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EMPIRICAL INVESTIGATION OF THE IRRELEVANCE OF THE DISTINCTION BETWEEN ANTICIPATED AND UNANTICIPATED MONEY IN EXPLAINING OUTPUT

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Introduction

The 1970's have witnessed dramatic developments in macroeconomic theory and practice. The New Classical Approach has brought forth a focus on the different effects of anticipated and unanticipated movements in nominal variables on real output. These preoccupations have supplanted the earlier Keynesian cum Monetarist ones of examining the transmission between monetary policy, whether expected or unexpected, and real output.

One particular expression of the distinction between the effects of anticipated and unanticipated movements in nominal variables is the hypothesis that the anticipated movements have no effect on real output. Empirical tests of this hypothesis have been carried out by many authors, but perhaps the most renowned models are those of Mishkin and Barro. Barro (1977, 1978) found support for the neutrality hypothesis in the United States, using annual data. Leiderman (1980) also found that he could not reject policy neutrality using Barro's model. Mishkin (1983) estimated a slightly different model using quarterly data. His conclusions agreed with Barro's and Leiderman's when the length of the lag of the nominal variables in the output equation was short, but he discovered the hypothesis was rejected when the lag distribution was substantially lengthened. While mixed, these results, along with the theoretical pedigree of the model on which they are based, have caused the research agenda of the New Classical view to dominate the activities of empirical macroeconomists.

In our earlier papers we demonstrated that problems inherent in measuring rational expectations correctly cast doubt on the validity of the statistical inferences required to support the conclusions of these studies. Rappoport (1984) demonstrated that the expectations models used by Barro and Mishkin did not satisfy minimal conditions of rationality. Frydman and Rappoport (1984) showed that this kind of mismeasurement of rational expectations rendered Barro's and Mishkin's estimates inconsistent, and their test procedures invalid. Thus, the empirical evidence concerning the New Classical propositions has to be reassembled using methods that are immune to the problems arising from mismeasurement of rational expectations.

One tack is to test the hypothesis that the effect of monetary policy on output is the same, irrespective of whether policy is anticipated or unanticipated. We call this hypothesis the "Irrelevance of the Anticipated-Unanticipated Distinction" (IAUD). Under IAUD, the deviation of output from its natural rate depends only on the total money growth rate, that is, it does not matter whether a particular movement in the money growth rate is anticipated or unanticipated. Therefore, it will not matter for computing the distribution of test statistics under this null hypothesis, how money is decomposed into expected and unexpected components. A fortiori, it does not matter (for the probability of a Type I error) whether expectations are measured correctly or not.

The purpose of this paper is to test the IAUD hypothesis using the models of Barro and Mishkin. The hypothesis receives substantial empirical support when examined in this framework. This reinterpretation of the empirical information contained in these well-known empirical models suggests that the efforts of the past decade may have been misdirected.

It is necessary to explain the precise meaning of this result. The "standard framework" for testing neutrality is a model in which output is regressed on variables supposed to capture the natural rate of output, and on distributed lags of anticipated and unanticipated money growth. The coefficients in this equation are not permitted to vary over time. The sample period employed is typically part of the post-war era. In this "standard framework", we demonstrate that the IAUD hypothesis is convincingly supported. Thus, the version of the output equation that has been estimated in pursuit of the hypotheses of the New Classical Macroeconomics collapses into one in which money growth affects output directly, without the intermediation of expectational phenomena.

While the evidence that has been assembled in the literature concerning the rational expectations and neutrality hypotheses is uninterpretable as a result of the mismeasurement of expectations, the support evidences for IAUD in the standard framework allow some inferences to be made concerning these hypotheses. Since there is no distinction between the effects on output of anticipated and unanticipated money growth, the output equation evidently provides no information about expectations. That is, rational expectations do not imply any binding cross-equation restriction on the parameters of the output and money growth equations. Hence, the rational expectations hypothesis cannot be tested in the this framework. However, the effect of anticipated policy on output is the same as that of the entire policy variable, under IAUD. In the context of the models tested here, we find this effect to be non-zero. Consequently, the neutrality hypothesis, finds no support from our results. In summary, our results suggest that empirical research based on the Lucas supply curve, when carried out in the "standard framework," would lead one to believe that phenomena having to do with expectations do not intervene in the transmission from money to output. The IAUD hypothesis thus emerges as a simple first step in the effort to distinguish between the rational expectations approach and its predecessors.[1]

While the usual perspective on the determination of output thus delivers the IAUD hypothesis, this, of course, is not the end of the story. Other monetary forecast functions must be examined. More general specifications may reveal that IAUD is invalid when coefficients are allowed to vary over time, or that output depends on variables other than lags of the money growth rate and the hypothesised components of the natural rate.

