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John A. Tatom

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FEDERAL RESERVE BANK OF ST. LOUIS
Research Division
411 Locust Street
St. Louis, MO 63102

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John A. Tatom*

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Federal Reserve Bank of St. Louis
P.O. Box 442
St. Louis, MO 63166
(314) 444-8558

Comments are welcome.

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*Assistant Vice President, Federal Reserve Bank of St. Louis.

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ABSTRACT:

In the P-star model the price level is determined by the money stock per unit of potential output and the long-run equilibrium level of the velocity of money. This article applies this model to Austria. Problems in identifying permanent shocks to potential output and/or velocity lead to the rejection of such models of the price level, but their first-difference version is not so suspect. While evidence is found of a long-run relationship between Austria inflation and money growth, even the first-difference version of the P-star model is rejected for Austria. Since Austria is a small economy, closely tied to Germany, the article also investigates whether Austrian prices are tied to a German P-star measure. This hypothesis is also rejected, but there is a statistically-significant long-run relationship between Austrian and German inflation. Moreover, Austrian money growth remains significant even in this relationship.

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The P-Star Model and Austrian Prices

John A. Tatom

Several recent attempts have been made to incorporate the notion of a monetary-based equilibrium price level, called P-star, into discussions of monetary policy and inflation. The central premise of the P-star model is that the price level tends to an equilibrium determined largely by the domestic money stock. A corollary of this result is that the "price gap", the gap between the currrent price level and the equilibrium price level, is helpful in forecasting future inflation. The central conclusion, however, is that monetary policy can influence the prospects for inflation by controling the money stock and, thereby, the equilibrium price level.

This article explains the P-star model, how it has been estimated elsewhere and its estimation for Austria. The P-star model and a first-difference variant of it are examined below, followed by a discussion of the advantages of estimating the first-difference version without some simplifying restrictions from the quantity theory of money.

The article then turns to the consideration of Austria as a small open economy. Since Austria is small and trades extensively with Germany, its prices are largely determined in the German market for its goods and services. This has been especially the case since the late 1970s when the Mark-Schilling exchange rate became nearly fixed. Thus, the article investigates whether Austrian prices have a long-run equilibrium relationship with a P-star measure for Germany or with actual German prices. The article concludes that the Austrian money stock has a long-run relationship with Austrian prices, but that this relationship is somewhat different from that envisioned in the P-star model or in fixed-exchange rate models of prices in the small, open economy.

I. THE P-STAR MODEL

The equilibrium price level is determined from the Quantity Theory equation of exchange:

(1) $P^{*} = M\ V^{*}/Q^{*}$

where M is the domestic money stock and V^{*} and Q^{*} are long-run equilibrium values of the velocity of M and of potential or capacity output. Thus, Hallmann, Porter and Small (HPS) (1989 and 1991), the original proponents of the P-star model, refer to the price level as determined by the money stock per unit of potential output. HPS apply the P-star model to the U.S. GNP deflator; they use M2 as the measure of money and assume that the equilibrium velocity of M2 is a constant, based on their conclusion that M2 velocity has no trend.[1)]

Hoeller and Poiret (1991) question this approach in a study of P-star for 20 countries; they recommend the use of the "Hodrick-, Prescott filter" to estimate the equilibrium or trend component of velocity and output. For Austria, however, Hoeller and Poret find that trend measures are superior to the Hodrick-Prescott measures for potential output and velocity, but in their work, this variant of the P-star model for Austria is not supported by the data and it does not forecast inflation as well as some other techniques. A measure of potential output is available for this study, so a filtering method does not have to be used to measure potential output; a trend is used for velocity, initially. The equilibrium level of velocity and potential output are assumed to be exogenous to the measure of equilibrium prices in P-star studies, although this assumption is examined in more detail below.

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1) Tatom (1991) shows that this conclusion is doubtful using alternative methods, including trends in the HPS model. The evidence points to a positive trend in M2 velocity until mid-1981, which shifted subsequently to a negative trend.

In the P-star model, prices adjust to the equilibrium level following a process which is typically referred to as an "error-correction mechanism" (ECM), or "process". The P-star model is, however, a constrained version of an ECM model. In particular, the P-star model is typically estimated as a first-difference version of:

$$(2)\ \ln P_t - \ln P_{t-1} = \delta(\ln P_{t-1} - \ln P^*_{t-1}) + \sum_{i=1}^{n} \beta_i \Delta \ln P_{t-i}$$

to include the past "error", or price gap, and some time series dynamics, or transitory components for the inflation rate, measured by the first difference (Δ) of the logarithm of prices. Some studies also include other transitory influences on prices like price-control measures, or even measures of permanent supply-side shocks, on the basis that these are not adequately captured in movements of potential output.

Some Evidence on Austria's P-Star

To estimate a P-star model for the annual GDP deflator in Austria, an annual potential output measure prepared by the Austrian Institute of Economic Research was used along with the M3 monetary aggregate measure. Equilibrium velocity, V3, was obtained from a model containing a simple trend for the logarithm of V3, LV3. LV3 has an apparent trend over the period 1960-90:

$$(3)\ LV3_t = \underset{(644.54)}{7.745} - \underset{(-31.07)}{0.021}\, t + RV3_t$$

$$R^2 = 0.97 \qquad S.E. = 0.0343 \qquad D.W. = 0.68$$

where $RV3_t$ is the residual.

