Inflation and the growth rate of money

The P* model asserts that inflation results from changes in the money supply—specifically, M2—and ignores the effects of demand and supply shocks on prices

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There is little doubt that, in the long run, some appropriately measured monetary aggregate is closely linked to the price level and the rate of inflation. Less clear are the details of this linkage: Which of the existing monetary aggregates is tied most closely to the price level; to what extent money can be considered exogenous; how prices dynamically adjust to a monetary shock; and the importance of non-monetary factors, such as demand pressure and supply-price shocks.

Traditional monetarist thought, however, is unequivocal on these details, emphasizing a relatively rapid adjustment of prices to changes in M1 or the monetary base, and allowing little scope for demand-pull and cost-push inflation. But recent U.S. experience has undermined the empirical support for the strict monetarist view that non-monetary factors are unimportant. Since the inflationary oil shocks of the 1970s and the disinflationary recession of the early 1980s, most monetary aggregates' stable relationships with the value of the Gross National Product (GNP) have deteriorated, thus weakening the linkage between money and prices.[1]

Against this recent experience, the recently proposed P* (or "P-Star") model of Federal Reserve Board economists Jeffrey Hallman, Richard Porter, and David Small is particularly provocative. Using modern econometric techniques to analyze the sources of inflation, the authors find a single variable, which they label P*, to be the only relevant determinant of future inflation. As P* depends only on money (specifically M2) and potential GNP, this says that the gap between actual and potential output (or between actual unemployment and the natural rate of unemployment) is irrelevant to inflation, once the level of M2 is taken into account. In other words, they conclude that once money is controlled for, the demand-side effects disappear. In this sense, the P* hypothesis resurrects the monetarist monocausal explanation of inflation, using M2 in place of the narrower aggregates favored previously.

Behind the P* model lies the assumption that the inflationary effects of an increase in GNP, working through increased aggregate demand for goods, exactly offset its deflationary effects, which stem from the increased demand for money implied by the Quantity Theory of money. This article questions that assumption; not only does it lack any theoretical motivation, but it also fails a number of important empirical tests. These results indicate that demand conditions have a substantial inflationary impact in the short and medium term. Modifying the P* specification to incorporate these factors improves its performance, and reasserts the importance of policy indicators based on the state of the real economy.

The first section of this article discusses the P* model within a broader class of dynamic econometric equations, known as "error–correction" models, focusing on the assumptions embodied in the P* specification. The second section covers the estimation and testing of the P* specification within this larger set of models. These tests suggest an alternative equation, presented in the third section, which includes the output gap (the difference between actual and potential GNP) as a distinct exogenous variable. The final section concludes with a comparison of the two models' long-run properties, and their monetary policy implications.

Error–correction models

The best way to understand the P* model is through its relation to a broader class of econometric models, referred to as "error–correction" models. Introduced by Davidson, Hendry, Srba, and Yeo (1978) in an article on aggregate consumption behavior, this technique has caught on as an attractive means of imposing long-run equilibrium conditions on the flexible short-run adjustment dynamics captured by autoregressive moving-average (ARMA) models.

The error–correction framework is applicable if a steady-state relationship exists between two variables, and one (or both) of those variables adjust, over time, to restore that equilibrium. More concretely, any equation that expresses the change in a variable in terms of the difference between that variable and its "target" level is an error–correction specification—so called because the *error* (the gap between the endogenous variable and its target) induces a subsequent *correction* in the endogenous variable.[2]

The money stock and the price level are obvious candidates for a long-run equilibrium relationship; the notion that prices converge to proportionality with some monetary aggregate over a sufficiently long horizon seems inherently plausible. Most of the recent debate centers instead on the direction of causality between money and nominal income, the observability of the appropriate money stock, and stability of the money-price relationship in the face of payments system innovations.

If such a relationship holds, then an error–correction mechanism may be operating either between money and nominal income, or

between money and the price level, or both. The structure of this relationship is suggested by the logarithmic form of the familiar Quantity Equation, $MV=PQ$, where lower case letters denote logarithms:

$$m_t + v_t = p_t + q_t.$$

Here, M is the money stock, V is the velocity of circulation, P is the price level, and Q is real GNP. Although it has varied widely over time, since 1955 the M2 velocity has tended to return to its sample mean of approximately 1.65, labelled $\bar{v}$ in the following equations. This mean-reversion property suggests that the relationship between M2 and nominal income is sufficiently stable to anchor the price level, given a long-run equilibrium level of output.[3]