The plan of the paper is as follows. In section 1 we outline the model and the hypotheses to be tested, and in Section 2 we discuss the econometric properties of the estimation and testing procedures. Section 3 presents results for the models of Barro and Mishkin, and a summary is contained in Section 4.

1. The Model and Hypotheses

Several hypotheses concerning the relationship of money growth and output will be tested in this paper, in the context of

Barro's and Mishkin's models of these two variables. These models both have the following form:[2]

$$(1) \qquad y_t = \sum_{i=0}^{M} \beta_i \, (x_{t-i} - x^e_{t-i}) + \sum_{i=0}^{M} \theta_i x^e_{t-i} + y_{nt} + w_t$$

$$(2) \qquad x_t = z_t \delta + \lambda_t$$

The two empirical specifications differ in the length of the lag distributions in (1), the nature of the natural rate of output and the contents of z_t. Specific details will be given in Section 3.

The hypothesis of the irrelevance of the anticipated-unanticipated distinction (IAUD) is

$$(3) \qquad \theta = \beta$$

where $\theta = (\theta_0, \ldots, \theta_M)$ and β is similarly defined. If this hypothesis is valid, the output equation may be rewritten as[3]

$$(4) \qquad y_t = \Sigma \, \tau_i \, x_{t-i} + y_{nt} + w_t$$

Equation (4) motivates the question of whether money affects output at all, i.e. $\tau = 0$. This hypothesis will also be tested. However, a valid test will only emerge if $\theta = \beta$, and so the significance level of the $\tau = 0$ test should be adjusted. As the two hypotheses are not independent, this is complicated. Therefore, we shall also provide more easily interpretable evidence by testing $\theta = \beta = 0$.

The hypothesis that is usually tested on the parameters of equation (1) is the neutrality restriction $\theta=0$. Since consistent estimates and correct test statistics can only be obtained (in the presence of mismeasurement of expectations) when $\theta = \beta$, the neutrality restriction becomes $\theta = \beta = 0$, which is tested against $\theta = \beta \neq 0$. Thus, the test of neutrality collapses into the test of whether "money matters," i.e. $\tau=0$. Consequently, we only present the indirect evidence on the neutrality hypothesis that emerges from the tests of IAUD. The same comments apply, mutatis mutandis, for the hypothesis $\beta=0$.

The above tests examine whether there is any response to the nominal variables on the right hand sides of (1) and (4). One may also enquire whether the aggregate effect of the distributed lags of these variables is of importance, that is, if the response, if any, of output to nominal variables is transitory or permanent. This can be achieved by testing the hypotheses that sums of coefficients are zero. Thus, we test $\Sigma\beta_i = \Sigma\theta_i = 0$ on equation (1), and $\Sigma\tau_i = 0$ on equation (4). The distribution of these test statistics is computed under the relevant null *and* under the maintained hypothesis of IAUD.

In order to test hypotheses involving θ and β, it is necessary to provide a proxy for expectations, x^e. Following the practice of Barro and Mishkin, we take $z_t\delta$ in equation (2) as our measure of expectations. This is typically described as the assumption of rational expectations, although $z_t\delta$ is not an exact measurement of rational expectations when the agents' information set is larger than z_t. In order that the output equation can be rewritten correctly once this substitution is made, it is necessary to decompose rational expectations into measured and unmeasured parts.

Let rational expectations, x^{re}, be defined by

(5) $$x^{re}_t = x_t - e_t$$

where e_t is white noise. The projection of x^{re} on the (smaller) information set used by the investigator yields

(6) $$x^{re}_t = z_t \delta + v_t$$

where v and z are contemporaneously orthogonal by construction. v, which is not necessarily white noise, is the investigator's error in measuring rational expectations, since the "instrument" $z_t = \hat{x}^{re}_t$ is used to proxy rational expectations. Substituting this expression in (1) yields

(7) $$y_t = \Sigma\beta_i (x_{t-i} - \hat{x}^{re}_{t-i}) + \Sigma\theta_i \hat{x}^{re}_{t-i} + y_{nt} + \eta_t$$

or equivalently,

(8) $$y_t = \Sigma\beta_i (x_{t-i} - z_{t-i}\delta) + \Sigma\theta_i z_{t-i}\delta + y_{nt} + \eta_t$$

where

(9) $$\eta_t = \Sigma(\theta_i - \beta_i)v_{t-i} + w_t$$

The effects of mismeasurement on estimation will be addressed in the next section.