To test whether LV3 is trend stationary, the augmented Dickey-Fuller test is used. The direct estimate for the augmented Dickey-Fuller test is:

$$(4)\quad \Delta LV3 = \underset{(2.90)}{3.516} - \underset{(-2.92)}{0.455}\ LV3_{t-1} - \underset{(-2.72)}{0.0094}\ t - \underset{(2.05)}{0.383}\ \Delta LV3_{t-1}$$

$$R^2 = 0.210 \qquad S.E. = 0.025 \qquad D.W. = 1.66$$

No additional lags of the dependent variable are statistically significant at a 5 percent level. The time trend is again statistically significant, but the τ-statistic value of - 2.92 is not statistically significant at a 5 percent level; the critical value is - 3.60. Thus, V3 is not stationary around a deterministic trend, according to this estimate.[2] The nonstationarity of LV3 means that equation 3 does not provide a useful measure of equilibrium velocity because a P-star measure constructed using it is likely to result in a nonstationary price gap. Nevertheless, the equilibrium velocity measure from equation 3 is used provisionally to examine the P-star model.

The price level and P-star are shown in Figure 1. The level of price is typically higher that the equilibrium level because real GDP is typically below potential output. As the level of prices moves closer to equilibrium, the inflation rate tends to slow, as the theory suggests. This is most apparent in 1978-79, 1983 and 1987-88. Note that the gap in 1990 suggests that inflation should slow sharply, but this did not occur.

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2) An alternative test is to test whether the residuals from equation 3 are stationary using the augmented Dickey-Fuller test given in Engle and Granger. In a regression of the first-difference of the residual, $\Delta RV3$ on the lagged level of the velocity residual, $RV3_{t-1}$ and one significant lag of the dependent variable, the t-statistic on the lagged residual is - 3.05, which is slightly above the critical value of - 3.00 (5 percent) in absolute value. This suggests some marginal support for trend stationarity, although the appropriate test is the direct estimate given in the text.

Figure 2 show the inflation rate and the price gap, the gap between actual and equilibrium prices. This figure shows that inflation and the price gap appear to move together. The correlation between the price gap and inflation is 0.60. The theory, however, concerns acceleration and declerations in inflation and the level of the price gap; from 1962 to 1990, the correlation between the change in inflation and the price gap is 0.10 which is not significant, and with the previous price gap, it is - 0.35, which has the wrong sign.

An estimate of the P-star model (1962-90) including the only statistically significant lagged dependent variable and the relative price of energy is:

$$(5)\quad \Delta \ln P_t = \underset{(2.01)}{0.0153} - \underset{(-1.50)}{0.149}\,(\ln P_{t-1} - \ln P^*_{t-1}) + \underset{(3.81)}{0.701}\,\Delta \ln P_{t-1} + \underset{(2.04)}{0.054}\,\Delta \ln PE_{t-1}$$

$$R^2 = 0.533 \qquad S.E. = 0.012 \qquad D.W. = 2.28$$

The change in the relative price of energy with one lag is marginally statistically insignificant at a 5 percent level (critical value - 2.06); the price is the producer price for fuel. The price gap is not statistically significant, as the t-statistic (- 1.50) is too small.

Thus, the P-star model is easily rejected using equation 5. The estimate in equation 5 tends to overstate the importance of the price gap because the price gap is not stationary, so its t-statistic is biased upward in absolute value. A regression of changes in the price gap on its own past level for the period 1962-90 yields a coefficient of - 0.192 with a t-statistic of only - 1.62 which is too small in absolute value to reject non-stationarity; no lagged dependent variables or trend are included because these variables are not statisticially significant. The absence of a stationary price gap is sufficient to reject the P-star model because it rejects the hypothesis that P tends to equal P-star in the long run.

Estimation Problems and Interpretation

The principal problem above for estimating the Austrian P-star model is the nonstationarity of both trend velocity and the price gap. If trend velocity is not stationary, then its characterization as an equilibrium level is inappropriate. If the price gap is not stationary, then the hypothesis that P and P-star are contegrated, the central hypothesis of the P-star model, is rejected. Table 1 provides some insight into these difficulties. It provides a summary of unit root tests on the variables involved in the P-star model. The sample period for examining the existence of stationary series is quite short, especially for such an examination using annual data. This is also true for examining long-run relationships. Thus, conclusions about nonstationarity or the absence of long-run relationships may be biased due to the lack of a larger (longer) sample.

According to the evidence in table 1, the price level itself is an I(2) process, that is, the lag of the price level must be differenced twice to achieve stationarity. This implies that inflation is I(1). The P-star measure is I(1), or the first-difference of P-star is stationary. This explains why the price gap is not stationary; it is a linear combination of an I(1) and an I(2) process, which theoretically is, at least, an I(1) process, not stationary or I(0). The evidence in table 1 indicates that the price gap is, indeed, an I(1) process, meaning that the price gap is only stationary if differenced once.

What about the P-star measure itself? The evidence in the table on its components shows that both M3 and potential output are I(2), or that their growth rates are I(1). Also, M3 velocity is

I(1), or it must be differenced to be stationary. Thus, while the evidence suggests that M3 velocity is not trend stationary, allowing for a stochastic trend, its growth rate is stationary. One implication is that, since P-star, an I(1) series, is a linear combination of one I(1) series and two I(2) series, the two I(2) series, M3 and XP, must be cointegrated. Second, and more important, these results suggest that an equilibrium inflation rate can be defined using the P-star methodology and that this equilibrium might be an "anchor" for, or bear a long-run equilibrium relationship to, actual inflation.

