation (7), one takes into account interactions between price setting at different firms in the economy, under the assumption that all firms act like those described in the previous section. No formal strategic considerations are taken into account, except for those imbedded into the perceived demand curve of the individual firms. Because equation (5) incorporates expectations of future prices in the price setting decisions of firms, the same persistence effects discussed in the previous section will be important in the size of the response of x to a change in p, or the size of the matching. Moreover, now the interaction of this different pass through with other firms is taken into account.

Equation (7) closes the model. The three equations together represent a linear expectational difference equation system, with three leads, three lags and three endogenous variables (x, p, y) and one exogenous variable. Many solution methods are now available to solve such systems. I used the extended path algorithm of Fair and Taylor (1983).

By simulating and solving the model for different paths of the money supply one can see how different patterns of expected price persistence affect the price-output correlations. I examine several different representative paths for the money supply. The simulations are meant to shed light on how expectations of low inflation and the resulting small pass-through and low measured pricing power affect the price-output correlations. The results are shown in Figures 3 through 8. In each case the time period is from the first quarter of 1997 through the fourth quarter of 2005. Each figure shows the path of the aggregate price level (p), real GDP (y), and the money supply (m). Observe that each variable is measured as a percentage deviation from its baseline. In each case the change in the money supply generates an increase in real GDP growth above baseline for the late 1990s. However, the related pattern of prices differs greatly from simulation to simulation as discussed below.

A persistent shock

For the simulation in Figure 3, the money supply is increased gradually over the four quarters of 1997 and then is held steady at 4 percent above baseline. The increase in the money supply is unanticipated before 1997:1, but the whole path shown in Figure 3 is fully anticipated starting in 1997:1. This simulation corresponds to a surge in aggregate demand in which firms expect that the price increases they see at other firms will be very persistent; in fact, in this case they are permanent. As a result firms raise their own prices by a large amount; one would say that there is a big pass-through or that the firms are exhibiting a large amount of pricing power. The results shown in Figure 3 indicate that there would be a big increase in inflation (the price level grows more rapidly before returning to its trend path) under such circumstances.

Less persistent shocks

Figure 4 changes the money supply in a way that generates much less persistence in price movements and thereby less pass through according to the theoretical model. The increase in the money supply is also unanticipated before 1977:1, but in this case it is anticipated to be phased out starting in 1998. Not that there is a boom in real GDP in the late 1990s, but that in this case there is a much smaller increase in the price level. In this case the deviation of the price level from the baseline is about the same size as the deviation of real GDP from baseline, and much smaller than in Figure 3, the case of a permanent increase in the money supply.

Although a comparison of Figure 3 and Figure 4 shows that expectations of the persistence of price movements can make a big difference for the price-output correlation, the increase in the price level in Figure 4 is still large for fairly large. Moreover, the decline in real GDP below trend in Figure 4 is large in comparison to the rise above potential and could be large

enough to represent a recession rather than a slow down. Since few people have been expecting a recession in the late 1990s in the United States, this example may not be entirely convincing.

Figures 5 through 7 endeavor to match more closely the type of price-output patterns of the last few years in the United States. The scenarios in these pictures have people gradually becoming surprised about the persistence of the demand shocks. At first they think the money supply increases are temporary, but they gradually learn that they are long lasting. These simulations capture the forecasts of an economic growth slowdown that did not materialize. In each of these scenarios, the money supply increases, with people first expecting the increase to end and then subsequently learning that the increase is lasting for a longer time. In Figure 5 there is an increase in the money supply, which ends abruptly, and people expect that ending as of 1997:1. However, in Figure 6 there is a continued surprise increase in the money supply that people learn about in 1998:1. In Figure 7 there is an expectation that this increase will end as it does in Figure 6, but when 1999 begins people realize that the level will stay high for the next few years. Finally in the scenario in Figure 8, people learn in 1999:1 that the money supply increase is permanent. In this case the path for the money supply is exactly like the first scenario in Figure 3, but people learn about it gradually and as a result the price and output movements are much different.

Figure 7 comes very close to matching a pattern of price and output changes in which the aggregate price level changes very little. There is a large boom with real GDP growing much more than potential GDP; there is also an expectation of a very small slowdown. With potential GDP growth of at least 2.5 percent, economic growth would slow only to 2.0 percent, which would be a very soft landing. Note, however, that this pattern is heavily dependent on a set of expectations that whatever is causing the increase in real GDP above baseline will eventually

end. If this reversal does not occur, then the scenario like that of Figure 8 is what we might expect in the future.