2. Econometric Issues

The principal model to be estimated is described by equations (8) or (7) and (2). Equation (8) embodies the rational expectations hypothesis. While these are measured with error, equation (9) shows that when $\beta = \theta$, the effects of mismeasurement disappear from the output equation, i.e. $\eta_t = w_t$.

Since test statistics are evaluated under the null hypothesis, expectations figure nowhere in the model, hence the way they are measured does not affect estimation and inference. Only when the power of the tests is considered (i.e., distributions are computed under the assumption $\theta \neq \beta$) does mismeasurement affect the results. Unfortunately, to calculate the power is a formidable task, since, in general under the alternate hypothesis, the estimators of all overidentified parameters are inconsistent.[4]

In the literature, estimation has proceeded under the assumption that λ_t and w_t are contemporaneously independent, and we shall invoke this assumption too. We shall use a two-step method of estimation, in which (2) is run first to provide an estimated proxy for rational expectations, $\hat{x}_t^{re} = z_t\hat{\delta}$, where $\hat{\delta}$ is the OLS estimator of δ . $\hat{x}_t^{re}$ is then substituted for $\hat{x}_t^{re}$ in equation (7)[5], and θ and β are then estimated by least squares yielding $\hat{\theta}$ and $\hat{\beta}$[6].

The alternative method of estimation is a systems method such as FIML.[7] Since this uses information from both the output equation (8) and the money growth equation (2), it provides more efficient estimates in tests of the rational expectations and neutrality hypotheses (when the mismeasurement of rational expectations not present). A further disadvantage of the two-step method is that, in general, the variance of $\hat{\theta}$ and $\hat{\beta}$ must be corrected to allow for the fact that $\hat{\delta}$ rather than δ is

B

used in the second stage.

It turns out that both of these problems disappear when $\theta = \beta$, even in the presence of mismeasurement of rational expectations. It is convenient to deal first with the problem of the sampling variance of θ and β . Murphy and Topel (1983, pp 7 and 11) show that the standard estimator of the asymptotic covariance matrix of $(\beta', \theta')'$ (for example that provided by a computer regression package) has to be altered by a factor that is a function of the sampling variance of $\hat{\delta}$, computed from the first stage regression of (2). However, this factor is also a quadratic form in $\theta - \beta$. Since it is to be evaluated under the null hypothesis, in which $\theta - \beta = 0$, the correction factor disappears.

We now turn to the relative efficiency of the two step and systems methods, under the assumption of IAUD. It is convenient in sketching this argument to omit y_{nt} from the output equation. This does not affect the generality of the argument. The system to be estimated may be written as

$$y_t = \Sigma\beta_i(x_{t-i} - z_{t-i}\delta) + \Sigma\theta_i z_{t-i}\delta + \eta_t$$
$$x_t = z_t\delta + \lambda_t$$

Let the $2(M + 1)$ variables whose coefficients are β and θ be represented by $B(\delta)$.

Under the assumption that λ_t and η_t are uncorrelated (which, amounts to λ_t and w_t being uncorrelated when IAUD is true), FIML amounts to minimization of

$$\lambda'\lambda\eta'\eta$$

(where $\lambda' = (\lambda_1, \ldots, \lambda_T)$, and η is similarly defined) with respect to β, θ and δ. The covariance matrix of the FIML estimators (which are consistent under IAUD) is given by the inverse of the information matrix. The information matrix is block diagonal in δ and (β', θ') when evaluated at $\theta = \beta$. Hence, so is its inverse. The block corresponding to (β', θ') is

$$\sigma_\eta^2 \{B(\delta)'B(\delta)\}^{-1}$$

This is the formula for the covariance matrix of the two step estimator of β and θ under IAUD (c.f. Murphy and Topel 1983). Hence, we conclude that the two-step method is asymptotically efficient under IAUD. Furthermore, since the two step estimators of σ_η^2 and δ are consistent under IAUD, a consistent estimator of (10) may be constructed from the parameters estimated in the two-step method.