II. A P-STAR BASED MODEL OF AUSTRIAN INFLATION

Consider the equilibrium inflation rate π^e found by differencing equation 1 above.

$$(6)\ \pi^e = \Delta lnM3 + \Delta lnV3^* - \Delta lnXP$$

According to the unit root tests above, ΔlnV3 is a stationary process, so that equilibrium ΔlnV3 is a constant. For the period 1961-90, the mean of ΔlV3 is - 0.01985, and this is the best statistical estimate of equilibrium velocity. Combining this measure with M3 and potential output growth yields a π^e measure which is essentially the same as that in Figure 2.

Does π^e provide a meaningful model of equilibrium inflation? If it does, then controlling M3 growth would provide a meaningful anchor for the inflation rate, despite the fact that the stock of M3 does not bear a fixed relation to the level of prices. These results can very readily occur if there are other factors influencing the level of prices besides M3 and the measure of potential output.

To test this model, one need only examine whether π^e and π, the actual inflation rate are cointegrated. If they are, then a model of inflation drawing on the inflation gap, $(\pi^e{}_t - \pi^e{}_t)$, is easily derived. To test for cointegration, the linear regression of π on π^e is estimated. The result is

$$(7)\quad \pi_t = \underset{(6.43)}{0.037} + \underset{(1.95)}{0.206}\ \pi^e{}_t$$

$$R^2 = 0.088 \qquad S.E. = 0.0165 \qquad D.W. = 0.90$$

The t-statistic on π^e indicates that it is insignificant; the critical value (5 percent) with 28 degrees of freedom is 2.05. This result suggests that even π and π^e are not related in the long run. A test of the stationarity of residuals for this estimate yields a t-statistic for the lagged residual of - 2.88 which is too small in absolute value, compared with the critical value given by Engle and Granger (5 percent) of - 3.37, to reject the absence of cointegration.

Another approach is to consider the inflation gap, the difference in π and π^e. The difference is stationary, which supports the presence of cointegration. When the first-difference of the inflation rate is regressed on the lagged level of this gap, the t-value for the coefficient (- 0.844) is - 4.55, which rejects the absence of cointegration. Nevertheless, an error correction model for this gap, G, yields

$$(8)\quad \Delta^2 \ln P = \underset{(-0.31)}{-\,0.001} - \underset{(-0.56)}{0.050}\ G_{t-1}$$

and this estimate has a negative adjusted R^2. Thus, even if π and π^e are cointegrated, the information is not useful for forecasting inflation. In addition, while the gap is stationary, the gap construction essentially means that the coefficient on π^e in equation 7 can be constrained to one. When this constraint is tested, the t-value for the constraint is - 7.50 which decisively rejects the constraint. Thus, even the fact that the gap is stationary is purely a statistical artifact.

Is There A Link Between M3 Growth and Inflation In Austria?

While the P-star model and its inflation variant are rejected for Austria, it is possible that M3 growth and inflation have a statistically significant long-run relationship.

In particular the P-star and π^e measures constrain the influence of M3 and XP to have very specific effects on the price level or inflation. Relaxing the constraint that M3 and XP have these precise effects can alter the result above. In particular, a more general error correction model yields quite different results.

First, the cointegrating vector relating inflation, M3 and potential output growth is estimated.

$$(9)\quad \Delta \ln P_t = \underset{(1.24)}{0.0137} + \underset{(2.64)}{0.274}\,\Delta \ln M3_t + \underset{(0.80)}{0.152}\,\Delta \ln XP_t$$

$$R^2 = 0.20 \qquad S.E. = 0.0154 \qquad D.W. = 1.03$$

This estimate differs considerably from the identity in equation 6. An F-test of the constraint that the money and potential output coefficients sum to zero and that the money coefficient is one is $F_{2,27} = 34.59$ which rejects these constraints quite handily (the critical value is 3.35)[3] Nonetheless, the coefficient on M3 is statistically significantly different from zero.

Another factor that is important for inflation is past oil and energy price shocks. In a P-star framework, the permanent influence of a supply shock theoretically is expected to be captured in its effect on potential output. But if potential output does not fully reflect this change, then a measure of the supply shock should still be significant in the

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3) When output growth is dropped in the cointegrating vector, the coefficient on M3 growth (0.295) remains significant (t = 2.95).

cointegrating vector for inflation. When this variable is added to equation 9 above, its coefficient is statistically significant (t = 4.05), but that of potential output (- 0.045) is even less significant (t = - 0.28).

Without potential output growth, the cointegrating vector estimate is:

$$(10)\quad \Delta \ln P_t = \underset{(1.64)}{0.0134} + \underset{(3.75)}{0.295}\ \Delta \ln M3_t + \underset{(4.24)}{0.086}\ \Delta \ln PE + RES$$

$$R^2 = 0.51 \qquad S.E. = 0.0121 \qquad D.W. = 1.77$$

The test for cointegration comes from a regression of the change in the vector's residual on its own past residual and any significant lags of the dependent variable; the estimate is

$$(11)\quad \Delta RES_t = \underset{(-4.81)}{-\ 0.907}\ RES_{t-1}$$

$$R^2 = 0.45 \qquad S.E. = 0.0117 \qquad D.W. = 1.91$$

and the t-statistic is much larger in absolute value than the 3.37 critical value found in Engle and Granger. Thus, the absence of cointegration in equation 10 is rejected.

The error correction model that uses this cointegrating vector is:

$$(12)\quad \Delta^2 \ln P_t = \underset{(-0.25)}{-\ 0.001} - \underset{(-3.25)}{0.602}\ RES_{t-1}$$

$$R^2 = 0.254 \qquad S.E. = 0.0115 \qquad D.W. = 2.02$$

This result is statistically significant and indicates that M3 growth provides an anchor for Austrian inflation and that departures from its equilibrium relationship with inflation are significant in accounting for inflation dynamics.

