

A TEST OF PRICE SLUGGISHNESS IN THE SIMPLE RATIONAL EXPECTATIONS MODEL:

U.K. 1950-1980

G. Alogoskoufis and C. A. Pissarides

A recurrent feature of the empirical output and price equations derived from simple rational expectations models is that the effects of nominal shocks persist for a long period of time. In Barro's (1977*a*) unemployment equation, unanticipated monetary growth influences unemployment with lags of up to 2 years; in his price equation (Barro, 1981) unanticipated money has a lag of up to 5 years. In the price equation fitted to UK data by Attfield *et al.* (1981) real money balances influence prices with a one-year lag, and unanticipated monetary growth influences them with a 2-year lag.

Of course, the existence of lags is neither necessary nor sufficient for the negation of the neutrality proposition of rational expectations models. Lucas (1975), Sargent (1979) and Blinder and Fischer (1981) have provided rationales for the existence of lags in the supply equation, and demonstrated their consistency with the neutrality proposition. Similarly, the work of Attfield *et al.* (1981) has indicated that lagged adjustments in the demand for money are also consistent with neutrality. In both cases, the combination of lagged adjustments with perfectly flexible market-clearing prices yields all the neutrality propositions of the models of Lucas and others.

However, it is also the case that traditional Keynesian-type models with sluggish price adjustment imply lags in output and price equations. The final equations with Keynesian-type lags may look very similar to the equations derived by Lucas, Barro and others, but their implications about the effectiveness of policy may be very different. In the model with sluggish price adjustment supply is not equal to demand, so some other rule will have to be found to determine employment and output. Anticipated monetary policy may be able to influence real economic variables if the employment and output rules are not specifically designed to offset the effects of anticipated policy.¹

For this reason, a strong test of the neutrality proposition should be able to differentiate between different sources of lags, and be able to identify them empirically. If the test consists merely of a reduced form equation that identifies the lags, and a rationalisation of them that is consistent with the neutrality proposition, it can provide only weak evidence which may also be consistent

¹ See, for instance, the exchanges between Barro (1977*b*) and Fischer (1977*b*), and between Hahn (1980) and McCallum (1980). In the former, Barro makes the point that employment may be fixed by a contract at the point where demand equals supply, independently of price. In the latter, McCallum makes the point that even if output is demand-constrained, an anticipated shift in demand may simply change prices and leave output unchanged. A similar 'neutrality' result can be obtained from the price equation derived by Mussa (1981).

with non-neutrality.¹ But if the test can differentiate between different sources of lags, it may be possible to provide a stronger test for the neutrality proposition. For instance, a test that can differentiate between different sources of lags may show that there is no price sluggishness, in which case the conventional output equations where supply equals demand are vindicated. Alternatively, it may show that there is price sluggishness, in which case new output equations have to be derived from alternative rules and tested explicitly against market-clearing, or non-neutral 'disequilibrium' rules.

In this paper we propose a simple test which differentiates between two sources of lags. We derive and test a price equation similar to the one fitted to US data by Barro (1981), and to UK data by Attfield *et al.* (1981), but which can differentiate between (1) lags due to partial adjustments in the monetary sector, combined with continuous market clearing, and (2) lags due (in addition) to sluggish price adjustment. We accept all the lags introduced into the Lucas supply function, by Lucas (1975), Sargent (1979) and others, and we do not attempt to test for their validity.

Partial adjustment in the monetary sector was proposed by Attfield *et al.* (1981) as the reason for the existence of some of the lags detected with UK data. Sluggish price adjustment is shown in this paper to lead to an equation that is 'almost' equivalent to the one obtained with partial adjustment in the monetary sector, but with small differences which enable us to differentiate empirically between them. Because the differences are rather small, it is possible for an investigator to get a good statistical fit by assuming partial adjustment in the monetary sector, when the true reason for the lags is sluggish price adjustment (and vice versa). It is only when the propositions are tested explicitly against each other that we can hope to avoid making the error of accepting the wrong proposition.

We introduce partial adjustments in the rational expectations model in the conventional way of empirical models. First, we solve the model for its full equilibrium solution, with lags in the supply function only. Then we assume that the actual variable (in our case the demand for money or the price level) moves sluggishly towards its full equilibrium value. This way of introducing lags can only be justified as an approximation to an underlying process that cannot be modelled and tested precisely. It has a long history in empirical economics because of its tractability, though it is not entirely satisfactory in theory.

Section I derives the equations for the two adjustment mechanisms. Section II tests the model by applying it to annual UK data for the years 1950–80. Our results show that the hypothesis of partial adjustment in the monetary sector is easily rejected by the data. Sluggish price adjustment cannot be rejected. Our best estimate of the speed of price adjustment indicates that only 25 % of the gap between actual and market-clearing prices is closed during a year.

Our results favour the hypothesis of sluggish price adjustment against the alternative of continuous market clearing with lags in the monetary sector. We

¹ This point is related to the 'observational equivalence' problem, discussed by Sargent (1976). The same point was also made with some force by Gordon (1980), and it was hinted at by McCallum (1979).

do not proceed from here to test the neutrality proposition by fitting an output equation, which would require the specification of employment and output rules. But the results do indicate that care should be taken in the interpretation of empirical output equations whose derivation assumes, implicitly or explicitly, that prices clear all markets (like Lucas's derivation of the output supply function).¹

I. DERIVATION OF THE EQUATIONS

Equilibrium with lags in the supply function

Consider first the conventional model discussed in the literature, consisting of a money equation, an output equation, and continuous market clearing. In this version of the model we assume that the only lags are in the supply function. The model is

$$m_t - p_t = \alpha_0 + \alpha_1 y_t^d - \alpha_2 r_t + v_t, \quad (1)$$

$$y_t^s = \beta_0 + \beta_1 T_t + \beta_2 y_{t-1} + \sum_{i=0}^k \beta_{3i} \epsilon_{t-i} + u_t, \quad (2)$$

where ϵ_{t-i} are 'unanticipated' disturbances in the supply of money, defined by

$$\epsilon_{t-i} = m_{t-i} - E(m_{t-i} | I_{t-i-1}).$$

I_{t-i-1} includes all the information available at $t-i-1$, when expectations are formed. The other variables have conventional meaning, and they are all in logarithms except for r_t : m_t is the nominal money supply, p_t the price level, y_t the level of output, r_t the nominal interest rate, T_t a variable representing technological progress, and v_t , u_t are demand and supply disturbances. Super-scripts d and s denote, respectively, demand and supply.