Conclusion

This paper has shown that the low inflation observed in many countries in the past few years may itself have reduced the measured pass-through or pricing power of firms. In particular, it shows that models of staggered price setting, in which pricing decisions are optimally made in a monopolistically competitive environment, imply that pricing power and the persistence of costs and/or prices are directly related. To a firm deciding on how much to adjust its price, low inflation may be associated with less persistent changes in costs and the prices at other firms in the economy. If prices are set for several periods in advance, then the lower persistence will result in smaller pass-through (less matching of the price and cost increases), which is characteristic of reduced pricing power. This is true whether the cost increase is coming from a change in import prices due to a depreciation of the exchange rate or to a change in commodity prices or wages. Because there is evidence that lower inflation is associated with lower persistence of inflation, the model explains the very low exchange rate pass-through seen in the 1990s in low inflation countries.

Simulations of an empirical model show that the effects of expectations on pass through can have a quantitatively significant effect on the relationship between aggregate output and the price level. According to the model, the observed reduction in pricing power of firms would quickly be reversed if the current low inflation environment were reversed. If so, then the tendency for inflation to stay low in the face of strong growth in demand would disappear, and as in Figure 8, we would again see a large aggregate price response to output.

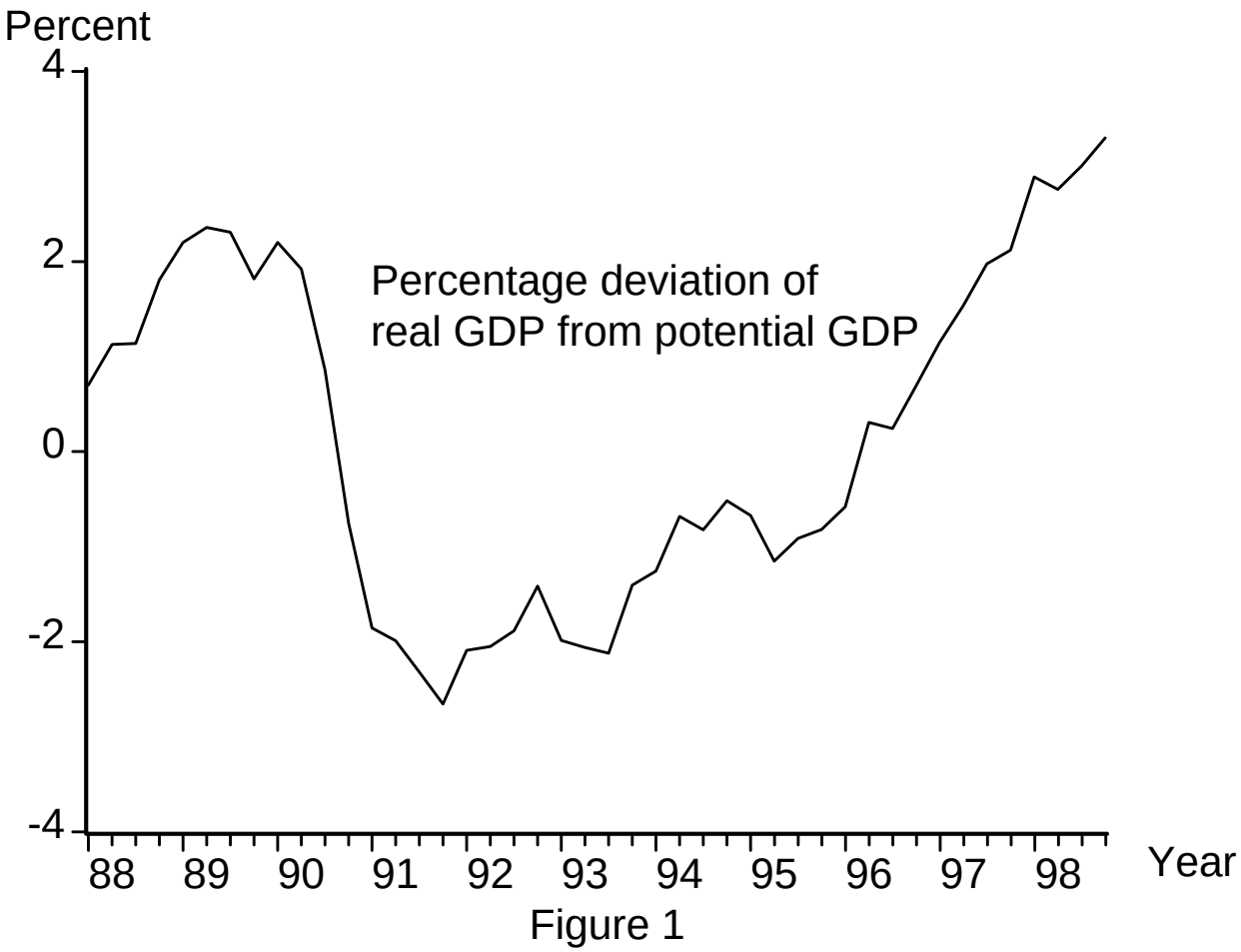

Figure 1

GDP Gap in the United States, 1988-99

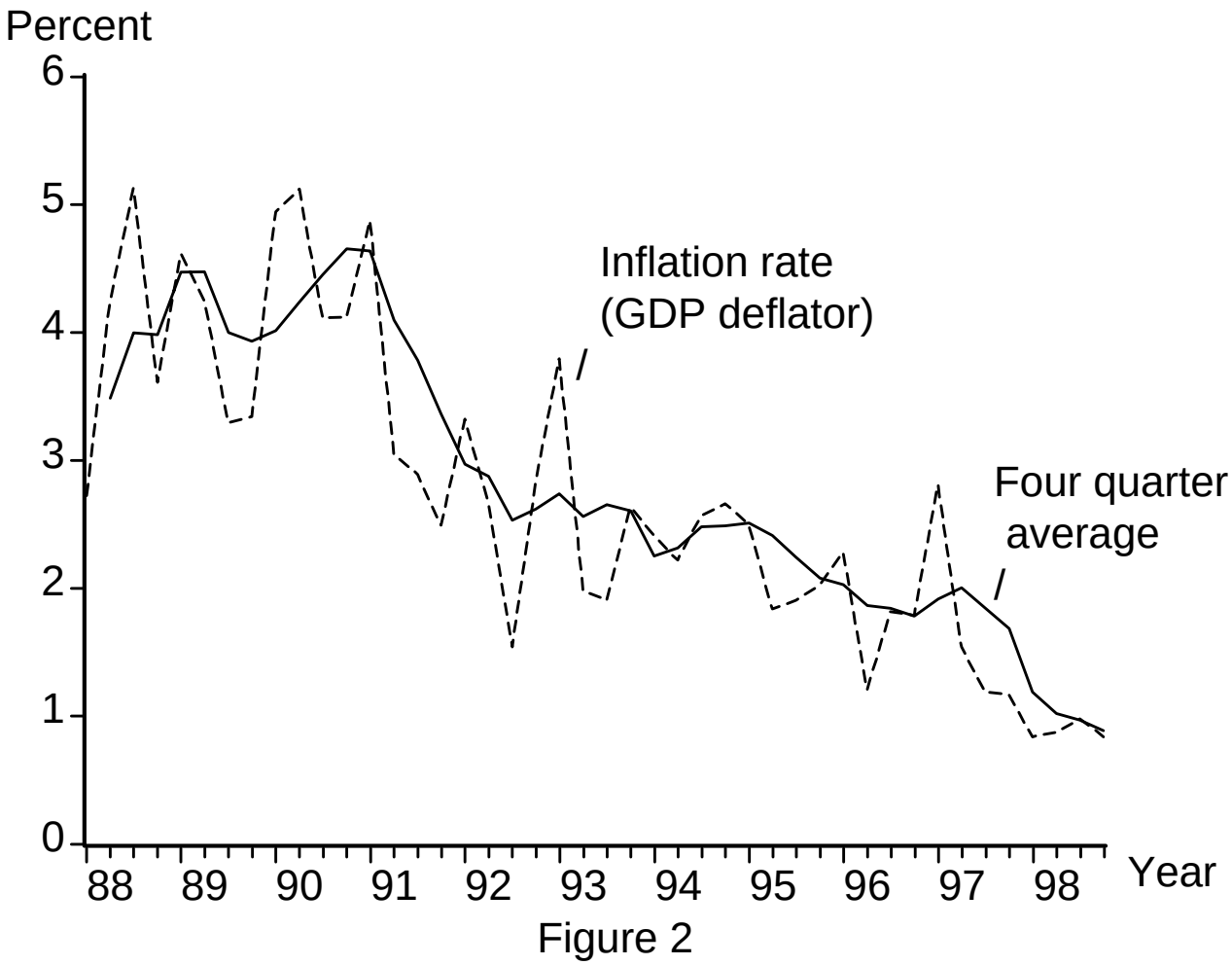

Figure 2

Inflation in the United States, 1988-99

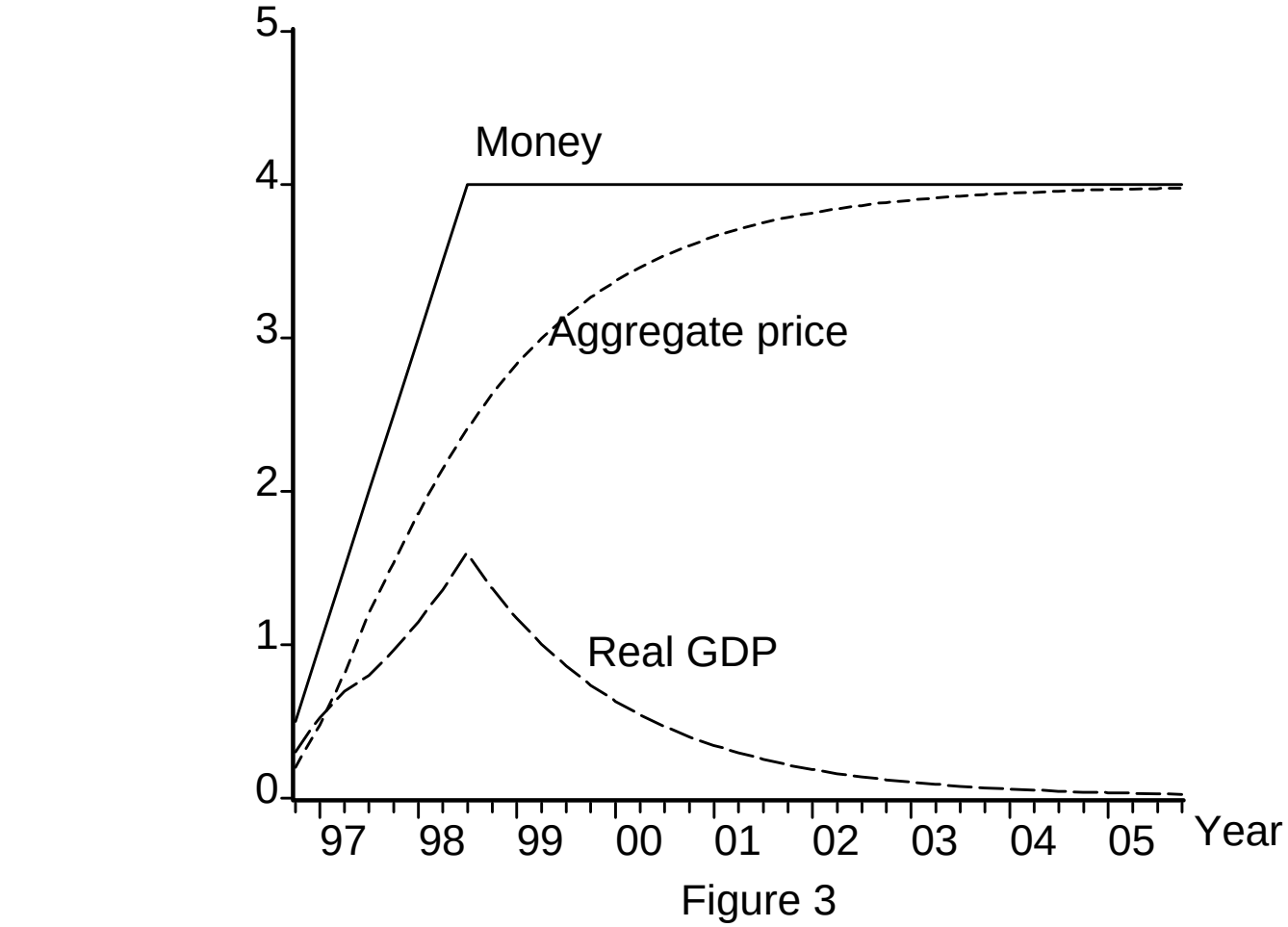

Figure 3

Effects of a Permanent Increase in Money, Unanticipated Before 1997:1 with Permanence Anticipated After 1997:1