What should one make of the relatively small coefficient on M3 growth in the cointegrating vector? It is significantly less than one (t = 8.95). It is possible that M3 growth is simply a proxy for the appropriate monetary aggregate, and that M3 systematically grows about 3.39 times faster that this "true" measure. What this measure might be has not been investigated. It is also possible that the omission of other variables, which are both highly correlated with M3 and which have a significant effect on Austrian prices, has biased down the coefficient on M3.[4)] Finally, the assumed independence of money growth and velocity and potential output growth could simply be incorrect. This is examined below.[5)]

Is Equilibrium Velocity Growth Independent of Monetary Growth?

If an increase in money growth permanently lowers velocity growth in Austria, then the assumed indipendence of these two variables is incorrect and the relatively small coefficient on M3 growth in the estimates above could be reasonable. To investigate this possibility, a potential cointegrating vector relating velocity growth, M3 growth, potential output growth

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4) A test of whether the exchange rate is a statistically significant omitted variable that also might account for the small coefficient on money growth was conducted. The first-difference of the logarithm of the exchange rate was added to equation 10. Three measures of the exchange rate were used: the schilling price of the German Mark, Austria's trade-weighted nominal effective exchange rate and a real effective exchange rate measure (1969-90), which uses relative unit labor cost in manufacturing to compute the real exchange rate. The t-statistic for each is 0.34, 0.35 and 0.37, respectively. Not only does the exchange rate have no effect, the latter two measures have the wrong sign because they measure the external value of the schilling, while the first measure is the price of the Mark.

5) Glück, Proske and Tatom (1992) show that the exchange rate regime is important for determining the nature of equilibrium relationships involving Austria and Germany. They discuss three regimes, roughly corresponding to 1960-70, 1971-78 and 1979-90, here. A check of the stability of equation 10, does not suggest any instability, although the number of degrees of freedom is quite limited. For example, the F-statistic for a break in 1971 is $F_{3,24}$ = 1.04 which does not reject the absence of a break there.

and the rate of increase of producer energy prices is estimated. The resulting estimate is:

$$(13)\quad \Delta lnV3 = \underset{(1.91)}{0.022} - \underset{(-6.66)}{0.713}\, \Delta lnM3 + \underset{(3.85)}{0.788}\, \Delta lnXP + \underset{(2.59)}{0.072}\, \Delta lnPE$$

$$R^2 = 0.68 \qquad S.E. = 0.0159 \qquad D.W. = 2.12$$

All three variables appear to have statistically significant effects on velocity. Of course, if the effect of M3 growth on velocity growth is minus one, then money growth has no effect on nominal output or prices, so this possibility must be tested. The t-statistic for this hypothesis is 2.66 which rejects the hypothesis. Thus, the coefficient on M3 growth is significantly less that one in absolute value, so money growth affects nominal output growth. Since the money growth coefficient equals about - 0.7, it is not surprising that the coefficient on money growth in equation 10 is only about 0.3.

Equation 13 has three other important properties. First, potential output growth is statistically significant and its coefficient is not significantly different from one.

The energy price coefficient is statistically significant, which suggest that energy prices affect nominal output through another channel besides potential output or that the potential output measure is biased.

Equation 13 is a significant cointegrating vector. In particular, a test of the stationarity of its residual does not reject stationarity. When the first-difference of the residual in equation 13 is regressed on the past level of this residual, the coefficient is - 1.075 (t = - 5.77); no lagged dependent variables are statistically significant and the t-value for the lagged residual is much larger in absolute value than the 5 percent critical value given in Engle and Granger of 3.17.

The result here remain a puzzle, however, because it is not obvious why a permanent increase in M3 growth would raise the growth rate of money demand, reducing velocity growth.

III. ARE AUSTRIAN PRICES TIED TO LONG-RUN EQUILIBRIUM PRICES IN GERMANY?

Since the breakdown of the Bretton Woods Agreement in 1971, monetary policy in Austria has focused on maintaining an exchange rate objective, especially with respect to the German Mark (DM). Austria's largest trading partner's currency. Indeed, since 1979, the target for policy has been a nearly fixed peg for the schilling against the DM.[6)] In principle, a fixed exchange rate should make prices in Austria equal those in Germany. Austrian money and prices are still be related under a fixed exchange rate, but the money stock becomes endogenous, increasing or decreasing with domestic prices, which, in turn, are determined in Germany.

The Bundesbank (1992) recently has prepared estimates of long-run equilibrium prices, or P-star (also called PGS below) since 1971. If Austrian prices are tied to the level of German prices, then lnPGS should be statistically significant when added to equation 13. For the period 1971 - 90, however, the estimate is:

$$(14)\quad \ln P_t = \underset{(-1.17)}{-\,2.864} + \underset{(7.20)}{0.430}\ \ln M3_t + \underset{(1.58)}{0.331}\ \ln XP_t + \underset{(3.75)}{0.057}\ \ln PE_t - \underset{(-0.57)}{0.097}\ \ln PGS_t$$

$$R^2 = 0.998 \qquad S.E. = 0.0144 \qquad D.W. = 0.94$$

If equation 14 is viewed as a potential cointegrating vector, the Austrian and German prices are unrelated; indeed, the sign

6) See Glück, Proske and Tatom (1992) for a recent discussion of Austrian monetary policy and for evidence on the link between nominal magnitudes in Austria and Germany.

on the German P-star variable is wrong and its t-value is only 0.57 in absolute value. When the insignificant potential output term is dropped, the German P-star variable has the right sign 0.039, but it remains statistically insignificant (t = 0.25).