Equation (1) describes equilibrium in the monetary sector, and it can be solved for aggregate demand. Fiscal variables influence aggregate demand through the nominal interest rate. Rather than derive a reduced form we keep the interest rate in the estimation and use its lagged value as the independent variable to avoid endogeneity bias. Equation (2) is a supply equation with a one-year lag on output and an unspecified number of lags on unanticipated money. The constant term includes any other variables influencing equilibrium output.

To derive a price equation we solve for equilibrium prices by equating the demand for, and supply of output, obtaining

$$p_t = -(\alpha_0 + \alpha_1 \beta_0) + m_t - \alpha_1 \sum_{i=0}^k \beta_{3i} \epsilon_{t-i} + \alpha_2 r_t - \alpha_1 \beta_1 T_t - \alpha_1 \beta_2 y_{t-1} - v_t - \alpha_1 u_t. \quad (3)$$

This is the conventional rational expectations price equation, with unit coefficient on the total supply of money, and negative coefficients on unanticipated

¹ We also did some preliminary tests for sluggishness with Barro's (1981) annual data for the United States. In contrast to the UK results we could not find evidence for sluggish price adjustment, and in most of the tests we could not find significant sluggishness in the monetary sector either. However, these conclusions should be treated as tentative.

money. It corresponds to the equation tested by Barro (1981) and others for the United States. Although Barro admitted some weaknesses in his estimation, the results were favourable overall. The coefficient on the total money supply was found to be insignificantly different from one, and unanticipated money had lags up to 5 years, with total coefficient $\alpha_1 \sum_{i=0}^5 \beta_{3i} = 6.63$.

Partial adjustment in the monetary sector

Suppose now that the demand for money does not adjust instantaneously to its long-run value. Evidence that adjustment is partial in the United Kingdom was found by Hendry and Mizon (1978), among others, using a broad monetary aggregate, like the one we use below. We now assume that equation (1) gives the 'long-run' demand for money, denoted by $m_t^0 - p_t^0$. The actual demand for money is consequently given by the partial adjustment equation

$$m_t - p_t = \mu(m_t^0 - p_t^0) + (1 - \mu)(m_{t-1} - p_{t-1}). \quad (4)$$

Adjustment is full if $\mu = 1$, and it never takes place if $\mu = 0$.

In order to derive the equation for the market-clearing price when (4) is valid we substitute from (1) into (4), to get a new money equation, and then equate output supply from (2) with output demand obtained from this new money equation. The resulting price equation is

$$p_t = -\mu(\alpha_0 + \alpha_1 \beta_0) + m_t - \mu \alpha_1 \sum_{i=0}^k \beta_{3i} \epsilon_{t-i} - \mu \alpha_1 \beta_1 T_t - \mu \alpha_1 \beta_2 y_{t-1} + \mu \alpha_2 r_t - (1 - \mu)(m_{t-1} - p_{t-1}) - \mu(v_t + \alpha_1 u_t). \quad (5)$$

Equation (5) has all the features of the previous price equation (3), except that it contains lagged real money balances as an independent variable. It is obviously more general than (3), because (3) can be obtained from (5) by imposing the restriction $\mu = 1$. Equation (5) corresponds to the price equation fitted to UK data by Attfield *et al.* (1981). Their OLS estimate of the coefficient on total money was insignificantly different from unity, they identified 3 lags on unanticipated money with $\mu \alpha_1 \sum_{i=0}^3 \beta_{2i} = 3.93$, and found $\mu = 0.43$. (Their maximum likelihood joint estimates were less favourable to the hypothesis underlying (5).)

Sluggish price adjustment

Sluggish price adjustment may be justified either by the existence of costs of changing prices in either labour or commodity markets, or by the existence of long-term (possibly overlapping) contracts, also in either market. Evidence for price sluggishness was presented by Gordon (1981), and others who fitted conventional Phillips curves to data, and theoretical reasons for rigid prices were explored by Barro (1972), Fischer (1977*a*), Phelps and Taylor (1977) and Gray (1978). For our purposes it suffices to assume

$$p_t = \lambda p_t' + (1 - \lambda) p_{t-1}, \quad (6)$$

where p_t' is the market-clearing level of prices. If there is partial adjustment in

the monetary sector p' is given by an equation like (5), but if there is not it is given by (3). Full price adjustment within the period occurs when $\lambda = 1$.

Equation (6) is an empirical approximation which is designed to capture any underlying influences that cause inertia in the movement of the aggregate price level. As such, it describes the movement of the aggregate price level, and not the behaviour of any particular agent in the economy. For this reason, the equilibrium price level in the right-hand side of (6) is the *actual* equilibrium price, and not the equilibrium price expected by agents. It is this feature of the equation which might make anticipated monetary policy effective as a stabilisation device in the short run (when $\lambda < 1$).¹

Equation (6) has the unsatisfactory property that if the equilibrium price level is rising the actual price level is always below the equilibrium level. For this reason we tested two alternative partial adjustment mechanisms, but without success. First, we assumed partial adjustment in the rate of inflation rather than the level of price. Instead of (6) we have

$$\dot{p}_t - \dot{p}_{t-1} = \lambda_1(\dot{p}'_t - \dot{p}'_{t-1}) + (1 - \lambda_1)(\dot{p}_{t-1} - \dot{p}_{t-2}).$$

This can be rearranged to give

$$p_t = \lambda_1 p'_t + 2(1 - \lambda_1)p_{t-1} - (1 - \lambda_1)p_{t-2}. \quad (6')$$

Empirically the main difference between (6) and (6') is that the latter includes a second lag in prices. This can be used to test (6') against (6).