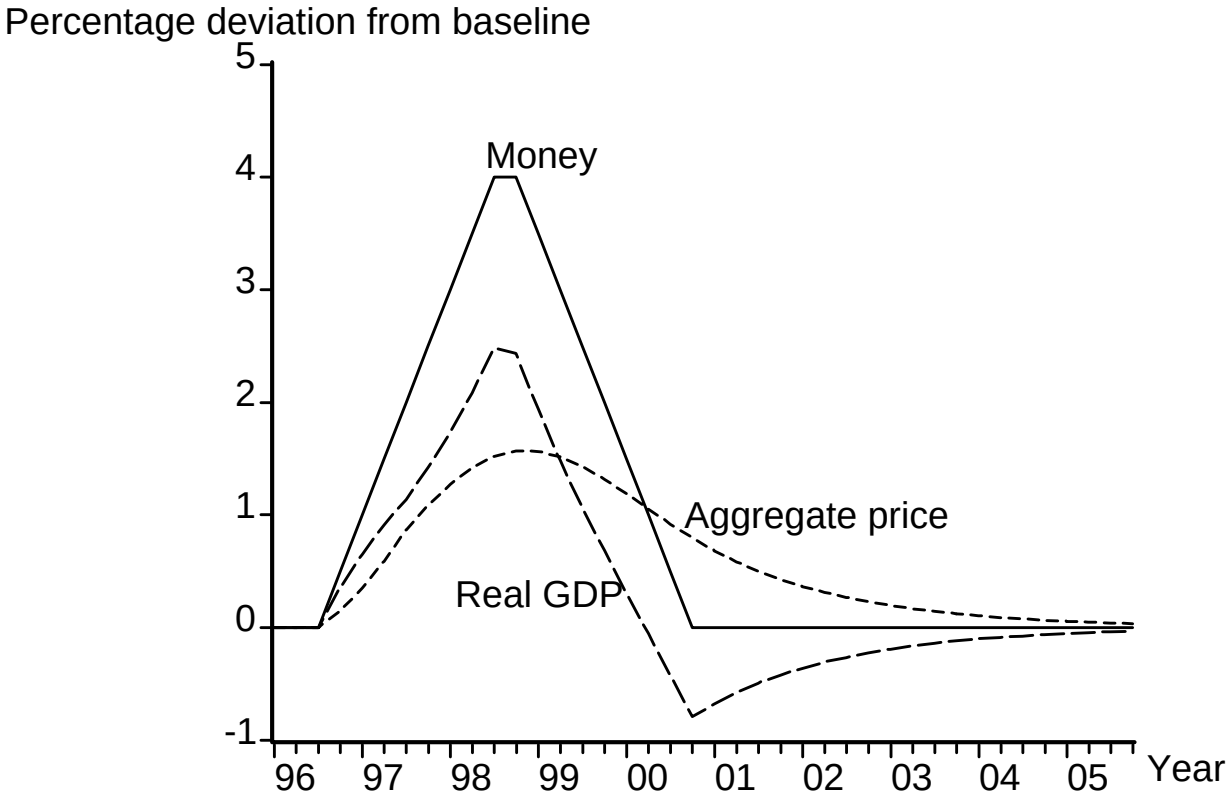

Figure 4.

Effects of a Temporary Increase in Money, Unanticipated Before 1997:1 with Gradual Decline Anticipated After 1997:1