Intuitively this result occurs because IAUD reduces (1) to (4), which does not contain expectations. Hence, under IAUD, the output and money growth equations are dislocated. Since their errors are assumed to be uncorrelated with each other, systems estimation results in statistics with the same properties as single-equation estimation.

While the first step of the estimation method provides proxies for the regressors in (1) related to expectations, this regression cannot be run until a proxy is found for the natural rate of output. Following Barro and Mishkin, we deal with this problem as follows: Equation (1) is rewritten:

$$(11) \qquad y_t = \Sigma\beta_i \left(x_{t-i} - x_{t-i}^{re}\right) + \Sigma\,\theta_i\, x_{t-i}^{re} + N_t\alpha + u_t$$

$$(12) \qquad u_t = \sum_{i=1}^{J} \rho_i u_{t-i} + w_t$$

where N_t is a list of variables, on which data are available and to which y_{nt} is related. Thus the natural rate is modelled by:

$$(13) \qquad y_{nt} = N_t\alpha + \sum_{i=1}^{J} \rho_i u_{t-i}$$

The parameters of equations (11) and (12) are estimated jointly by iterated generalized least squares. This has the same asymptotic properties as maximum likelihood estimation of the non-linear equation that results from applying the transformation $1-\rho(L)$ to equation (14). Thus, in summary, the two step estimation procedure used is as follows:

1. Estimate (2) by OLS, to yield $z_t\hat{\delta}$
2. Substitute $\hat{x}_t^{re}$ in (11)
3. Estimate this equation and (12) by GLS.

In analyses of the money-output equation system, it is customary to operate in terms of the asymptotic distributions of test statistics. While the asymptotic distributions of the three conventional statistics are identical under both the null and alternate hypotheses, we employ Wald statistics. In finite samples, when referrred to a χ^2 distribution, these are less favourable to the null than the Lagrange multiplier or likelihood ratio statistics. (c.f. Berndt and Savin (1977)). In order to correct the potential overstatement of the size of the test we use the degrees of freedom adjustment suggested by Evans and Savin (1982).

3. Empirical Results

In this section we present the results of estimation of the models of Barro and Rush (1980) and Mishkin (1983), and use them to test the hypotheses discussed in Section 1. The data used are quarterly,[9] and the sample period runs from 1954.I to 1976.IV. This is the sample period used by Mishkin, but is employed for both models to provide for uniformity of the results.

The first step in estimating the models is to estimate equation (2) by regressing the nominal variable (the quarterly growth rate of M1) on the list of explanatory variables chosen by each author.[10] To conserve space we do not exhibit the results of these regressions. They replicated the coefficient estimates reported by Barro and Rush (1980, p. 38) and Mishkin (1983, Table 6.A.20. Columns 1 and 4). Estimates of anticipated and unanticipated money growth are now constructed from the fitted part and residuals of the first step. This yields $\hat{x}_t^{re}$ and $x_t-\hat{x}_t^{re}$ respectively.

In order to estimate the output equation (11) and its autoregressive correction (12), three issues of specification must be dealt with. One concerns the variables in N_t, the known components of the natural rate of output. Again we follow Mishkin and Barro and Rush, using a constant and linear time trend in the first case, and add variables measuring the effects of minimum wages and the selective military draft in the latter.[11] A second question is the determination of J, the order of the autoregressive model in (12). Barro and Rush used a second-order model, while Mishkin set J at 4. We report results using a fourth order lag in both cases, since the results of no hypothesis test was changed when J was set at 2.

TABLE I

Amemiya's Prediction Criterion and χ^2 test for significance of lags of anticipated and unanticipated money growth beyond the seventh (a)/

Lag Length (M)	Barro		Mishkin	
	PC x 10^4	χ^2 p value(b)/	PC x 10^4	χ^2 p value
7	.817	-	.906	-
10	.904	.868	.967	.304
12	.975	.962	.956	.173
15	.962	.097	1.04	.341
18	.936	.13	.957	.044
20	.929	.069	.913	.009
25	.781	*(c)	.805	*

Notes

(a) The test has 2(M-7) degrees of freedom.

(b) The p-value is the probability of the data being generated by the model under the null hypothesis, i.e. the area under the χ^2 density function to the right of the computed value of the test statistic.

(c) An asterisk denotes a p-value less than .00001.