In a sense, this single piece of evidence would be sufficient to assert that M2 anchors the price level; inspecting the Quantity Equation, it is apparent that so long as v returns to $\bar{v}$, a given money stock will yield a determinate p, for any given q. Alternatively, one could use M2 to define a target price level, $\bar{p}$, as the price level which would prevail with velocity equal to its mean $\bar{v}$:

$$\bar{p}_t \equiv m_t - q_t + \bar{v}.$$

The fact that v does not always equal $\bar{v}$ gives $\bar{p}$ its interpretation as an "equilibrium" price level—the level towards which p reverts as v returns to $\bar{v}$. This suggests an error–correction mechanism which expresses the current change in p as a function of lagged gaps between $\bar{p}$ and p:

$$\Delta^k p_t = \sum_{i=1}^{N} a_i (\bar{p}_{t-i} - p_{t-i});$$

or, using lag operator notation,[4]

$$\Delta^k p_t = A(L) (\bar{p}_{t-1} - p_{t-1}),$$

where Δ denotes the difference operator ($\Delta p_t \equiv p_t - p_{t-1}$).

The degree of differencing, k, is one of the keys to the dynamic behavior of the model. For example, a first-differenced specification ($k=1$) says that inflation (Δp_t) responds to the gap between p and $\bar{p}$; a zero gap implies zero inflation. By contrast, a second-differenced specification ($k=2$) expresses the *change* in inflation as a function of the price gap. In this case, a zero gap between p and $\bar{p}$ implies a constant rate of inflation; $\bar{p}$ in excess of p

suggests an increasing rate of inflation. In general, increasing k increases the strength of the error–correction mechanism, forcing p to track $\bar{p}$ more closely. As discussed later in this article, the drawback to second-differenced (and higher) specifications is that they can imply overshooting and oscillatory behavior.

While this addresses the monetary side of the story, one might want to add to the equation additional variables capturing other sources of inflation. One candidate is a direct measure of demand pressure, as embodied in the widely-used Phillips Curve. According to this approach, excess demand for the economy's output causes the overall price level to rise as firms and consumers try to out-bid one another for its limited supply of goods and services. A common specification for the Phillips Curve is in terms of the gap between the unemployment rate and the "natural" rate of unemployment. Alternatively, because of the close link between employment and output, one can recast the unemployment gap in terms of the difference between (the log of) actual output, q, and potential output, $\bar{q}$.

As the employment or output gap is not a function of the price level, it would be thought of as something exogenous to the error–correction mechanism. With its inclusion, the error–correction specification becomes:

$$1) \quad \Delta^k p_t = A(L)\,(\bar{p}_{t-1} - p_{t-1}) + B(L)\,(q_{t-1} - \bar{q}_{t-1})$$

where $B(L)$ is another polynomial in the lag operator, representing a distributed lag on the exogenous output gap term.

With the general form of an error–correction equation in hand, one part of the search for an appropriate inflation model requires finding the right k, or degree of differencing. The second part of the search involves specifying the distributed lags on $(\bar{p}_{t-1} - p_{t-1})$ and $(q_{t-1} - \bar{q}_{t-1})$ as represented by the lag polynomials $A(L)$ and $B(L)$. The next subsection identifies the restrictions on k, $A(L)$, and $B(L)$ embodied in the P* model.

The P* restrictions

The general error–correction specification in Equation 1 includes an exogenous term in the "output gap," $(q_{t-1} - \bar{q}_{t-1})$, while the P* version excludes this term. This section shows how certain assumptions allow the $(\bar{p}_{t-1} - p_{t-1})$ term to absorb the output gap, leaving only an

error–correction component driven by a new variable, $p*$.

One starts by observing that real output actually appears *twice* on the right side of Equation 1; because $\bar{p}$ depends on q, it appears both in the error–correction term, $(\bar{p}_{t-1} - p_{t-1})$, and in the output gap term $(q_{t-1} - \bar{q}_{t-1})$. Writing out the $\bar{p}$ term explicitly, Equation 1 is:

$$\Delta^k p_t = A(L)\,(m_{t-1} - q_{t-1} + \bar{v} - p_{t-1}) + B(L)\,(q_{t-1} - \bar{q}_{t-1}).$$

With $A(L)$ different from $B(L)$, there is no way to eliminate the exogenous output gap term. However, if $B(L)$ happened to equal $A(L)$, the two terms could be combined into one:

$$\Delta^k p_t = A(L)(m_{t-1} - q_{t-1} + \bar{v} - p_{t-1} + q_{t-1} - \bar{q}_{t-1}).$$