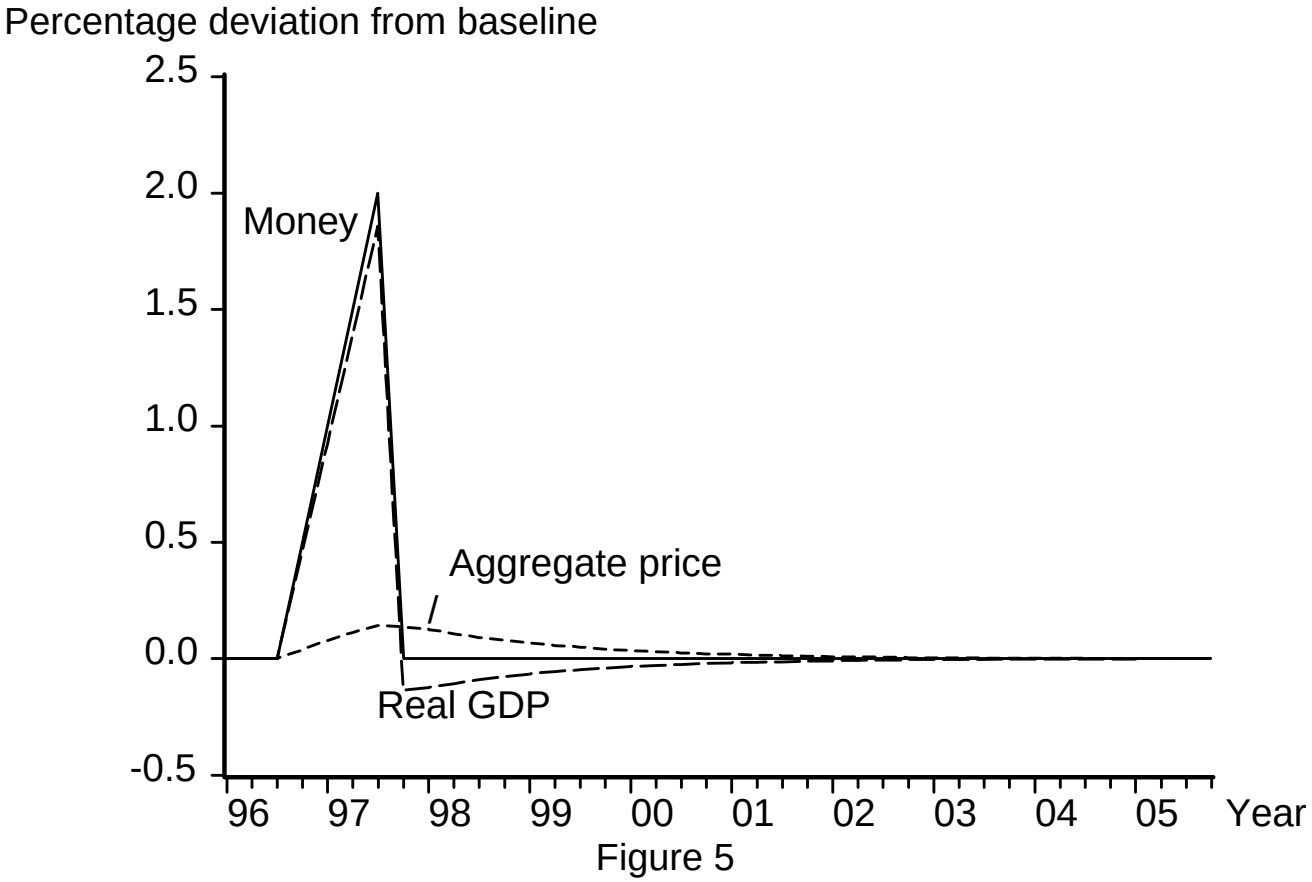

Figure 5

Effects of a Temporary Increase in Money, Unanticipated
Before 1997:1 With a Sharp Decline Anticipated After 1997:1

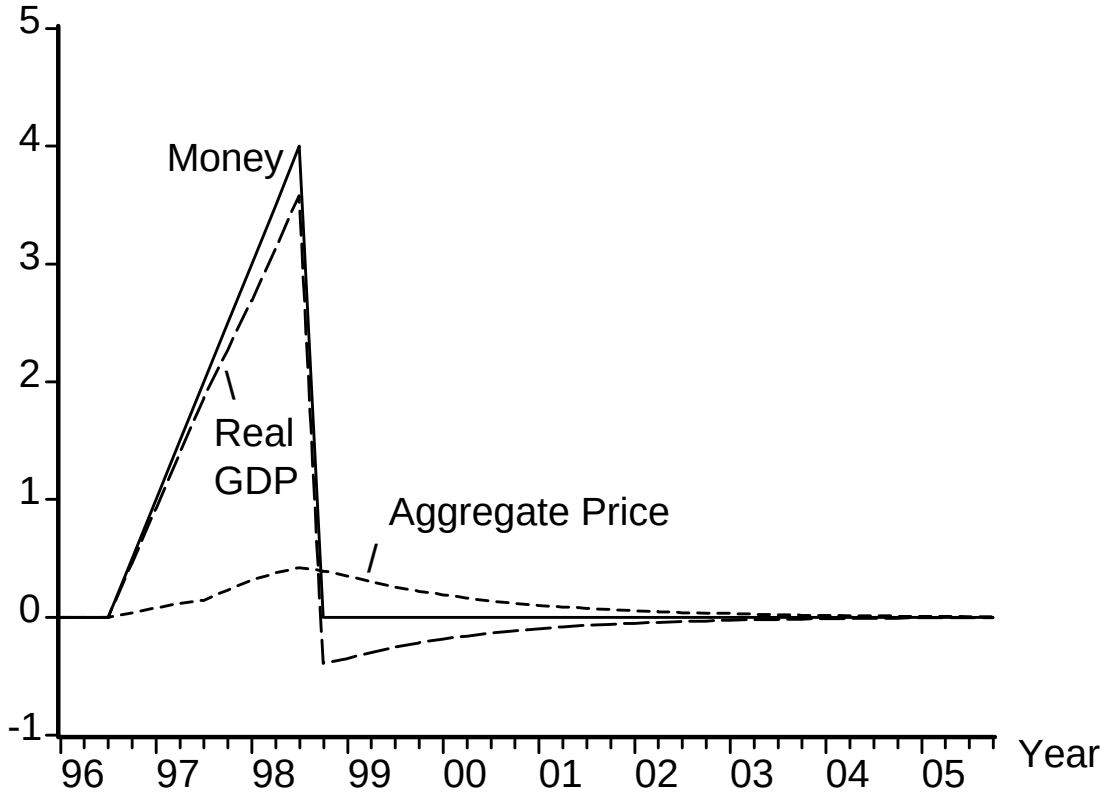

Figure 6

Scenario Starting as in Figure 5 with People First Learning in 1998:1
That Money Will Increase for One More Year