In a simple test of the relationship between Austrian prices and the German P-star measure, the estimated vector is:

$$(15)\quad \ln P_t = \underset{(-7.90)}{-\,1.155} + \underset{(38.32)}{1.270}\ \ln PGS_t$$

$$R^2 = 0.987 \qquad S.E. = 0.0329 \qquad D.W. = 0.55$$

The t-statistic on the lagged residual in the augmented Dickey-Fuller test (with only the first lagged dependent variable which is significant), is - 2.46, which is too small to support cointegration; the absolute critical value is 3.37 (5 percent).

The Measure of the Equilibrium German Price Level

There is evidence elsewhere that German and Austrian prices have been cointegrated at least since 1979.[7)] Thus, the failure to find a close statistical link between Austrian prices and the German P-star measure may reflect shortcomings of the latter measure. Indeed, there are reasons to doubt the claim that prices in Germany tend to this level. The model of German P-star has at least two questionable features.

The Bundesbank (1992) model assumes that velocity is a function of real output, so that long-run velocity is determined by potential output. In Austria, as in Germany, the elasticity of velocity with respect to output is negative (- 0.607) when this is the only variable considered. This implies that money demand has a real income elasticity of about 1.607. Simply adding a time trend or the money stock alters this result for Austria,

7) See Glück, Proske and Tatom (1992) for evidence on quarterly consumer price measures.

however. With a trend, the income elasticity of money demand falls to 0.756 and the time trend is statistically significant, - 0.030 (t = - 8.50). When the money stock is also included, the time trend is no longer statistically significant (t = - 0.44). Omitting this insignificant trend, the elasticity of velocity with respect to the money stock is negative, - 0.406, and statistically significant (t = - 11.37). In this case, the income elasticity of velocity is 0.632 (t = 5.74), implying an income elasticity of money demand of about 0.4. Thus, at least for Austria, the Bundesbank procedure for modelling long-run velocity appears suspect.

These anomalies sharply limit the simplicity and conceptual appeal of the P-star model. The equilibrium inflation rate associated with a given path of the money stock depends on the behavior of equilibrium velocity and on its sensitivity to money stock growth. Thus, for example, if equilibrium velocity declines at a 2.1 percent annual rate, the 1960-90 average for Austria's M3, and if potential output grows at 2.55 percent per year, the average annual rate in Austria from 1985 to 1990, then the simple quantity theory expression for equilibrium growth rates indicates that price stability requires an annual equilibrium rate of M3 growth of 4.65 percent [2.55 - (-2.1)]. On the other hand, the domestic cointegrating vector in equation 10 indicates that, in the absence of energy price shocks, such a pace of M3 growth would result in an equilibrium inflation rate of 1.37 percent ignoring the insignificant constant. To achieve zero inflation would require that M3 be held constant, according to this estimate. Thus, the simple P-star model yields money growth rate conclusions that differ sharply from those obtained from a closer look at the link between Austrian money growth and inflation.[8)]

The more serious difficulty is statistical; in particular, that the level of prices and of P-star in Germany may not be cointegrated. A simple regression of the logarithm of prices (lnPG) on the logarithm of P-star (lnPGS) using the German quarterly data for I/1971 to IV/1990 yields:

$$(16)\quad \ln PG_t = \underset{(0.75)}{0.566} + \underset{(57.57)}{0.987} \ln PGS_t + RPG$$

$$R^2 = 0.977 \qquad S.E. = 0.034 \qquad D.W. = 0.162$$

The augmented Dickey-Fuller test of the residual, RPG, uses the estimate:

$$(17)\quad \Delta RPG_t = \underset{(-2.51)}{-\,0.110}\, R_{t-1} + \underset{(3.12)}{0.343}\, \Delta R_{t-4}$$

$$R^2 = 0.14 \qquad S.E. = 0.013 \qquad D.W. = 1.95$$

Only the fourth lag of the dependent variable is statistically significant (for up to 8 lags). The t-statistic on the lagged level of the residual is too small in absolute value to reject the absence of cointegration. The critical value (5 percent) is

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8) The situation in Germany is equally sensitive. The elasticity of velocity with respect to potential output is - 0.632, nearly the same as in Austria, according to a regression of ln(M/P) on lnXP for the period I/1971 to III/1991. When LM3 is added to this equation, however, this elasticity switchs sign to 1.167 and the elasticity of velocity with respect to M3 is - 0.54 and statistically different from one. The income elasticity of velocity is not significantly different from one.
Thus, the Bundesbank (1992) model suggests that price stability can be achieved by setting M3 growth to accomodate a 2 percent growth rate of potential output and a trend rate of decline of velocity of about 1.2 percent. The latter is found from an elasticity of velocity with respect to potential output of - 0.6 and the assumed potential output growth rate. The three linkages involved in such an analysis of money growth are as easily rejected for Germany as they are for Austria.

3.17, according to Engle and Granger. Thus, it appears that the German measure of P-star may be flawed.[9)]

Are German and Austrian Prices Linked?