The q_{t-1} terms then cancel, leaving only:

$$\Delta^k p_t = A(L)\,(m_{t-1} + \bar{v} - \bar{q}_{t-1} - p_{t-1}).$$

This cancellation suggests defining a new target price level, $p*_t$, equal to $m_t + \bar{v} - \bar{q}_t$, or (the logarithm of) M2 per unit of *potential* GNP. In terms of this new variable, the error–correction mechanism is now simply:

$$\Delta^k p_t = A(L)\,(p*_{t-1} - p_{t-1}).$$

With this cancellation, the "P* gap" becomes the sole determinant of inflation; and, as $p*$ varies only with M2 and potential GNP, actual GNP (or its divergence from potential) is irrelevant to future inflation.

What does it mean to assume that $A(L)$ equals $B(L)$? To do so implies that inflation responds in exactly the same way to monetary and non-monetary factors. On one hand, the Phillips Curve relation implies that an increase in q above $\bar{q}$ is inflationary. On the other hand, an increase in real output, *ceteris paribus*, is deflationary from a monetary perspective; the Quantity Equation says that with M and V fixed, an increase in Q implies a smaller P. Thus, to assume that $A(L)$ equals $B(L)$ is to say that the former inflationary impact exactly offsets the latter deflationary impact, leaving no net effect. This is the central assumption underlying the P* specification, and it will be put to test in the following section.

Imposing $A(L) = B(L)$ is only the first step towards the P* specification; the second is to choose $k=2$,

$$\Delta^2 p_t = A(L) \ (p^*_{t-1} - p_{t-1}),$$

so that the *change* in inflation is a function of the gap between p and p^*. The motivation for choosing $k=2$ comes from adding inflationary expectations to the Phillips Curve mechanism described earlier. According to this story, firms (for instance) try to effect real price increases by raising their prices to reflect demand pressure *plus* the expected change in the overall price level:

$$\Delta p_t = \theta(q_{t-1} - \bar{q}_{t-1}) + (\Delta p_t)^e,$$

where $(\Delta p_t)^e$ is the expected rate of inflation, and θ is a positive constant reflecting the speed with which prices respond to demand pressure. A simple version of this equation can be obtained by assuming $(\Delta p_t)^e = \Delta p_{t-1}$; that is, setting tomorrow's expected inflation equal to today's rate of inflation. Consistent with elementary textbooks' discussion of the "Non-Accelerating Inflation Rate of Unemployment," this yields the change in the rate of inflation as a function of the output gap.

In the Phillips Curve contribution to the error–correction equation, therefore, the expectations mechanism motivates the specification in second differences. However, it is not clear that a similar specification is appropriate for the monetary part of the equation; its *a priori* specification in second differences is arbitrary. Because economic theory is silent on the proper degree of differencing associated with the monetary term, it must be determined empirically. In doing so, however, it is essential to allow for the different degrees of differencing between the monetary and the output gap terms.

Evaluating alternative inflation models

The task of this section is to determine an appropriate error–correction description of the price adjustment mechanism, and in doing so, test the restrictions implicit in the P* specification. As shown above, these restrictions amount to imposing $A(L) = B(L)$ and $k=2$ on Equation 1, implying identical adjustment dynamics for the monetary and non-monetary components, and expressing the change in inflation as a function of the price gap.

To test these models, one must be more specific about the distributed lags represented by the $A(L)$ and $B(L)$ lag polynomials. To this

end, we rewrite Equation 1, adding a stochastic disturbance term, ε:[5]

$$2) \quad C(L) \ \Delta^2 p_t = \alpha_1 \ (\bar{p}_{t-1} - p_{t-1}) + \alpha_2 \ (\bar{p}_{t-2} - p_{t-2}) + \beta_1 \ (q_{t-1} - \bar{q}_{t-1}) + \beta_2 \ (q_{t-2} - \bar{q}_{t-2}) + \varepsilon_t,$$

which now includes two lags of the output and price gaps. The $C(L)$ lag polynomial applied to the dependent variable is equivalent to including lagged values of $\Delta^2 p_t$ as additional regressors.