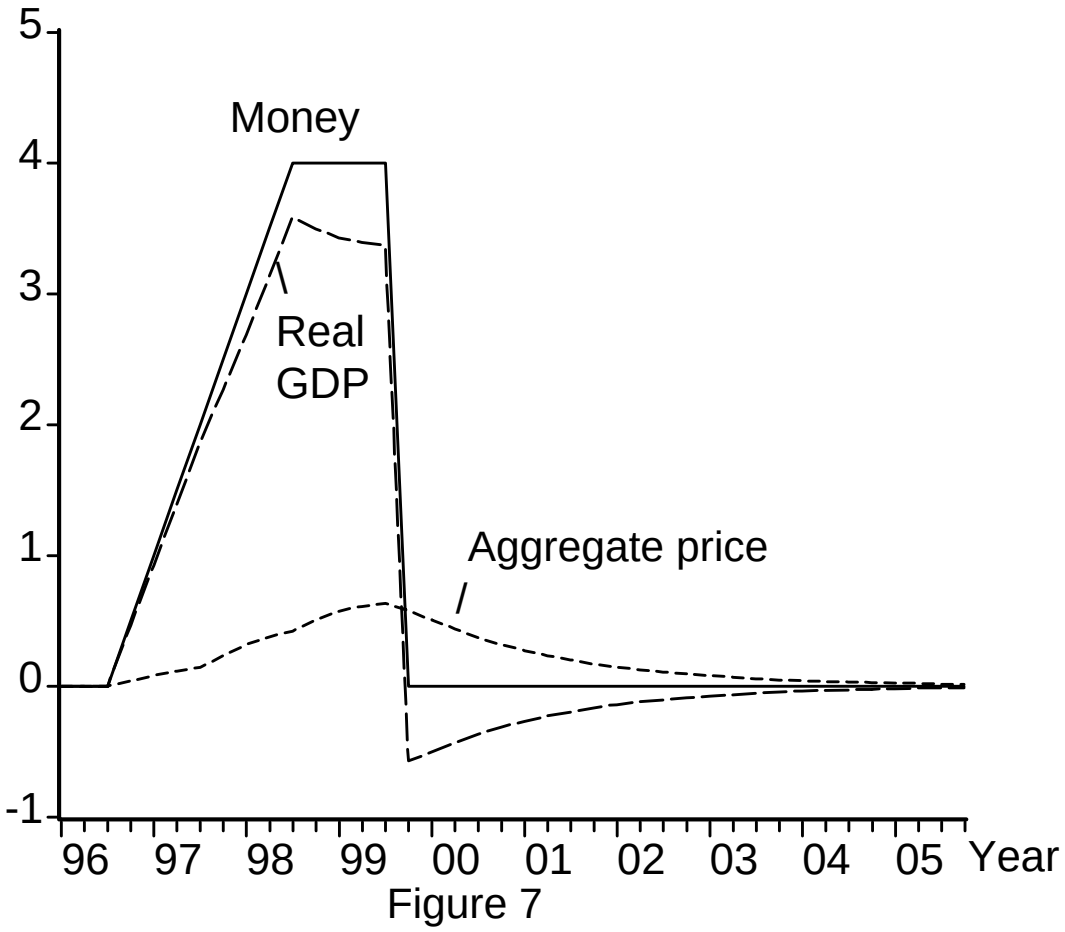

Figure 7

Scenario Starting as in Figure 6 with People First Expecting in 1998:1 that the Money Increase Will End and with People Then Finding out in 1999:1 that the Money Will Stay High for One More Year