If the German equilibrium price measure is flawed, the evidence above is not relevant for the issue of whether actual Austrian and German prices are linked through a cointegrating relation. When the logarithm of actual German prices (lnPG) replaces the P-star measure in equation 14, it is strongly significant and the domestic Austrian variables lose their significance:

$$(18)\quad \ln P_t = \underset{(-0.49)}{-\,0.839} + \underset{(1.30)}{0.116}\ \ln M3_t - \underset{(0.06)}{0.010}\ \ln XP_t - \underset{(-1.80)}{0.064}\ \ln PE_t + \underset{(3.55)}{1.078}\ \ln PG_t$$

$$R^2 = 0.999 \qquad S.E. = 0.0107 \qquad D.W. = 0.91$$

Deleting potential output does not alter the statistical insignificance of M3 or energy prices; the t-statistics are 1.34 and - 2.04, respectively. When domestic money is also excluded, the resulting estimate is:

$$(19)\quad \ln P_t = \underset{(-26.13)}{-\,1.302} - \underset{(-7.96)}{0.104}\ \ln PE_t + \underset{(63.52)}{1.433}\ \ln PG_t$$

$$R^2 = 0.999 \qquad S.E. = 0.0106 \qquad D.W. = 0.93$$

Only the domestic energy price measure is significant and it's sign has reversed, suggesting that a rise in energy prices in Austria is typically associated with external oil price shocks that have a bigger effect on German prices that on Austrian

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9) The critical value (5 percent) is - 3.42 using the values provided by McKinnon; the cointegration hypothesis is rejected as well at a 10 percent level where the critical value is - 3.10. Both lnP and lnPGS are I(2), suggesting that the difficulty could be, like in Austria or the United States, that monetary aggregates and prices are only cointegrated in growth rates and not in levels. This is not investigated here, however.

prices. Nevertheless, cointegration is rejected for equation 19 because the Engle-Granger test of the stationarity of the residuals, with no significant lagged dependent variables, results in a coefficient for the lagged residual, - 0.483, that is not statistically significant (t = - 2.29); the critical value for this test is 3.17. Thus, the two measures are not cointegrated according to this test.

Finally, a check of whether the inflation rates are cointegrated was conducted adding ▲lnPG to equations 9 and 10 above. In each case, the domestic variables are not statistically significant unless only the growth rate of energy prices or the growth rate of M3 is included. When only the energy price term is included, its t-statistic is - 2.33 and the standard error of the estimate is 1.045 percent. The better fit results when only domestic M3 growth is included:

$$(20)\quad \Delta \ln P = \underset{(0.40)}{0.003} + \underset{(2.57)}{0.192}\ \Delta \ln M3_t + \underset{(5.67)}{0.726}\ \Delta \ln PG_t + RG1$$

$$R^2 = 0.739 \qquad S.E. = 0.010 \qquad D.W. = 1.89$$

The Engle-Granger test for this vector supports cointegration. In particular, the estimate is:

$$(21)\quad \Delta RG1_t = \underset{(-3.99)}{-\ 0.971}\ RG1_{t-1}$$

$$R^2 = 0.482 \qquad S.E. = 0.0098 \qquad D.W. = 2.00$$

No lagged dependent variables are statistically significant. The t-value is much larger in absolute value than the critical value of 3.17 so that the absence of cointegration is rejected. The coefficient on German inflation is also not significantly different from one in equation 20; the t-value for this test is 2.14 which is lower that the critical value of 2.17 (5 percent) with 16 degrees of freedom. Thus, the hypothesis that a one percentage point rise in German inflation raises Austrian inflation by a like amount is not rejected. Domestic M3 growth remains statistically significant in equation 21, indicating that monetary growth exhibits an independent role for Austrian inflation.

Consideration of the link between Austrian and German prices reinforces the results above and confirms the theoretical result that when exchange rates are pegged, there is a strong relationship between prices in the home country and in the country to which the currency is pegged. Nevertheless, two cointegrating vectors are found here, equations 10 and 20. To discriminate between them one can compare the fit of the error correction model. That for the cointegrating vector in equation 20 is:

$$(21)\quad \Delta^2 \ln P = \underset{(-0.90)}{-\ 0.002} \ \underset{(-3.68)}{-\ 0.955}\ RG_{t-1}$$

$$R^2 = 0.425 \qquad S.E. = 0.0104 \qquad D.W. = 2.02$$

The error correction term is again statistically significant and the fit of the equation is somewhat better than that of equation 11 according to the summary statistics. An alternative approach adds the residuals from each model to the alternative model. For the cointegrating vectors, the residuals from equations 10 and 20 have significant explanatory power for the other, so that this test, the Davidson-McKinnon J-test, does not discriminate between the models. The purpose of this paper is not to find the best model of inflation, however. Instead, it is to test whether a monetary-based measure of equilibrium prices explain Austrian prices, and, with some qualifications, they do.

IV. CONCLUSION

Recent attention to a new model of the link between money and prices, the P-star model, suggests that it might usefully be applied to Austria. This would hold out the possibility that

Austrian policymakers could directly target their own monetary aggregates to control their price level.

The estimation of the P-star model here rejects the P-star model for Austria. This rejection could arise because the velocity of M3 in Austria does not have the equilibrium properties required by the model. A variant of the P-star model in terms of an equilibrium inflation rate does have the required statistical properties, but this variant of the P-star model and the constraints implicit in the construction of its equilibrium inflation rate are also both rejected here.

Since the P-star model can be viewed as a constrained error correction model, the constraints are relaxed to determine whether an error correction approach using only the factors determining the equilibrium inflation rate would also be rejected. In this case, it is possible to find a statistically significant relationship between M3 growth and inflation in Austria. The results suggests that this relationship provides a nominal anchor for inflation and that this relationship is useful for forecasting movements in inflation. Unfortunately, the quantitative effect of M3 growth on inflation is too small relative to the theoretically expected effect.