Second, we experimented with the 'error correction' mechanism (Davidson *et al.* (1978))

$$p_t = \lambda p'_t + (1 - \lambda)p_{t-1} + \lambda_2(\dot{p}'_t - \dot{p}'_{t-1}). \quad (6'')$$

This can be tested against (6) by testing for the statistical significance of the change in equilibrium prices in the price equation.

Returning now to the partial adjustment mechanism (6) we derive a testable price equation by substituting market-clearing prices from (5) into (6). This gives a price equation with positive coefficient on total money equal to λ , and includes a lagged price variable with coefficient $1 - \lambda$. Since we can write these two variables as

$$\lambda m_t + (1 - \lambda)p_{t-1} = m_t - (1 - \lambda)(m_t - p_{t-1}),$$

it follows that the equation with sluggish price adjustment may be made to have a unit coefficient on total money. What distinguishes it from (5) is that it includes an extra term not in (5), $m_t - p_{t-1}$, which enters the equation with a negative coefficient. Writing out the new price equation in full we have

$$p_t = -\lambda\mu(\alpha_0 + \alpha_1\beta_0) + m_t - \lambda\mu\alpha_1 \sum_{i=0}^k \beta_{3i} \epsilon_{t-i} - \lambda\mu\alpha_1\beta_1 T_t - \lambda\mu\alpha_1\beta_2 y_{t-1} + \lambda\mu\alpha_2 r_t - \lambda(1 - \mu)(m_{t-1} - p_{t-1}) - (1 - \lambda)(m_t - p_{t-1}) - \lambda\mu(v_t + \alpha_1 u_t). \quad (7)$$

¹ In the models of Mussa (1981) and McCallum (1980) the movement of prices is governed by the *expected* equilibrium price, with unit coefficient. Anticipated monetary policy does not affect real variables in that case, because it is fully reflected in price movements. Buiter (1980, p. 42) works out a similar model with a price adjustment equation like (6), and demonstrates the effectiveness of anticipated monetary policy. In his model output is always equal to effective demand, which is consistent with (6) only if firms and workers come into contract to produce as much as is demanded regardless of the position of the profit-maximising supply curve. If output is determined instead by the short side of the market, (6) implies that the economy will be supply-constrained when equilibrium prices rise.

In this equation y_{t-1} is lagged *actual* output regardless of the magnitude of λ , because it is this variable that enters the supply function (2). But if $\lambda \neq 1$, output is no longer given by the equality between demand and supply; in general, in this case we cannot write an output equation, unless we also specify the rule determining output when demand is not equal to supply.

Equation (7) nests both (5) and (3), since (5) may be obtained by imposing the restriction $\lambda = 1$, and (3) by imposing the two restrictions $\lambda = \mu = 1$. Of interest, however, is the comparison between (5) and (7). If there is full adjustment in the monetary sector but sluggish price adjustment ($\mu = 1$, $\lambda < 1$), the term $m_{t-1} - p_{t-1}$ drops out of equation (7) but we are still left with $m_t - p_{t-1}$. Because the money supply is highly trended there is likely to be a high correlation between $m_{t-1} - p_{t-1}$ and $m_t - p_{t-1}$.¹ Hence, inclusion of either $m_{t-1} - p_{t-1}$ or $m_t - p_{t-1}$ in the right-hand side of the price equation is likely to give 'a good fit' if there is either partial adjustment in the monetary sector, or sluggish price adjustment. It will not be able to tell us if the maintained hypothesis is wrong. The only way to differentiate between these two hypotheses is to try and identify the coefficients of both $m_{t-1} - p_{t-1}$ and $m_t - p_{t-1}$, not test for the significance of either variable in isolation.

If we use (6') instead of (6) the final price equation includes p_{t-2} in the right-hand side, with the restriction that the coefficient of p_{t-2} be equal to half the coefficient of p_{t-1} , and of opposite sign. If we use (6'') the final price equation includes also the change in equilibrium prices, i.e. the change in all the independent variables other than lagged prices.

The remainder of this paper is devoted to a test of these partial adjustment mechanisms.

II. EMPIRICAL RESULTS

Before fitting the price equation we need to derive a series for unanticipated money, e_t . We do this by fitting a money equation in the tradition of Barro's (1977*a*) pioneering article. The various price equations that we have derived can be estimated directly, either singly by ordinary least-squares, or jointly with the money supply equation by maximum likelihood techniques. We report below both single-equation and joint estimates, starting with the former.

The money equation: OLS results

Our purpose is to derive measures of unanticipated money, so only variables in the agents' information set should be included in the right-hand side of the equation. For this reason we included only lagged variables, assuming the existence of a one-year information lag. Our preferred equation is

$$\begin{aligned} \Delta m_t = & -0.029 + 0.49\Delta m_{t-1} + 0.73\Delta(y_{t-1} + p_{t-1}) + 1.22(b_{t-1} - m_{t-1}) \\ & (0.018) (0.15) \quad (0.24) \quad (0.36) \\ & - 0.55\Delta(b_{t-1} - m_{t-1}) \\ & (0.29) \end{aligned}$$

$$R^2 = 0.71, \text{ s.e.} = 0.036, \quad h = 1.14, \quad \text{sample } 1950-80.$$

¹ Over our sample period the simple correlation coefficient was 0.968.