By contrast, the P* model,

$$3) \qquad C(L) \ \Delta^2 p_t = \alpha \ (p^*_{t-1} - p_{t-1}) + \varepsilon_t,$$

includes only one lag of its explanatory variable, $(p^*_{t-1} - p_{t-1})$; and, as described earlier, it forces the two components of $(p^*_{t-1} - p_{t-1})$ to enter as a single unit. The extra lags included in Equation 2 will prove to be useful in conducting tests of the P* restrictions. Specifically, in the expanded model, the P* specification requires that:

$$\alpha_2 = \beta_2 = 0 \text{ and } \alpha_1 = \beta_1,$$

which reduces Equation 2 to the P* model in Equation 3. These restrictions are quite strong, as they imply that *only* the period $t-1$ exogenous variables matter (once lagged $\Delta^2 p_t$ is controlled for), and that the inflationary excess-demand effects disappear.

Before turning to the results, one additional issue requires attention. While the introduction spoke of the inflationary effects of supply shocks, the analysis thus far has focused exclusively on the demand and monetary sources of inflation. The main source of supply shocks in the 1955–88 sample period has been the supply price of crude petroleum, which had a particularly large impact in 1973–74 and 1979–80. It should be noted that these were not the only two episodes during which oil prices exerted a major influence on the overall price level; for example, the steady decline in crude oil prices undoubtedly had a strong deflationary effect during the late '80s.

The HPS approach to modelling the impact of oil prices is to include a (differenced) dummy variable for the large positive oil price shock of 1973:4. As noted in Kuttner (1989), this method suffers from overfitting, and produces parameter estimates with problematic economic interpretations.[6] Furthermore, this approach ignores other important oil price changes. The results in this article replace the

HPS dummy variable with a direct measure of the change in petroleum price inflation, $\Delta^2 p''$, based on the crude petroleum component of the Producer Price Index.

Test results

Writing out the $C(L)$ polynomial as a fourth-order distributed lag, and including as additional regressors two lags of the change in crude petroleum, yields the final form of the equation that is to be estimated:

4)
$$\Delta^2 p_t = \alpha_1 (\bar{p}_{t-1} - p_{t-1})$$
$$+ \alpha_2 (\bar{p}_{t-2} - p_{t-2})$$
$$+ \beta_1 (q_{t-1} - \bar{q}_{t-1}) + \beta_2 (q_{t-2} - \bar{q}_{t-2})$$
$$+ \delta_1 \Delta^2 p''_{t-1} + \delta_2 \Delta^2 p''_{t-2}$$
$$+ c_1 \Delta^2 p_{t-1} + c_2 \Delta^2 p_{t-2}$$
$$+ c_3 \Delta^2 p_{t-3} + c_4 \Delta^2 p_{t-4} + \varepsilon_t.$$

Under the usual assumptions about the disturbance term ε, estimating this equation poses no special econometric problems, and can be performed efficiently using ordinary least squares. As in HPS, the potential GNP series is from the Federal Reserve Board staff,[7] and all variables are expressed as natural logarithms. Except in the case of the fixed-weight GNP deflator, the regressions use quarterly data from 1955:1 through 1988:1. Because the fixed-weight deflator series only starts in 1959:1, this regression begins in 1960:3 to allow for the required lags.

Test statistics from Equation 4 appear in Table 1, which includes four sets of results, using each of four alternative price measures. The first uses the implicit price deflator used in deflating nominal GNP (labelled IPD), which is the index used in HPS; the second is the fixed-weight GNP deflator (FWD); the third is the Consumer Price Index (CPI); and the fourth is the Producer Price Index (PPI).

The main result is that the P* restrictions fail using every index except the implicit price deflator. Lines 1 and 2 of Table 1 show the results from successively imposing the P* restrictions. The first test encompasses a subset of the P* restrictions; by excluding both $(\bar{p}_{t-2} - p_{t-2})$ and $(q_{t-2} - \bar{q}_{t-2})$, it restricts the independent variables' lag lengths to one. These restrictions fail at the five percent level using the PPI

TABLE 1

F-tests of alternative inflation models

Restriction	DF	IPD	Price index FWD	CPI	PPI
1 Excluding $(\bar{p}_{t-2} - p_{t-2})$ and $(q_{t-2} - \bar{q}_{t-2})$	2	0.57 (0.57)	2.96 (0.06)	3.84 (0.02)	3.58 (0.03)
2 P* model	3	0.49 (0.68)	5.56 (0.00)	3.68 (0.01)	4.31 (0.01)
3 Alternative model	1	1.27 (0.26)	3.30 (0.07)	0.61 (0.44)	0.92 (0.34)

Note: p-values are in parentheses.

and CPI. The second test combines the joint exclusion restriction with the imposition of equality between the $(\bar{p}_{t-1} - p_{t-1})$ and $(q_{t-1} - \bar{q}_{t-1})$ coefficients—the restrictions embodied in P*. The strongest rejection comes from the fixed-weight deflator, which delivers a p-value of 0.0012. The CPI and PPI tests also reject the P* model at the one percent level.