The evidence suggests that movements in money growth have permanent effects on the demand for money, offsetting to a degree, the effects of money growth on nominal measures. The reason for this result is unknow, however.

The appropriate concept of the equilibrium price level is not obvious for a small open economy that attempts to fix its exchange rate. Indeed, the Austrian peg to the Deutsche Mark, especially since 1979, suggests that domestic monetary aggregates and other nominal magnitudes are endogeneously determined by German monetary policy. Thus, a monetary-based measure of German prices could be the relevant monetary anchor for Austria.

The evidence here suggests such a long-run equilibrium level of prices for Germany is subject to the same criticism as in Austria and the United States. In particular, other factors can influence the level of prices besides the money stock, in particular factors that influence potential output. Statistically, the best one can do is find long-run relationships for the growth rate of monetary aggregates of foreign prices and the rate of change of domestic prices. In Austria's case, there is a strong long-run link between Austrian and German inflation rates. Nevertheless, domestic monetary growth exerts an independent long-run influence on Austrian prices even in this case.

There are several practical implications of these results. They suggest that policymakers in Austria (and Germany) could usefully develop long-run equilibrium inflation measures that can be used to assess the inflation outlook and provide a signal for economic policy and that this measure is influenced by domestic monetary growth. Whether there is room, however, for the active use of monetary policy in Austria remains an open issue, however. In any case, the evidence here supports the view that inflation in Austria is a monetary phenomenon.

Figure 1

THE LEVEL OF ACTUAL AND EQUILIBRIUM PRICES IN AUSTRIA

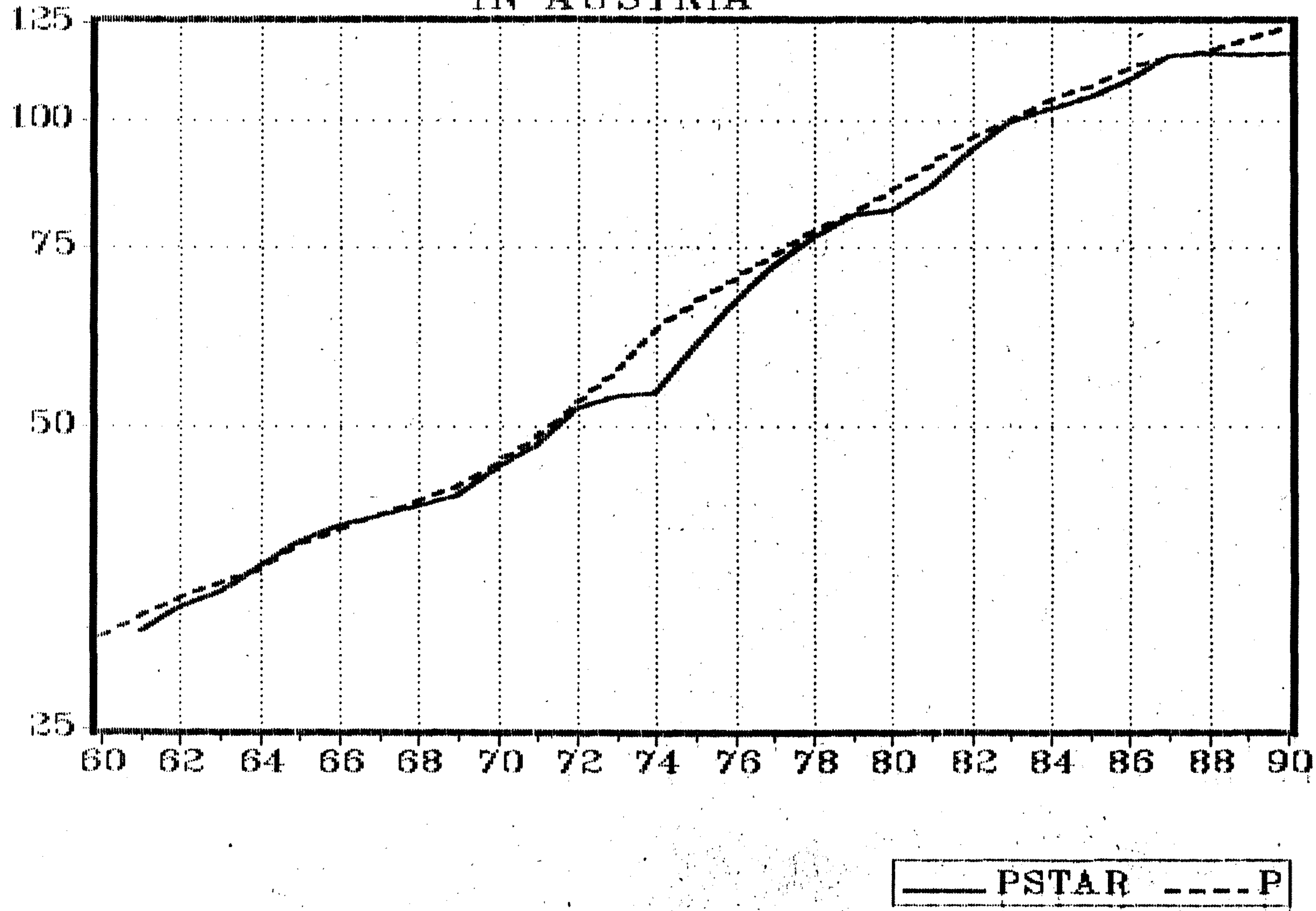
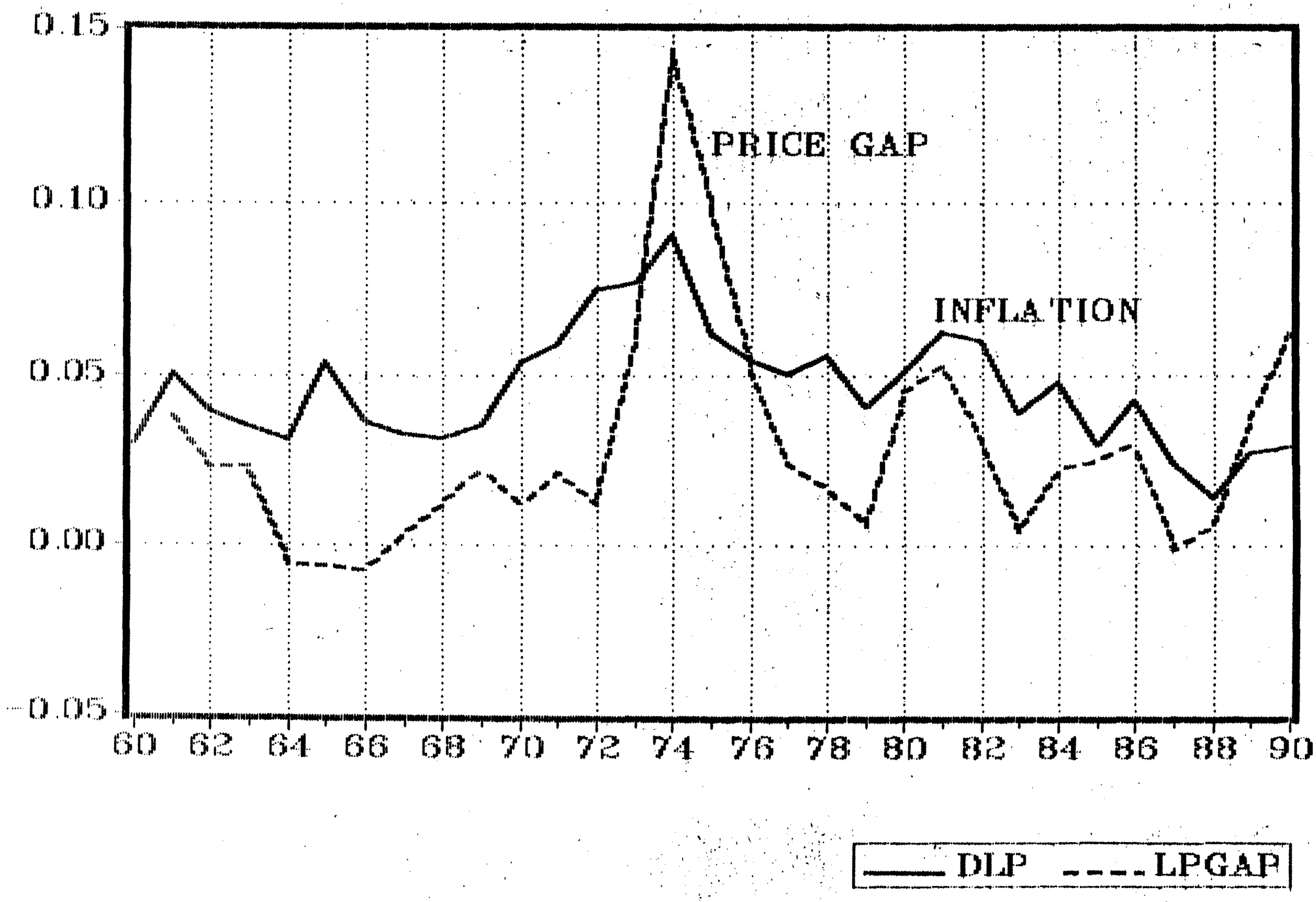