We have used the broad definition of money (£M₃). Δ is the first-difference operator, and b is the current account of the balance of payments.¹

The equation fits the data well, and shows some persistence and some accommodation of the rate of growth of the money supply to the rate of growth of nominal GNP. This is consistent with the widely held view that the money supply in the United Kingdom has been accommodating during this period. The balance of payments also exerts a significant influence on the money supply process, with a surplus leading to an expansion in the money supply. We could not identify a significant influence from the budget deficit (PSBR in British terminology) to the money supply, in contrast to Attfield *et al.* (1981). However, they used unlagged real PSBR as an independent variable, which we excluded by the assumption of the existence of an informational lag (which would be present in this case in particular, because of the endogeneity of real PSBR). Including real PSBR in our equation, lagged one year, gave a t -ratio of -0.49 . Various other variables that we tried also proved insignificant, so we dropped them from the final equation. These include a time trend and additional lags of the included variables, as well as the level of nominal income.

The regression is free of autocorrelation, a property which is important for an equation meant to provide 'rational' forecasts. Durbin's h statistic for first-order autocorrelation is below its 95% critical value (1.96), and the residual correlogram did not hint at possible higher-order autocorrelation.

As a further test of the money equation, we split the sample in 1971 and tested for the constancy of the coefficients of the equation before and after the split. We chose 1971 because of the change in the exchange rate regime, and the changes in banking policy associated with competition and credit control. The calculated F statistic for the hypothesis that there was a break in the equation, with (5, 21) degrees of freedom, is 2.37, which is below its 95% critical value of 2.68. We therefore adopted the estimated money equation as a satisfactory forecasting equation, and we used the fitted residuals, denoted $\hat{\epsilon}$, as the series for unanticipated money.

The price equation: OLS results

The results from fitting the price equation are given in Table 1. Column (1) reports the results from fitting the unrestricted equation (7), except that we drop $m_t - p_{t-1}$ and write instead m_t and p_{t-1} as two unrestricted variables. In these circumstances the model suggests that the coefficient on m_t should be λ_t and on p_{t-1} it should be $1 - \lambda$. Since there is likely to be some multicollinearity present, the estimates of the coefficients are probably not precise. They are reported here for comparison with the coefficients obtained when the various constraints are imposed.

We included 2 lags of unanticipated money, though the second lag was not significant at conventional levels. Higher order lags were also insignificant. The lagged interest rate is used in place of the current rate with some success. We could not identify any variables which might enter through their influence on the

¹ A list of all the variables and their source is given in the Data Appendix.

Table 1
Price equations for the United Kingdom, 1953-80

Independent variables	Restriction		
	Unrestricted (1)	$\lambda = 1$ (2)	$\mu = 1$ (3)
m_t	0.12 (0.13)	0.91 (0.048)	0.21 (0.035)
p_{t-1}	0.87 (0.14)		0.78 (0.048)
$m_{t-1} - p_{t-1}$	0.11 (0.16)	-0.82 (0.093)	
\hat{e}_t	-0.19 (0.19)	-0.98 (0.25)	-0.28 (0.14)
\hat{e}_{t-1}	-0.54 (0.19)	-0.98 (0.29)	-0.58 (0.18)
\hat{e}_{t-2}	-0.13 (0.15)	-0.28 (0.25)	-0.13 (0.15)
r_{t-1}	0.64 (0.36)	1.44 (0.57)	0.73 (0.34)
Trend $\times 10^{-4}$	0.50 (26.83)	15.87 (44.86)	0.25 (26.51)
Constant	-2.43 (0.50)	-1.12 (0.77)	-2.18 (0.36)
R^2	0.999	0.997	0.999
S.E.	0.021	0.035	0.020
h	1.44	2.64	0.86

Notes: (1) Dependent variable p_t . For precise definitions of the variables see the Appendix. (2) All variables are in logarithms except for the interest rate and the time trend.

equilibrium rate of output. Both the time trend and lagged output were insignificant. This is probably due to correlations that exist between the independent variables and the time trend and lagged output. We omitted lagged output from the regression but left the time trend in.

It is clear from the results of this regression that there are significant lags either in the adjustment of prices or in the demand for money, or in both. Imposing the restriction that there are no lags in either (i.e. omitting lagged prices and the lagged real money supply) raises the standard error of the regression significantly. The calculated F statistic, with (2, 20) degrees of freedom, is 131.27.

Column (2) reports results under the assumption that the lags are due to partial adjustments in the demand for money, but imposes the restriction of no sluggish price adjustment. It corresponds to the equation fitted to UK data by Attfield *et al.* (1981), and on the face of it gives a 'good fit'. The coefficient on money is insignificantly different from unity (but only just), and unanticipated money influences prices with negative coefficient. The interest rate is significant, and the estimate of μ is 0.18.

However, comparison with column (1) reveals that the restriction $\lambda = 1$, which is imposed by the estimate in column (2), cannot be accepted by the data. This restriction amounts to omitting the lagged price level from the right-hand

side of the equation. In column (1) this variable has a t -ratio of 6.26, which exceeds its critical value at both the 5 and 1 % levels of significance. In addition, the equation reported in column (2) cannot reject first-order serial correlation, so there may be dynamic mis-specifications present.

Closer inspection of the estimate in column (2) reveals two further problems. First, the estimate of μ is very low, and it is not significantly different from zero. The point estimate suggests that it takes 12 years for actual money holdings to move within 10 % of the desired demand for money. Second, the long-run interest elasticity of the demand for money at the sample mean of the interest rate ($\bar{r} = 0.0645$) is $-1.44\bar{r}/\mu = -0.52$, which is much higher than the elasticity estimated by any other study.