(d) Lack of data required that this model be estimated on the sample 1955.II - 1976.IV, which contains 87 observations.

The final, and most problematic matter of specification is the length of the lag distributions on unanticipated and anticipated money growth in equation (1). Barro and Rush (1980, p. 36) reported results for 7, 8 and 10 lags. Mishkin found that the results of his tests of the neutrality hypotheses were sensitive to the lag length used: with seven lags the hypothesis was not rejected, whereas with twenty it was.

The attempt to distinguish among different specifications of the lag length does not yield an unambiguous answer. In Table I the first column for each model exhibits the computation of Amemiya's Prediction Criterion[12] for models with 7, 10, 12, 15, 18, 20 and 25 lags.

For both specifications, the seven lag model yields a lower value of PC than does the twenty lag specification, indicating that the former is to be preferred between these two, although it is a close race in the case of Mishkin's model. The conventional test of significance of lags of anticpated and unanticipated money beyond the seventh is also reported in Table I. The seven lag specification is not rejected at all for Barro's model and for Mishkin's model it is not rejected when compared with models containing up to 15 lags. However, the seven lag specification is rejected at the 5% level for eighteen lags and at the 1% level for twenty lags.

If the twenty lag model is correct then the coefficient estimates that it provides will be consistent. These estimates, which are exhibited in Table II, evidence some perplexing movements. Both models show large (absolute) responses at very long lags, and there is no tendency for the lag distributions to die out. This latter fact suggests that if a model with long lag distributions is to be favored, the lag distribution should be even longer. This motivates our examination of the model with twenty five lags, which is clearly favored by the tests in Table I. However, the estimated lag distributions for the twenty five lag model are even more problematic than those for the twenty lag models, exhibiting larger amplitudes and again no tendency to dies out after six years.[13]

There are two obvious ways of interpreting these results. On the one hand, one may conclude that the lag length is in fact long, and the results for shorter lag lengths emerge because a misspecified model is forced on the data. On the other hand, one may decide that the results for long lag lengths are spurious, and arise because too many degrees of freedom are used up. In short, somewhere between seven and twenty-five lags a threshold is crossed, and either this threshold divides economically incorrect from correct (but overparameterised) specifications, or it divides adequate specifications from those that use too many degrees of freedom.

While the issue of the appropriate lag length cannot be settled statistically beyond doubt, we believe that the shapes of the long lag distributions are implausible on economic grounds. The statistical results seem to arise from near exhaustion of degrees of freedom.[14] Nevertheless, for completeness, we present the results for tests of the IAUD hypothesis for all the lag lengths examined above. They are to be interpreted in the light of this discussion.

TABLE II

Coefficients of Unanticipated and Anticipated Money Growth

	Barro-Rush				Mishkin			
	20 lags		25 lags		20 lags		25 lags	
Lag	$\hat{\beta}_i$	$\hat{\theta}_i$	$\hat{\beta}_i$	$\hat{\theta}_i$	$\hat{\beta}_i$	$\hat{\theta}_i$	$\hat{\beta}_i$	$\hat{\theta}_i$
0	0.76*	-0.58	0.85*	-4.43	0.82*	0.69	0.94*	-0.21
1	1.63	7.83	4.33	24.74	0.66	0.42	1.53*	-1.21
2	-3.27	-1.81	13.13*	-17.32	1.19	1.25	3.04*	-0.17
3	1.51	2.21	8.54*	17.54*	0.97	0.74	3.13*	-0.23
4	-0.03	-2.53	-9.03*	-1.11	1.14	0.94	3.02*	0.55
5	4.06	0.42	2.89	-2.80	0.97	0.36	1.86*	0.54
6	2.54	2.94	3.25	16.96	0.78	0.31	1.08	1.27
7	0.03	0.06	-9.03*	-8.25	0.72	0.89	0.82	1.04
8	0.32	-1.21	5.16	6.53	0.17	0.29	0.89	-0.86
9	0.98	-0.99	-3.23	-7.69	0.31	-0.04	2.54*	-2.03
10	1.95	3.55	7.57*	8.54	0.24	-0.01	4.64*	-1.28
11	-1.04	-0.36	-0.89	-8.38	0.24	-1.27*	5.28*	-1.79
12	-0.35	4.87	6.22	10.79	1.58	0.45	5.95*	0.08
13	-4.37	0.26	-4.92	-5.28	0.79	-0.07	4.21*	-2.03
14	-2.20	-3.78	2.96	-2.92	0.36	0.23	4.77*	-1.35
15	1.16	5.29	2.41	14.62*	0.40	-0.83	5.44*	-0.88
16	-3.16	0.78	-7.91	-9.04	1.29	-2.32*	4.99*	-0.97
17	-1.57	-1.33	3.29	5.93	2.65*	-0.07	3.966*	1.80*
18	-1.53	-0.45	-5.93	2.62	1.44	-1.35*	1.49	-0.42
19	-0.15	-1.38	-2.59	-4.3	2.13*	1.22*	2.69*	2.21*
20	2.23	0.78	1.49	6.98	0.54	0.60	0.98	0.52
21			-6.39*	-3.03			0.99	0.11
22			0.40	1.12			1.75	-2.75*
23			-1.92	0.64			4.97*	-0.80
24			-1.21	0.01			4.41*	1.26
25			-0.70	-0.57			1.57*	0.95