Which set of results is to be believed? None of the four price indices is perfect. However, in its statistical releases, the Department of Commerce warns of the pitfalls inherent in using the implicit price deflator, stating: "[Because] the prices are weighted by the composition of GNP in each period, ...the implicit price deflator reflects not only changes in prices but also changes in the composition of GNP, and its use as a measure of price change should be avoided."[8] This contamination of price movements with quantity changes may well account for the HPS finding of similar dynamics on the price and output gap terms. By contrast, because changes in the fixed-weight deflator, CPI, and PPI reflect pure price movements, they are more appropriate for use with models of inflation, and can be expected to give more sensible results.

An alternative model

The third row of Table 1 presents a test of an alternative to the P* restrictions,

5)
$$\Delta^2 p_t = \alpha \Delta (\bar{p}_{t-1} - p_{t-1})$$
$$+ \beta_1 (q_{t-1} - \bar{q}_{t-1}) + \beta_2 (q_{t-2} - \bar{q}_{t-2})$$
$$+ \delta_1 \Delta^2 p''_{t-1} + \delta_2 \Delta^2 p''_{t-2}$$
$$+ c_1 \Delta^2 p_{t-1} + c_2 \Delta^2 p_{t-2}$$
$$+ c_3 \Delta^2 p_{t-3} + c_4 \Delta^2 p_{t-4} + \varepsilon_t$$

which, by constraining $\alpha_2 = -\alpha_1$, excludes the $(\bar{p}_{t-1} - p_{t-1})$ term in levels, while allowing it to enter only as a first difference. The α parameter (without a subscript) is the coefficient on the difference term. This version is based on the observation that the estimates of α_1 and α_2 obtained from Equation 4 are very nearly equal and opposite in sign. In fact, the third row of Table 1 shows that the $\alpha_2 = -\alpha_1$ constraint cannot be rejected at the five percent level using any of the four price indices, although it fails at the ten percent level using the fixed-weight deflator. Table 2 shows the parameter estimates of this model, for each of the price indices. Again, two lags of the change in crude petroleum inflation are included to capture oil price movements.

The point estimates of interest depend somewhat on the price index. Each index yields an estimate of the coefficient on $\Delta(\bar{p}_{t-1} - p_{t-1})$ close to 0.1 (with a somewhat weaker effect found using the FWD), which implies that 10 percent of the gap between current and target inflation (determined by M2 growth) is closed each quarter.

The magnitude of the demand effects is typically large, with a one-time-only one percent increase of GNP above its potential delivering a 0.11 to 0.27 percent increase in the rate of inflation. Nearly three-fourths of the increase is reversed in the subsequent quarter, but some inflationary effect persists. Consistent with the "accelerationist" hypothesis, holding GNP permanently in excess of potential implies an ever-increasing rate of inflation.

The real significance of this modification is that it embodies a first-differenced ($k=1$) error–correction mechanism not between the price level and the money stock, but between their growth rates, i.e., between inflation and M2 growth. This mechanism does not imply that the price level converges to that determined by a given money stock. Because it takes some time for inflation to catch up to a change in the rate of money growth, a non-zero discrepancy between the levels of p and $\bar{p}$ may persist over

time. In the Quantity Equation, this divergence would appear as a shift in the velocity of circulation, like the shifts evidenced by other aggregates' velocities.

A model characterized by this looser link between money and prices might be termed "weak-form" monetarist. Here, inflation is indeed a monetary phenomenon in the long run, as it converges to the rate of money growth. However, even in the long run, it implies that some slack exists between the monetary aggregate and the price level. In