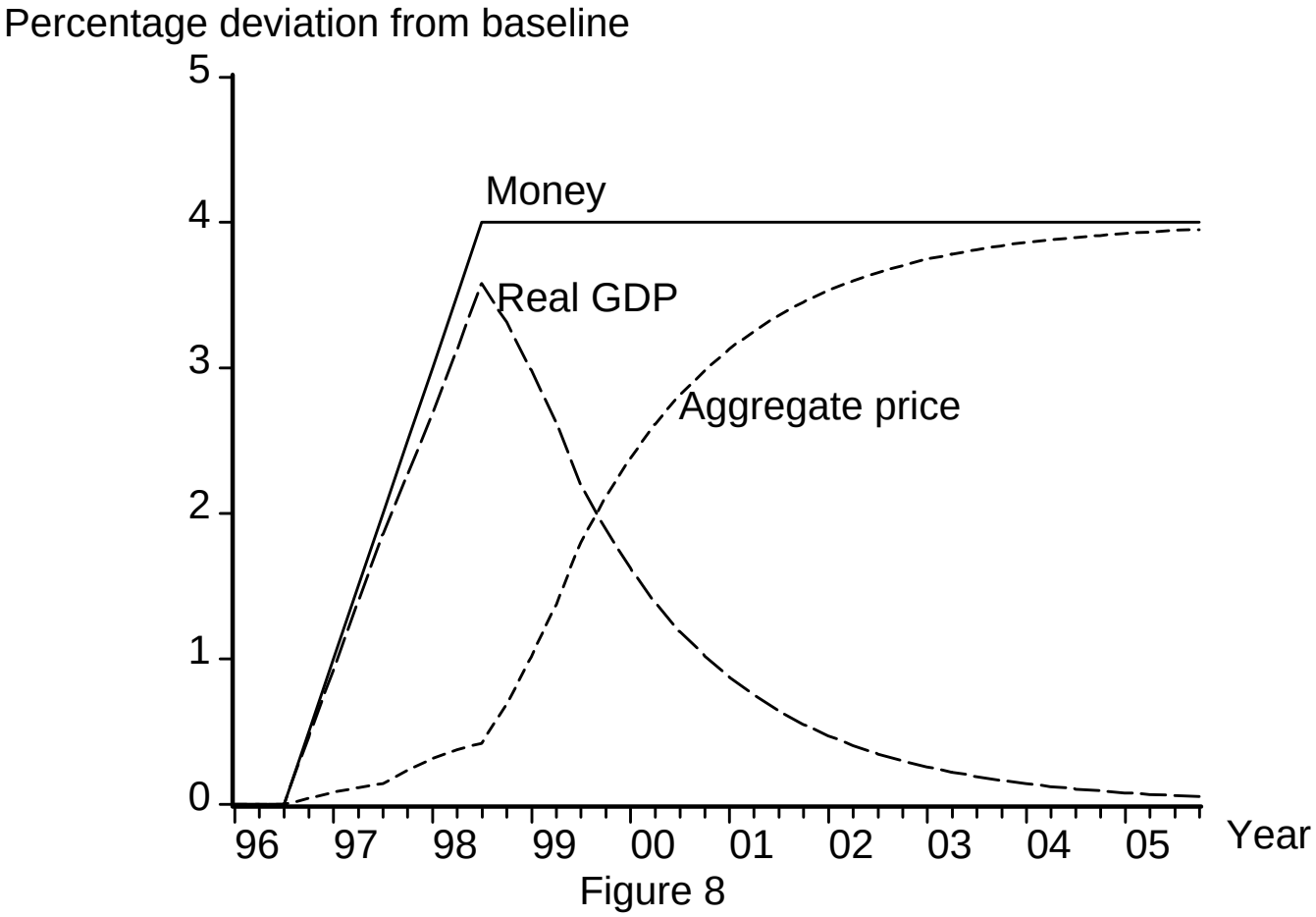

Figure 8

Effects of a Permanent Increase in Money Only Partially Anticipated until 1999:1

TABLE 1.
Confidence Intervals for the Largest Autoregressive Root in the U.S. Inflation Rate. The quarterly inflation rate (π_t) is the percentage change in the GDP deflator stated at annual rates. Source: Bureau of Economic Analysis, Dec 2, 1999. Standard errors are in parentheses. See Stock (1991) for the econometric theory underlying the computation of the confidence interval for the largest root.

Sample: 1960:2 1979.1

Estimated autoregression:

$\pi_t = .4215 + .6025\pi_{t-1} + .0556\pi_{t-2} + .0582\pi_{t-3} + .2200\pi_{t-4}$

(.2943) (.1158) (.1363) (.1369) (.1159)

Sum of coefficients on π_t lags = .9363

95 percent confidence interval for largest root = (.939, 1.049))

Sample: 1982.1 1999.3

Estimated autoregression:

$\pi_t = .5868 + .4144\pi_{t-1} - .0007\pi_{t-2} + .3299\pi_{t-3} - .0008\pi_{t-4}$

(.2185) (.1234) (.1245) (.1212) (.1040)

Sum of coefficients on π_t lags = .7429

95 percent confidence interval for largest root = (.503, .864)

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