Figure 2

INFLATION AND THE PRICE GAP IN AUSTRIA



Unit Root Tests on the Components of P-Star

Model: $\Delta X = \beta_0 + \beta_1 X_{t-1} + d\ t + \sum_{i=1}^{n} \beta_{i+1} \Delta X_{t-i}$

Observations: 1960 - 90

X	β_1	d	n	R^2	S.E.	D.W.	χ^2(d.f.)
lnP	-0.005 (-1.01)	-	1	0.47	0.0126	2.22	(6) 4.91
lnM3	-0.010 (-1.96)	-	2	0.49	0.0210	1.59	(5) 7.28
lnV3	-0.455 (-2.92)	-0.009 (-2.72)	1	0.21	0.0250	1.66	(6) 3.75
lnXP	-0.033 (-4.79)*	-	0	0.42	0.0119	1.64	(7) 6.55
lnPSTAR	-0.012 (-0.99)	-	1	0.11	0.0278	1.79	(6) 5.05
ΔlnP	-0.302 (-2.26)	-	0	0.12	0.0126	2.16	(7) 4.38
ΔlnM3	-0.711 (-3.77)*	-0.0012 (-2.03)	1	0.30	0.0208	1.59	(6) 7.17
ΔlnV3	-1.103 (-4.48)*	-	1	0.44	0.0258	1.94	(6) 2.33
ΔlnXP	-0.898 (-5.30)*	-0.001 (-3.40)	0	0.47	0.0122	1.87	(7) 5.67
ΔlnPSTAR	-0.600 (-3.18)*	-	0	0.25	0.0278	1.77	(7) 5.14
Δ^2lnP	-1.250 (-6.83)*	-	0	0.61	0.0135	1,90	(7) 5.18

* Critical values, based on 25 observations and a 5 percent significance level, are - 3.00, without a time trend, and - 3.60 when the trend is included.

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