TABLE 2

Estimates of the alternative specification

| Regressor | Price index | | | |
	IPD	FWD	CPI	PPI
1 $\Delta(\bar{p}_{t-1} - p_t)$	0.0953	0.0665	0.1034	0.1087
	(2.1)	(1.9)	(2.7)	(1.9)
2 $(q_{t-1} - \bar{q}_{t-1})$	0.1374	0.1138	0.1699	0.2711
	(2.9)	(3.1)	(4.3)	(3.9)
3 $(q_{t-2} - \bar{q}_{t-2})$	−0.0969	−0.0828	−0.1287	−0.2077
	(2.1)	(2.3)	(3.2)	(3.1)
4 $\Delta^2 p_{t-1}$	−0.5200	−0.3951	−0.2838	−0.5264
	(5.3)	(3.9)	(3.0)	(5.0)
5 $\Delta^2 p_{t-2}$	−0.3171	−0.2532	−0.3416	−0.3138
	(2.9)	(2.2)	(3.3)	(2.8)
6 $\Delta^2 p_{t-3}$	−0.2816	−0.1688	−0.1542	−0.0544
	(2.7)	(1.6)	(1.7)	(0.5)
7 $\Delta^2 p_{t-4}$	−0.0624	0.0406	−0.0231	−0.0632
	(0.8)	(0.4)	(0.3)	(0.7)
8 $\Delta^2 p^o_{t-1}$	−0.0101	−0.0027	0.0081	0.0184
	(2.1)	(0.2)	(1.8)	(2.0)
9 $\Delta^2 p^o_{t-2}$	0.0073	0.3939	0.0151	0.0073
	(1.5)	(1.1)	(3.2)	(0.8)
$\bar{R}^2$	0.3357	0.2307	0.3336	0.2744

Note: t-statistics are in parentheses.

LM tests for serial correlation

	IPD	FWD	CPI	PPI
AR(1) errors	1.08	0.20	0.01	0.52
	(0.30)	(0.65)	(0.90)	(0.47)
AR(4) errors	2.97	2.95	0.83	2.48
	(0.56)	(0.57)	(0.93)	(0.65)

Note: p-values are in parentheses.

fact, the precise value of the price level in the steady state will exhibit path dependence, and vary with the growth path followed by the money stock on the way to the steady state.

By contrast, the second-differenced P* specification forces long-run convergence in levels, relying on the stationarity of the M2 velocity. An undesirable side effect of the second-differencing is to build some rather implausible dynamics into the P* model. These dynamics are illustrated in Figure 1, which displays its predicted inflation rate in response to a reduction in the M2 growth rate to 2.5 percent annually, equal to the growth rate of potential GNP. The salient features of this simulation are its large medium-run oscillations. In response to the decrease in the rate of money growth, inflation plunges to nearly – 4 percent by 1997; but by 2004, it rises again to 3 percent. Although the inflation rate eventually converges to zero, sizeable fifteen-year oscillations continue for over a century.

The source of the cyclical behavior can be traced directly to the second-differenced specification. Assuming that the change in the rate of inflation depends on $(p^*_{t-1} - p_{t-1})$ builds in an ''accelerationist'' dynamic—inflation does not abate when a balance is reached between p and p^*. Instead, it continues even after p reaches p^*, causing the price level to over-

shoot its target. As demonstrated by an analogous simulation of the alternative model plotted in Figure 2, sacrificing long-run convergence and going to a first-differenced specification eliminates this overshooting, and assures a smooth convergence to a new long-run inflation rate.

While the alternative model represents one avenue for improving the P* specification, it is only a first step towards a satisfactory inflation model. In particular, it retains certain unsatisfactory *ad hoc* aspects of the P* equation which deserve more rigorous scrutiny. One of these is the naive modelling of inflationary expectations in the Phillips Curve portion of the model. Another is the unsophisticated approach to incorporating supply shocks. Through an aggregate cost or price function, it may be possible to motivate an additional error–correction term incorporating the oil supply price as one of the inputs. Furthermore, by re-introducing real GNP as a determinant of inflation, the alternative model is not closed, but requires an additional equation relating real output to a set of exogenous variables, including money.

Conclusions and policy implications

While one might plausibly assert that the general price level will, in the long run, be

FIGURE 1

P* looks to the future
(Simulated inflation path)