Column (3) relaxes the restriction $\lambda = 1$, but imposes the restriction $\mu = 1$, i.e. it assumes that there is sluggish price adjustment, but the demand for money adjusts fully within a year. The data satisfy this restriction since the omitted variable, lagged real money balances, has a t -ratio of less than unity. The calculated value of Durbin's h statistic when this variable is omitted rejects first-order serial correlation. In addition this equation obviously satisfies the constraint that the sum of the coefficients of money and lagged prices should equal unity. Imposing this constraint and calculating a t -statistic for it gives $t = 0.37$. The final equation with the constraint imposed is

$$\begin{aligned} p_t - p_{t-1} = & -2.15 + 0.21(m_t - p_{t-1}) - 0.26\hat{\epsilon}_t - 0.54\hat{\epsilon}_{t-1} - 0.097\hat{\epsilon}_{t-2} \\ & (0.35) (0.034) \quad (0.13) \quad (0.14) \quad (0.12) \\ & + 0.74r_{t-1} - 0.00077 \text{ Trend} \\ & (0.33) \quad (0.0015) \end{aligned}$$

$$R^2 = 0.895, \quad \text{s.e.} = 0.020, \quad h = 0.75.$$

This is our preferred OLS equation. It implies that adjustment to the desired value of the demand for money is completed within a year, but only 21 % of the gap between the equilibrium and actual price level is closed within the year. Alternatively, it takes the price level about 10 years to move within 10 % of its equilibrium value, following a once and for all change in the latter.

The total elasticity by which unanticipated changes in money influence prices is

$$\alpha_1 \sum_{i=0}^2 \beta_{3i} = -0.897.$$

The individual effects exhibit the familiar 'triangular' shape, with the first lag having the strongest influence. If the income elasticity of the demand for money (α_1) is close to unity, unanticipated changes in money influence the supply of output by an elasticity of the same order of magnitude.

The estimated price equation also implies a reasonable estimate of the interest elasticity of the demand for money. At the sample mean of the interest rate, $\bar{r} = 0.0645$, the elasticity is $-0.74\bar{r}/\lambda = -0.23$. This is consistent with Hendry and Mizon's (1978, p. 561) estimate (also at sample means) of -0.2 .

Joint estimation of the money and price equations

The OLS estimates which we reported, though consistent, are not efficient because they ignore the cross-equation restrictions, and any error covariances, which are implied by the model. Unfortunately we cannot re-estimate the model taking into account all the cross-equation restrictions, because when there is sluggish price adjustment the output equation is not observable. So we cannot re-estimate the model by full-information maximum-likelihood to check whether unanticipated changes in money influence prices via the supply function, and not directly. However, we can still estimate jointly the two equations which are observable, the money rule equation and the price equation. The joint estimates are more efficient than the OLS estimates, and they enable a test of the hypothesis that the variables in the money equation influence prices only through the money supply, and not directly.

The joint estimates of the two equations, with the cross-equation restrictions imposed, are as follows:

$$\begin{aligned} \Delta m_t = & -0.005 + 0.55\Delta m_{t-1} + 0.45\Delta(y_{t-1} + p_{t-1}) + 1.00(b_{t-1} - m_{t-1}) \\ & (0.018) \quad (0.13) \quad (0.15) \quad (0.21) \\ & - 0.36\Delta(b_{t-1} - m_{t-1}) + \hat{\epsilon}_t \\ & (0.30) \end{aligned}$$

$$\text{s.e.} = 0.039, \quad h = 0.66.$$

$$\begin{aligned} p_t - p_{t-1} = & -2.60 + 0.25(m_t - p_{t-1}) - 0.35\hat{\epsilon}_t - 0.69\hat{\epsilon}_{t-1} - 0.24\hat{\epsilon}_{t-2} \\ & (0.37) \quad (0.036) \quad (0.15) \quad (0.19) \quad (0.16) \\ & + 0.66r_{t-1} - 0.00026 \text{ Trend} + \hat{\eta}_t \\ & (0.45) \quad (0.0020) \end{aligned}$$

$$\text{s.e.} = 0.018, \quad h = 1.21.$$

The cross-equation restrictions imposed by the model are satisfied at the 95 % level of significance. The likelihood ratio test for the nine restrictions implied by the three unanticipated money terms in the price equation, distributed as χ^2 , is 8.65. The critical value at the 95 % level is 16.92, so the restrictions cannot be rejected.

The joint estimates are similar to the OLS estimates, but with some differences. In the money equation there is now more persistence and less accommodation to changes in nominal GNP. In the price equation, unanticipated changes in money now have a greater effect, with total coefficient 1.28. The triangular shape of the coefficients' pattern is still present. The interest rate has a slightly smaller effect, with implied interest elasticity of the demand for money at sample means -0.17 . Finally, the estimates imply a slightly faster adjustment of prices towards equilibrium, with a quarter of the gap between actual and equilibrium prices closing every year. The faster adjustment implies that it takes the price level about 8 years to move within 10 % of its equilibrium level, following a once-for-all change, instead of the OLS estimate of 10 years.

Some further tests

As a further check on the specification of the price equation when there is sluggish price adjustment we tried two alternative, and more general, adjustment mechanisms. First, partial adjustment of the inflation rate. This, as we argued in the last section, amounts to adding a second lag of the price level as explanatory variable, with constrained coefficient equal to minus one-half the coefficient of the first lag. Introducing first the second lag without the constraint in the OLS equation we obtain a coefficient of -0.18 , with standard error 0.17 . Imposing the constraint that minus this coefficient be equal to one-half the coefficient of the first lag on price raises the residual sum of squares significantly, with a calculated F value (with 1,20 degrees of freedom) of 17.62 . Thus the partial adjustment mechanism on the level of prices cannot be rejected for a partial adjustment mechanism on the rate of inflation.

Second, we generalised the adjustment mechanism to 'error correction', which amounts to introducing the first difference of the equilibrium level of prices as an additional explanatory variable. Since the equilibrium level of prices is a linear function of the supply of money, unanticipated money, lagged output, and the lagged rate of interest, this leads to the introduction of the first difference of these variables in the equation. But because the number of lags on unanticipated money in the supply equation is unspecified, we cannot test the error correction mechanism by introducing extra lags of this variable. So we test by introducing the first difference of the two variables: supply of money and lagged interest rate.

Introducing the first difference of these variables in the price equation gives insignificant estimates for each coefficient. A joint test of the zero restrictions on the two coefficients (implied by our partial adjustment mechanism) cannot be rejected, with a calculated F (2,19) value of 0.02 . Thus the partial adjustment mechanism on the level of prices is again a more satisfactory specification.