Note: an asterisk indicates a coefficient significantly different from zero at the 5% level

Table III contains the results of tests of the IAUD and related hypotheses. For the shorter lag lenghts, the IAUD hypothesis is strongly supported by the data, and even at 20 lags it is not rejected at the 1% level, the p-values being in excess of 2%. A further (informal) piece of evidence is given by the Box Pierce statistics for the restricted models. As Wald tests are carried out, the restricted model is estimated on data transformed according to the pattern of the ρ's in (12) that was estimated using the unrestricted model. In all cases, the p-values are high, indicating that deviations of the residuals of the restricted model from white noise are not detected by the Box-Pierce test. Similarly, visual inspection of the autocorrelations and partial autocorrelations of the errors from the restricted model does not yield evidence of any systematic patterns. This means that imposing the restriction in estimation does not leave unexplained any less of the serial correlation in output than estimating the unrestricted model in which $\theta = \beta$ is not imposed.

The IAUD hypothesis is only soundly rejected when the lag length is extended to 25 quarters. As mentioned above, in the case of the Barro-Rush model, for example, the unrestricted model involves estimating 60 parameters using 87 observations, while restricted estimation involves only 34 parameters.

Table III also presents tests of two other hypotheses. The restriction $\theta = \beta = 0$ may be regarded as a check on whether the decomposition of money into anticipated and unanticipated components is irrelevant because the components are irrelevant

TABLE III

p-values for χ^2 Tests on Equation (10)

	Barro				Mishkin			
	Box Pierce Test	$\theta=\beta$	$\theta=\beta=0$	$\Sigma\theta i=\Sigma\beta i=0$	Box Pierce Test	$\theta=\beta$	$\theta=\beta=0$	$\Sigma\theta i=\Sigma\beta i=0$
degrees of freedom	24	M+1	2(M+1)	2	24	M+1	2(M+1)	2
lag length M								
7	.91	.658	.0009	*	.79	.954	.00073	*
10	.87	.807	.01804	.0002	.945	.825	.00014	.00009
12	.79	.83	.06	.00487	.79	.467	.00013	.00066
15	.45	.045	*	*	.87	.516	.00126	.0089
18	.72	.045	*	*	.628	.14	*	.15
20	.75	.021	*	.0001	.186	.023	*	.026
25	.006	*	*	*	.045	*	*	*

to the determination of output. This restriction is soundly rejected for all models, except for the Barro-Rush models with 10 and 12 lags. In the former case it is rejected at the 5% level and not at the 1% level, whereas in the latter it is not rejected at the 5% level. For longer lag lengths, the strength of the rejection (the low p-values of the tests) is likely to result from the number of restrictions imposed. The restriction $\Sigma\theta_i = \Sigma\beta_i = 0$ imposes the condition that the total or permanent effects of anticipated and unanticipated money on output are zero. Because of the presence of mismeasurement of rational expectaions, the test statistics for this hypothesis only possess a χ^2 distribution if it is also true that $\theta = \beta$. However, this maintained hypothesis is imposed neither in the unrestricted nor in the restricted estimation procedures. The hypothesis is rejected at conventional significance levels for all specifications except Mishkin's model with 18 and 20 lags.