percent inflation

Annual M2 growth = 2.5%
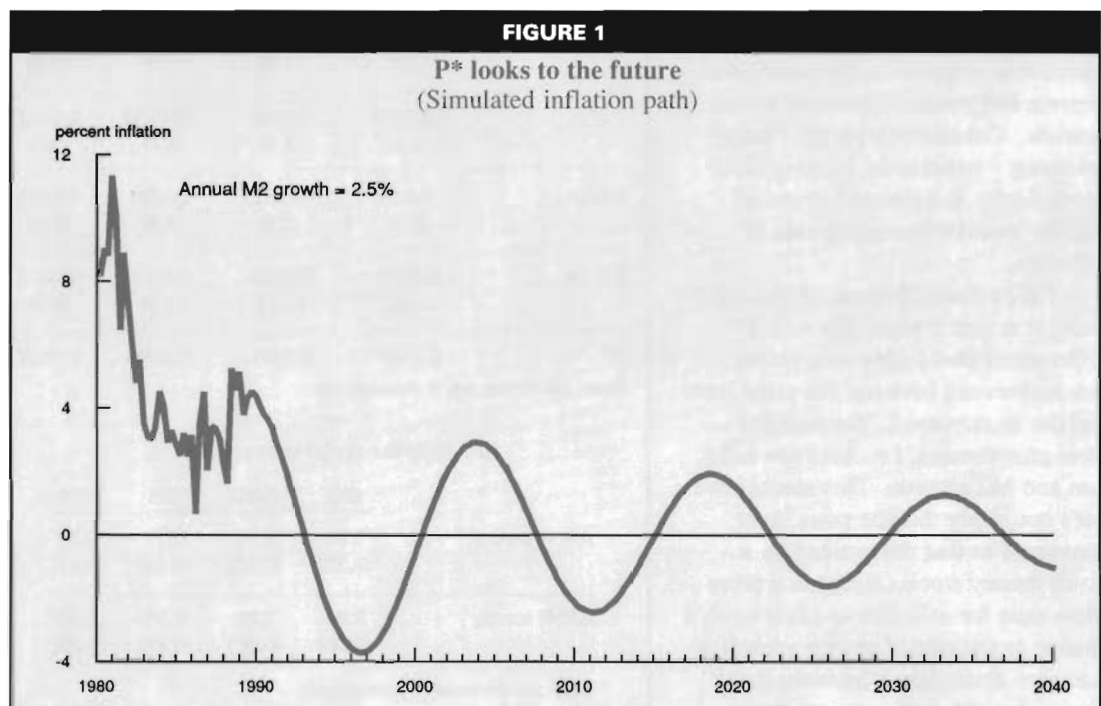
proportional to some measure of money, it does not follow that *only* money determines inflation over all horizons. Aside from the important practical considerations of *which* monetary aggregate ties down the price level, and whether that relationship will survive continuing financial innovation, the first assertion is a straightforward implication of the well-known Quantity Theory of money.
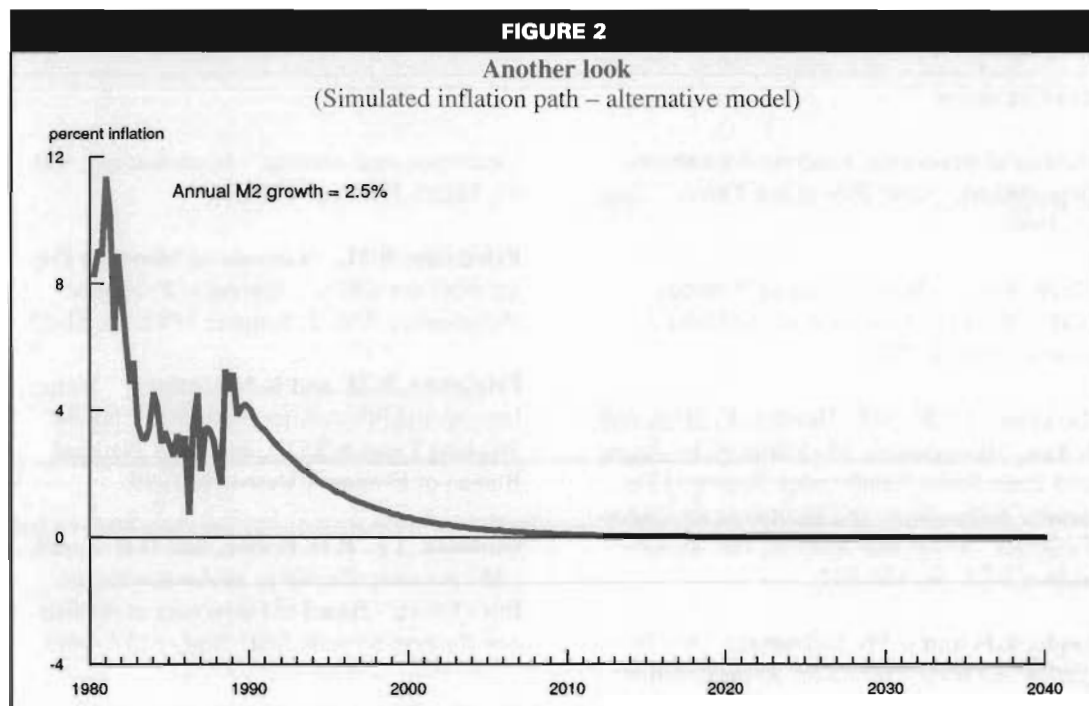
The P* model of Hallman, Porter, and Small errs in going from the first proposition to the second, and concluding that only money matters. In technical terms, theirs is an error–correction inflation model whose sole exogenous variables are M2 and potential GNP. In practical terms, this means that demand measures, such as the level of actual output, unemployment, or capacity utilization have no inflationary implications, once the level of M2 is accounted for.