It may, of course, still be objected that what we have estimated is not a partial adjustment equation for prices, but a more elaborate adjustment mechanism in the monetary sector. In other words the reduced form that we have estimated may be consistent with a short-run demand for money which is different from the one that we have assumed, and with continuous market-clearing. But if this is the case then we should be able to derive the implicit demand for money directly from the estimated equation. Using the estimate in the jointly estimated price equation, we derive the real demand for money consistent with continuous market-clearing as

$$m_t - p_t = 10.4 + 3.00(p_t - p_{t-1}) - 2.64r_{t-1} + 1.40\hat{e}_t + 2.76\hat{e}_{t-1} + 0.96\hat{e}_{t-2} + 0.001 \text{ Trend.}$$

The terms following r_{t-1} stand for the level of income, so this demand for money function depends negatively on interest rates and positively on income. But to be consistent with continuous market-clearing it must also depend positively on the rate of inflation, with elasticity equal to 3. No theory of the short-run demand for money predicts such an over-reaction of real money balances to prices. Empirical

studies of the demand for money which used the contemporaneous inflation rate as a proxy for expected inflation found a negative (or zero) elasticity, not a positive one (Hendry and Mizon (1978), p. 560). Thus our estimate of the price equation cannot be rationalised by appealing to a different short-run demand for money function. Sluggish price adjustment appears to be the only plausible rationalisation of this estimate.

III. CONCLUSIONS

We argued that the observed lagged response of prices and output to changes in nominal variables may or may not be consistent with the neutrality propositions of the rational expectations model. Whether it is consistent or not depends on the source of the observed lags and on the rules used to determine output. If the lags originate in the supply or demand equations, but at each point in time prices equilibrate supply and demand, the neutrality propositions hold. But if there are also lags because of partial adjustment in prices neutrality may not hold. Empirically we demonstrated that the reduced form equations for prices look very similar when the lags originate in either the demand function or sluggish price adjustment. Thus identifying the lag only, and not trying to differentiate between its sources, is not likely to tell us which is the true underlying model.

The main empirical section of the paper was devoted to an attempt to differentiate between the lags due to partial adjustment in the demand for money, and the lags due to partial adjustment in the level of prices. Using annual data for the United Kingdom for the period 1950–80 we found that there was no evidence of partial adjustments in the demand for money, but there was evidence of partial adjustment in the price level. The best adjustment mechanism we could identify for prices was the traditional one which assumes that in each period only a fraction of the gap between actual and equilibrium prices is closed. This fraction was estimated to be about one quarter. Two alternative adjustment mechanisms that we tried, partial adjustment of the rate of inflation and an error correction mechanism, were found to be less satisfactory descriptions of the data.

If our estimate is correct, anticipated monetary policy may have a significant stabilisation role to play in the short-run. Although in the supply function that we have used only unanticipated monetary policy influences output, our estimates imply that the price level is not always at the point where the demand for output is equal to its supply. It takes several years for actual prices to move close to equilibrium prices following a once and for all change in the latter. During this time output must be given by some rule other than equality between supply and demand. Unless this rule is specifically designed to offset the effects of anticipated changes in monetary policy, monetary policy can speed up the adjustment of the economy towards equilibrium, even if it follows a pre-announced accommodating rule.

London School of Economics

Date of receipt of final typescript: November 1982

DATA APPENDIX

y is GDP at factor cost at 1975 prices. Source: *Economic Trends, Annual Supplement* (1982).

m is sterling M_3 from Attfield *et al.* (1981). Extended from the *Bank of England Quarterly Bulletin*, to 1980.

p is GDP deflator 1975 = 100, from *Economic Trends, Annual Supplement* (1982).

r is the treasury bill rate from *Bank of England Quarterly Bulletin*, various issues.

b is the Current Balance, from *Economic Trends, Annual Supplement* (1982).

All variables in the regression are in logs, except for $(b - m)$, which is the ratio of the current balance to the money supply, and r which is the actual interest rate.

REFERENCES

- Attfield, C. L. F., Demery, D. and Duck, N. W. (1981). 'Unanticipated monetary growth, output and the price level: U.K. 1946-1977.' *European Economic Review*, vol. 16, pp. 367-85.
- Barro, R. J. (1972). 'A theory of monopolistic price adjustment.' *Review of Economic Studies*, vol. 39, pp. 17-26.
- (1977a). 'Unanticipated money growth and unemployment in the United States.' *American Economic Review*, vol. 67, pp. 101-15.
- (1977b). 'Long-term contracting, sticky prices, and monetary policy.' *Journal of Monetary Economics*, vol. 3, pp. 305-16.
- (1981). 'Unanticipated money growth and economic activity in the United States.' Ch. 5 in *Money, Expectations and Business Cycles*. New York: Academic Press.
- Blinder, A. and Fischer, S. (1981). 'Inventories, rational expectations and the business cycle.' *Journal of Monetary Economics*, vol. 8, pp. 277-304.
- Buiter, W. H. (1980). 'The macroeconomics of Dr. Pangloss: a critical survey of the New Classical Macroeconomics.' *ECONOMIC JOURNAL*, vol. 90, pp. 34-50.
- Davidson, J. E. H., Hendry, D. F., Srba, F. and Yeo, S. (1978). 'Econometric modelling of the aggregate time-series relationship between consumers' expenditure and income in the United Kingdom.' *ECONOMIC JOURNAL*, vol. 88, pp. 661-92.
- Fischer, S. (1977a). 'Long term contracts, rational expectations and the optimal money supply rule.' *Journal of Political Economy*, vol. 85, pp. 191-205.
- (1977b). 'Long-term contracting, sticky prices, and monetary policy: a comment.' *Journal of Monetary Economics*, vol. 3, pp. 317-24.
- Gray, J. (1978). 'On indexation and contract length.' *Journal of Political Economy*, vol. 86, pp. 1-18.
- Gordon, R. J. (1980). 'Comment' in S. Fischer (ed.), *Rational Expectations and Economic Policy*. Chicago: University of Chicago Press.
- (1981). 'Output fluctuations and gradual price adjustment.' *Journal of Economic Literature*, vol. 19, pp. 493-530.
- Hahn, F. H. (1980). 'Unemployment from a theoretical viewpoint.' *Economica*, vol. 47, pp. 285-98.
- Hendry, D. F. and Mizon, G. E. (1978). 'Serial correlation as a convenient simplification, not a nuisance: a comment on a study of the demand for money by the Bank of England.' *ECONOMIC JOURNAL*, vol. 88, pp. 549-63.
- Lucas, R. E. (1975). 'An equilibrium model of the business cycle.' *Journal of Political Economy*, vol. 83, pp. 1113-44.
- McCallum, B. (1979). 'The current state of the policy-ineffectiveness debate.' *American Economic Review*, vol. 69, pp. 240-5.
- (1980). 'Hahn's theoretical viewpoint on unemployment: a comment.' *Economica*, vol. 47, pp. 299-303.
- Mussa, M. (1981). 'Sticky prices and disequilibrium adjustment in a rational model of the inflationary process.' *American Economic Review*, vol. 71, pp. 1020-7.
- Phelps, E. S. and Taylor, J. (1977). 'Stabilizing powers of monetary policy under rational expectations.' *Journal of Political Economy*, vol. 85, pp. 163-90.
- Sargent, T. J. (1976). 'The observational equivalence of natural and unnatural rate theories in macroeconomics.' *Journal of Political Economy*, vol. 84, pp. 631-40.
- (1979). *Macroeconomic Theory*. New York: Academic Press.