In summary, the IAUD hypothesis is supported by the data except in models with long lag distributions. The results are slightly more ambiguous for the other two hypotheses tested. The Barro-Rush model with 10 or 12 lags suggests that no part of money growth has an effect on output, while for some longer lags, Mishkin's model suggests that the permanent effects of the components of money growth on output may be zero. However, none of these results impugn the conclusion to be drawn from the IAUD tests: in the way the specification (11), (12) summarises the data, short of there being a case for believing the lag distributions to be very long, there are no grounds for distinguishing between the effects on output of unanticipated and

anticipated money growth, in the usual framework analysis.

As the IAUD hypothesis **is supported by the data, a next** step would be to estimate the model (4). The coefficient estimates for the lag distributions on money growth are presented in Table IV. Only the results for the Barro-Rush model are exhibited. For the Mishkin model, the lag distributions follow the same pattern extremely closely.[15] The lag distributions in this table evidence none of the anomalies that were present in estimation of equations (11) and (12). All lag distributions exhibit the same plausible shape. They have a maximum at two periods and tail off after that. Table IV evidences a remarkable similarity among the different models. The values of the coefficients of lags 0 through 7 differ very little across equations, in spite of the fact that the lag distribution is permitted to "spread" itself over more than seven lags. The values of all coefficients beyond seven lags are close to zero, and are individually statistically insignificant. A formal test of the proposition that lags beyond the seventh do not belong to the equation is given in the first column of Table V. In no case is the p-value for this hypothesis less than 50%.[16] These results are consistent with our earlier arguments for the appropriateness of the model with shorter rather than longer lags.

Table V also presents results on two hypotheses analogous to those tested on equation (11). The second column contains tests of the hypothesis that money has no effect at any lag; it is soundly rejected in all cases. The third column presents the

TABLE IV

Coefficients of Lags of Money Growth in Equation (4)

Barro-Rush Model

lag length: lag	7	10	12	15	18	20	25
0	0.71*	0.74*	0.77*	0.78*	0.80*	0.76*	0.77*
1	0.57*	0.65*	0.64*	0.65*	0.67*	0.63*	0.52*
2	1.08*	1.14*	1.12*	1.12*	1.15*	1.12*	1.16*
3	1.02*	1.02*	1.00*	1.03*	1.01*	0.97*	1.03*
4	0.93*	1.00*	1.01*	1.03*	1.04*	0.98*	1.05*
5	0.61*	0.73*	0.73*	0.73*	0.75*	0.74*	0.86*
6	0.40*	0.51*	0.46*	0.43	0.43	0.41	0.61*
7	0.56*	0.64*	0.61*	0.61*	0.64*	0.65*	0.94
8		0.12	0.10	0.13	0.12	0.09	0.31
9		0.29*	0.28	0.24	0.23	0.18	0.51
10		0.04	0.01	-0.04	-0.09	-0.10	0.16
11			-0.11	-0.16	-0.23	-0.18	0.07
12			0.09	0.05	-0.05	0.14	0.32
13				-0.07	-0.21	-0.20	-0.03
14				-0.19	-0.32	-0.32	-0.12
15				0.01	-0.14	-0.03	0.15
16					-0.25	-0.11	0.04
17					-0.12	0.00	-0.03
18					-0.35	-0.21	-0.17
19						0.27	0.39
20						0.37	0.49
21							0.04
22							0.29
23							0.20
24							0.12
25							-0.47*

Note: an asterisk indicates a coe-ficient significantly different than zero at the 5% level.

TABLE V

p-values for χ^2 tests of Equation (4)

Barro-Rush Model

	Hypothesis		
	$\tau_8 \ldots \tau_M = 0$	$\tau = 0$	$\Sigma \tau i = 0$
degrees of freedom	M-7	M+1	1
lag length M			
7	-	.0001	*
10	.552	*	*
12	.737	.00004	.00002
15	.886	.00052	.00022
18	.742	.0008	.0097
20	.518	.00016	.00195
25	.507	.00004	.00017

results on the hypothesis that the permanent effect of money growth on output is zero. This hypothesis is rejected at the 5% level for all models, although at the 1% level it survives in the twenty lag case, and is marginally rejected in the eighteen lag model. Thus, in the context of the models examined here not only is money non-neutral in the short-run, it is also non-neutral in the long-run.

4. Summary

At this point we are able to summarize the empirical results that emerge from the standard models used in testing the New Classical propositions. We find that these models lead one to believe that there is no distinction between the output effects of anticipated and unanticipated money growth. Furthermore, this result does not arise because "money does not matter." Ironically, in these models, it matters both in the short and long runs. This seems to close a chapter in the study of the determination of output. A careful reconsideration of the specification of the output equation is motivated.