This article questions that finding, arguing that while some measure of money (possibly M2) may be the main determinant of inflation in the long run, the HPS conclusion that nothing else matters is unwarranted. In rejecting the P* model in favor of a less restrictive alternative, we find that demand-side effects *do* exert an influence over relevant policy horizons. Therefore, while P* may be a useful forecasting tool in certain situations, it ignores

one of the principal medium-run sources of inflationary pressure..

Price level convergence is another area in which the alternative inflation model parts company with P*. While the alternative model acknowledges the contribution of demand factors to inflation, it also sacrifices the property, embodied in the P* specification, that prices converge to the level determined by M2. In other words, the alternative does not build in mean reversion in the M2 velocity. If we somehow knew with certainty that the M2 velocity would continue to revert to its post-1954 mean, this fact could be exploited to improve long-run price level forecasts. However, given the rapid and unexpected disintegration of other aggregates' velocities and the continuing brisk pace of payments system innovation, it may be a serious mistake to base policy on a model which depends critically on the continuing stationarity of the M2 velocity.

In implementing monetary policy designed to maintain a stable rate of inflation, one key issue is whether the state of the real economy has a role as an indicator of inflation, or as a valid intermediate policy target. The empirical results presented here indicate that it does, contrary to the implications of the P* model. A more subtle question is whether any forecast refinements derived from imposing

FIGURE 2

Another look
(Simulated inflation path – alternative model)

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price level convergence outweigh the risk of future deterioration of the M2 velocity. However, to the extent that the focus of Federal Reserve policy is on inflation rather than the long-run price level *per se*, the value of relying on M2 as a price level anchor appears small.

In concluding, it is important to emphasize that while the alternative model conflicts with P* in these two important areas, they share one important policy implication. Assuming

a stable relationship between M2 and prices endures, both establish a link between inflation and the growth rate of M2 in the long run; both suggest that over long horizons, one can expect the inflation rate to equal the growth rate of M2, less the growth rate of potential GNP. Therefore, although M2 is not the only indicator worthy of attention, its growth rate may serve as a useful guidepost for long-run inflation trends.

FOOTNOTES

[1] For an overview of this argument, see Benjamin Friedman's (1988) survey.

[2] Engle and Granger (1987) show that an error–correction mechanism exists in cases where two variables each contain unit roots, while some linear combination of the two is stationary.

[3] The fact that most statistical tests fail to reveal a unit root in the M2 velocity indicates mean-reverting behavior. Friedman and Kuttner (1989) examine the properties of the monetary aggregates, finding that the recent deterioration of the M2 velocity has been mild compared with that of the other aggregates.

[4] For notational simplicity, lag operators are used throughout this article. The lag operator, L, when applied to a period t variable, y_t, shifts the time subscript back one period: $L^N y_t = y_{t-N}$. A polynomial in the lag operator, $A(L)$, is a polynomial in powers of L: $a_0 L^0 + a_1 L^1 + a_2 L^2 + ... + a_N L^N$. A polynomial in the lag operator applied to a variable

produces a distributed lag: $A(L)y_t = a_0 y_t + a_1 y_{t-1} + a_2 y_{t-2} + ... + a_N y_{t-N}$. See Sargent (1979), pp. 171-176.

[5] This equation is equivalent to the original error–correction model in Equation 1, where rational transfer functions ($\alpha_1 + \alpha_2 L) C^{-1}(L)$ and ($\beta_1 + \beta_2 L) C^{-1}(L)$, replace the lag polynomials $A(L)$ and $B(L)$.

[6] A similar problem appears with the use of dummy variables to model the effects of the Nixon Administration's Phase I and Phase II price controls. These dummies are therefore omitted from the regressions in this article.

[7] The potential GNP series used is the one constructed by Federal Reserve Board staff members, based on the methodology in Clark (1983).

[8] Bureau of Economic Analysis, "GNP Report and Tables," p. 6. For an overview of the issues involved in price level measurement, see Webb and Willemse's (1989) survey of macroeconomic price indices.

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