LINKED CITATIONS

- Page 1 of 5 -



You have printed the following article:

A Test of Price Sluggishness in the Simple Rational Expectations Model: U.K. 1950-1980

G. Alogoskoufis; C. A. Pissarides

The Economic Journal, Vol. 93, No. 371. (Sep., 1983), pp. 616-628.

Stable URL:

<http://links.jstor.org/sici?sici=0013-0133%28198309%2993%3A371%3C616%3AATOPSI%3E2.0.CO%3B2-U>

This article references the following linked citations. If you are trying to access articles from an off-campus location, you may be required to first logon via your library web site to access JSTOR. Please visit your library's website or contact a librarian to learn about options for remote access to JSTOR.

[Footnotes]

¹ **Unemployment from a Theoretical Viewpoint**

F. H. Hahn

Economica, New Series, Vol. 47, No. 187, Special Issue on Unemployment. (Aug., 1980), pp. 285-298.

Stable URL:

<http://links.jstor.org/sici?sici=0013-0427%28198008%292%3A47%3A187%3C285%3AUFATV%3E2.0.CO%3B2-5>

¹ **Hahn's Theoretical Viewpoint on Unemployment: A Comment**

Bennett T. McCallum

Economica, New Series, Vol. 47, No. 187, Special Issue on Unemployment. (Aug., 1980), pp. 299-303.

Stable URL:

<http://links.jstor.org/sici?sici=0013-0427%28198008%292%3A47%3A187%3C299%3AHTVOUA%3E2.0.CO%3B2-P>

¹ **Sticky Prices and Disequilibrium Adjustment in a Rational Model of the Inflationary Process**

Michael Mussa

The American Economic Review, Vol. 71, No. 5. (Dec., 1981), pp. 1020-1027.

Stable URL:

<http://links.jstor.org/sici?sici=0002-8282%28198112%2971%3A5%3C1020%3ASPADAI%3E2.0.CO%3B2-1>

NOTE: *The reference numbering from the original has been maintained in this citation list.*

LINKED CITATIONS

- Page 2 of 5 -



¹ **The Observational Equivalence of Natural and Unnatural Rate Theories of Macroeconomics**

Thomas J. Sargent

The Journal of Political Economy, Vol. 84, No. 3. (Jun., 1976), pp. 631-640.

Stable URL:

<http://links.jstor.org/sici?sici=0022-3808%28197606%2984%3A3%3C631%3ATOEONA%3E2.0.CO%3B2-8>

¹ **The Current State of the Policy-Ineffectiveness Debate**

Bennett T. McCallum

The American Economic Review, Vol. 69, No. 2, Papers and Proceedings of the Ninety-First Annual Meeting of the American Economic Association. (May, 1979), pp. 240-245.

Stable URL:

<http://links.jstor.org/sici?sici=0002-8282%28197905%2969%3A2%3C240%3ATCSOTP%3E2.0.CO%3B2-Q>

¹ **Sticky Prices and Disequilibrium Adjustment in a Rational Model of the Inflationary Process**

Michael Mussa

The American Economic Review, Vol. 71, No. 5. (Dec., 1981), pp. 1020-1027.

Stable URL:

<http://links.jstor.org/sici?sici=0002-8282%28198112%2971%3A5%3C1020%3ASPADAI%3E2.0.CO%3B2-1>

¹ **Hahn's Theoretical Viewpoint on Unemployment: A Comment**

Bennett T. McCallum

Economica, New Series, Vol. 47, No. 187, Special Issue on Unemployment. (Aug., 1980), pp. 299-303.

Stable URL:

<http://links.jstor.org/sici?sici=0013-0427%28198008%292%3A47%3A187%3C299%3AHTVOUA%3E2.0.CO%3B2-P>

¹ **The Macroeconomics of DR Pangloss A Critical Survey of the New Classical Macroeconomics**

Willem H. Buiter

The Economic Journal, Vol. 90, No. 357. (Mar., 1980), pp. 34-50.

Stable URL:

<http://links.jstor.org/sici?sici=0013-0133%28198003%2990%3A357%3C34%3ATMODPA%3E2.0.CO%3B2-U>

References

NOTE: *The reference numbering from the original has been maintained in this citation list.*

LINKED CITATIONS

- Page 3 of 5 -



A Theory of Monopolistic Price Adjustment

Robert J. Barro

The Review of Economic Studies, Vol. 39, No. 1. (Jan., 1972), pp. 17-26.