FOOTNOTES

1. It is surprising that this hypothesis was not tested at the outset. The explanation may be that it does not arise naturally from the New Classical perspective.

An early examination of this hypothesis was carried out by Rappoport (1981). Subsequent to writing this paper we discovered that some tests for the UK have been done by Bean (1984). Neither considered the relationship of the IAUD hypothesis to the issue of mismeasurement of rational expectations.

Another paper that examines the New Classical model from a Keynesian perspective is Pesaran (1982).

2. Here, y represents real output, y_n its natural rate, x the rate of growth of the money supply, and x_t the forecast at t-1 of x_t. z_t is a list of regressors chosen by the investigator, and w_t and λ_t are random error terms.

3. In the sequel, an unadorned summation sign will stand for $\sum_{i=0}^{M}$.

4. If $x_t - z_t\delta$ is white noise, inconsistency does not result if (c.f. Frydman and Rappoport, 1984). However, Rappoport (1984) demonstrated that this case does not characterise the rational expectations proxies of Barro and Mishkin used below.

5. This method has been used by Barro (1977) and Barro and Rush (1980).

6. In practice, y_{nt} is modelled as containing a serially correlated process, so the procedure used to derive $\hat{\theta}$ and $\hat{\beta}$ is (iterated) generalized least squares. Details will be discussed in section 3

7. Systems estimators are used by Leiderman (1980) and Mishkin

(1983).

8. C.f. Murphy and Topel (1983) and Pagan (1984). Again, the treatment of this issue in the literature abstracts from the problem of mismeasurement of rational expectations.

9. The data for Barro's model were those used by Barro and Rush (1980), and were kindly provided by John Merrick. The additional data series required to implement Mishkin's model were taken from the Citibase databank.

10. Barro and Rush regress the money growth rate an a constant, six lagged values of the dependent variable, three lagged values of the logit of the unemployment rate and the contemporaneous value of "FEDV", a measure of the deviation of federal government expenditure from its normal value. Mishkin's regressors are a constant and four lagged values each of the dependent variable, the average rate on month bank treasury bills and the high employment government surplus. The data in the Barro and Rush dataset are seasonally adjusted, and we used adjusted data for Mishkin's model.

11. Barro and Rush did not use both of these variables in any single equation. We do so only for conciseness.

12. The formula for this is $\frac{SSR}{T}\frac{(T+K)}{(T-K)}$, where SSR is the sum of squared residuals and K is the number of parameters estimated in the model. We have used Amemiya's Criterion because he shows that it is appropriate for non-linear models, of which (11) and (12) constitute an example. Thus, we include in K the four lags of u specified in equation (12). Amemiya (1980) demonstrates his

criterion to be equivalent to a version of Akaike's Criterion in the case of the standard regression model.

13. One possible explanation for these results may be collinearity among the regressors. If the variables other than lags of money growth in equation (2) have negligible contributions to the money growth rate equation, then $\hat{\hat{x}}_t^{re}$ is close to being a linear combination of a constant and lags of the money growth rate, variables which can be constructed from the other regressors in the output equation. Indeed, none of these non-money variables is significant in the Barro-Rush money growth equation, although some are in Mishkin's model. However, what matters is not the statistical significance of coefficients but the size of the effect of the variable. This may be measured, for example, by the mean of the regressor multiplied by its coefficient, relative to the mean of the dependent variable. This turns out to be substantial (around 10%) in the case of the variables other than lags of money growth in Barro and Rush's equation.

14. In the 25 (20) lag Barro-Rush model, unrestricted estimation involves fitting 87 (92) observations on by selecting 60 (50) parameters. The restricted model imposes 36 (26) restrictions. It therefore seems plausible that the unrestricted regression is spurious, and the restricted regression results in a much higher sum of squared residuals because it imposes so many restrictions on an already spuriously parameterised model. We also note that Amemiya's model selection criterion (see footnote 12) may be unreliable when K becomes large, since it is continuous in K and undefined for K=T.

15. The two models are estimated with the fourth order autoregressive correction described by equation (15). They differ only in their specification of the natural rate of output.

16. Table V only reports results for the Barro-Rush model. Those for Mishkin's model offer a similar picture.

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