Stable URL:

<http://links.jstor.org/sici?sici=0034-6527%28197201%2939%3A1%3C17%3AATOMPA%3E2.0.CO%3B2-J>

Unanticipated Money Growth and Unemployment in the United States

Robert J. Barro

The American Economic Review, Vol. 67, No. 2. (Mar., 1977), pp. 101-115.

Stable URL:

<http://links.jstor.org/sici?sici=0002-8282%28197703%2967%3A2%3C101%3AUMGAUI%3E2.0.CO%3B2-L>

The Macroeconomics of DR Pangloss A Critical Survey of the New Classical Macroeconomics

Willem H. Buiter

The Economic Journal, Vol. 90, No. 357. (Mar., 1980), pp. 34-50.

Stable URL:

<http://links.jstor.org/sici?sici=0013-0133%28198003%2990%3A357%3C34%3ATMODPA%3E2.0.CO%3B2-U>

Econometric Modelling of the Aggregate Time-Series Relationship Between Consumers' Expenditure and Income in the United Kingdom

James E. H. Davidson; David F. Hendry; Frank Srba; Stephen Yeo

The Economic Journal, Vol. 88, No. 352. (Dec., 1978), pp. 661-692.

Stable URL:

<http://links.jstor.org/sici?sici=0013-0133%28197812%2988%3A352%3C661%3AEMOTAT%3E2.0.CO%3B2-J>

Long-Term Contracts, Rational Expectations, and the Optimal Money Supply Rule

Stanley Fischer

The Journal of Political Economy, Vol. 85, No. 1. (Feb., 1977), pp. 191-205.

Stable URL:

<http://links.jstor.org/sici?sici=0022-3808%28197702%2985%3A1%3C191%3ALCREAT%3E2.0.CO%3B2-M>

On Indexation and Contract Length

Jo Anna Gray

The Journal of Political Economy, Vol. 86, No. 1. (Feb., 1978), pp. 1-18.

Stable URL:

<http://links.jstor.org/sici?sici=0022-3808%28197802%2986%3A1%3C1%3AIOIACL%3E2.0.CO%3B2-T>

NOTE: *The reference numbering from the original has been maintained in this citation list.*

LINKED CITATIONS

- Page 4 of 5 -



Output Fluctuations and Gradual Price Adjustment

Robert J. Gordon

Journal of Economic Literature, Vol. 19, No. 2. (Jun., 1981), pp. 493-530.

Stable URL:

<http://links.jstor.org/sici?sici=0022-0515%28198106%2919%3A2%3C493%3AOFAGPA%3E2.0.CO%3B2-H>

Unemployment from a Theoretical Viewpoint

F. H. Hahn

Economica, New Series, Vol. 47, No. 187, Special Issue on Unemployment. (Aug., 1980), pp. 285-298.

Stable URL:

<http://links.jstor.org/sici?sici=0013-0427%28198008%292%3A47%3A187%3C285%3AUFATV%3E2.0.CO%3B2-5>

Serial Correlation as a Convenient Simplification, Not a Nuisance: A Comment on a Study of the Demand for Money by the Bank of England

David F. Hendry; Grayham E. Mizon

The Economic Journal, Vol. 88, No. 351. (Sep., 1978), pp. 549-563.

Stable URL:

<http://links.jstor.org/sici?sici=0013-0133%28197809%2988%3A351%3C549%3ASCAACS%3E2.0.CO%3B2-D>

An Equilibrium Model of the Business Cycle

Robert E. Lucas, Jr.

The Journal of Political Economy, Vol. 83, No. 6. (Dec., 1975), pp. 1113-1144.

Stable URL:

<http://links.jstor.org/sici?sici=0022-3808%28197512%2983%3A6%3C1113%3AAEMOTB%3E2.0.CO%3B2-5>

The Current State of the Policy-Ineffectiveness Debate

Bennett T. McCallum

The American Economic Review, Vol. 69, No. 2, Papers and Proceedings of the Ninety-First Annual Meeting of the American Economic Association. (May, 1979), pp. 240-245.

Stable URL:

<http://links.jstor.org/sici?sici=0002-8282%28197905%2969%3A2%3C240%3ATCSOTP%3E2.0.CO%3B2-Q>

LINKED CITATIONS

- Page 5 of 5 -



Hahn's Theoretical Viewpoint on Unemployment: A Comment

Bennett T. McCallum

Economica, New Series, Vol. 47, No. 187, Special Issue on Unemployment. (Aug., 1980), pp. 299-303.

Stable URL:

<http://links.jstor.org/sici?sici=0013-0427%28198008%292%3A47%3A187%3C299%3AHTVOUA%3E2.0.CO%3B2-P>

Sticky Prices and Disequilibrium Adjustment in a Rational Model of the Inflationary Process

Michael Mussa

The American Economic Review, Vol. 71, No. 5. (Dec., 1981), pp. 1020-1027.

Stable URL:

<http://links.jstor.org/sici?sici=0002-8282%28198112%2971%3A5%3C1020%3ASPADAI%3E2.0.CO%3B2-1>

Stabilizing Powers of Monetary Policy under Rational Expectations

Edmund S. Phelps; John B. Taylor

The Journal of Political Economy, Vol. 85, No. 1. (Feb., 1977), pp. 163-190.

Stable URL:

<http://links.jstor.org/sici?sici=0022-3808%28197702%2985%3A1%3C163%3ASPOMPU%3E2.0.CO%3B2-I>

The Observational Equivalence of Natural and Unnatural Rate Theories of Macroeconomics

Thomas J. Sargent

The Journal of Political Economy, Vol. 84, No. 3. (Jun., 1976), pp. 631-640.

Stable URL:

<http://links.jstor.org/sici?sici=0022-3808%28197606%2984%3A3%3C631%3ATOEONA%3E2.0.CO%3B2-8>