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AN ECONOMETRIC ANALYSIS OF UK MONEY DEMAND IN *MONETARY TRENDS IN THE UNITED STATES AND THE UNITED KINGDOM* BY MILTON FRIEDMAN AND ANNA J. SCHWARTZ

David F. Hendry and Neil R. Ericsson

ABSTRACT

This paper evaluates an empirical model of UK money demand developed by Friedman and Schwartz in *Monetary Trends...* . Testing reveals mis-specification and hence the potential for an improved model. Using recursive procedures on their annual data, we obtain a better-fitting, constant, dynamic error-correction (cointegration) model. Results on exogeneity and encompassing imply that our money-demand model is interpretable as a model of money but *not* of prices since its constancy holds only conditional on contemporaneous prices.

An Econometric Analysis of UK Money Demand in *Monetary Trends in the United States and the United Kingdom* by Milton Friedman and Anna J. Schwartz

David F. Hendry and Neil R. Ericsson*

In their 1982 book, *Monetary Trends in the United States and the United Kingdom: Their Relation to Income, Prices, and Interest Rates, 1867–1975*, Milton Friedman and Anna Schwartz present a wealth of empirical findings as support for a range of economics hypotheses.[1] To isolate the longer-term relationships that are their primary concern, Friedman and Schwartz estimate their empirical models from data transformed by averaging annual observations over phases of NBER reference cycles. In our analysis, we first replicate one of their preferred models for UK money demand on the phase-average data and then evaluate it econometrically to investigate aspects of model specification about which the data are most informative. The outcome indicates the potential for an improved equation but does not entail the form of re-specification required. In seeking to construct an improved model, we formulate an equation which integrates long-run properties with short-run dynamics, based on the recent merging of the theories of error-

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[1]For helpful reviews and summaries of Friedman and Schwartz (1982), see *inter alia* Charles Goodhart (1982), Thomas Mayer (1982), Tim Congdon (1983), Michael Artis (1984), and Basil Moore (1983).

correction and cointegration. Moreover, because phase-averaging may entail a loss of information about relevant parameters, we return to analyzing the underlying annual observations. Finally, the resulting model is critically evaluated.

The sequence in the previous paragraph involves a natural progression from model discovery to model evaluation through replication and testing, and then via new conjectures back to discovery seeking models which account for previous findings and explain additional phenomena. The paper's main objective is to achieve that last goal for UK money-demand models over the period 1878–1970. An additional objective is to exposit an econometric framework which makes precise the notion of an improved model, explains the construct of accounting for previous findings (denoted encompassing), and delineates the criteria for model evaluation. This enables us to clarify the concepts of exogeneity, invariance, encompassing, and cointegration in the context of an important economics debate. The empirical model reported below improves upon the phase-average UK money-demand equation from Friedman and Schwartz, our first annual-data specification (proposed in 1983), and those in the studies which the latter stimulated, thus illustrating a progressive research methodology in action.

In Section I, we consider the data and data transformations used by Friedman and Schwartz. In Section II, we discuss the money-demand relationships they estimated from the phase-average data for the United Kingdom and evaluate many of their empirical claims about the selected money-demand equation. The statistical framework and its associated concepts are briefly exposited in Section III to clarify the joint destructive and constructive roles for tests. In Section IV, we constructively apply that approach to modeling money demand using the annual UK data series. Section V concludes the paper.

I. The Data Series and Transformations

In Friedman and Schwartz's and our studies of UK money demand, the basic data series are annual values for the UK from 1871 to 1975 of the broad money stock (M), real net national income (I), the price level (P), short-term and long-term nominal interest rates (RS and $R\ell$), population (N), and high-powered money (H); and the price level (P*) in the USA. All series are in Friedman and Schwartz's Tables 4.8 and 4.9; for details of construction and definition of the series, see both Friedman and Schwartz (1982, chapters 4 and 5) and our Appendix, which note reservations on the measurement and interpretation of those series. Unless otherwise indicated, capital letters denote both the generic name and the level; logs of scalars are in lower case. Figures 1, 2, and 3 respectively show the annual time series for velocity V ($\equiv$PI/M) and RS, real money (M/P) and real income, and nominal money and prices.[2]

From Figure 1, three distinct episodes are discernible in the behavior of velocity, coinciding with historical periods before the First World War (1871–1914), interwar (1918–1939), and after the Second World War (1945–1975). Initially, velocity and RS cycle around constant levels. Then, in the interwar period, velocity is lower and more volatile. It falls during the Second World War, reaching its lowest observed level in 1947, corresponding to the lowest level for interest rates (of 0.5% p.a.). Next, velocity trends upwards, more than doubling by 1970, while interest rates fluctuate increasingly around an upward trend. Finally, between 1971 and 1975 velocity falls while RS rises.

Some insights into this behavior of velocity can be gleaned from Figure 2 which plots two of its constituents, (m–p) and i. The interwar period begins with a sharp fall in i being matched by a large rise in (m–p) which then remains systematically above i with its greatest departure from i in 1947. Thereafter, (m–p) falls steadily till around 1960 whereas i rises considerably, and then (m–p) "levels off" till its sharp rise in 1971. Thus, between 1947 and 1970 measured velocity more than doubles because (m–p) drops while i rises. Lastly, Figure 3 shows nominal money and the price level. These series are highly correlated in levels although, overall, money increases 5.6 times relative to p (real income

[2]When there is no loss of clarity, we often refer to v (= p+i–m) as velocity.

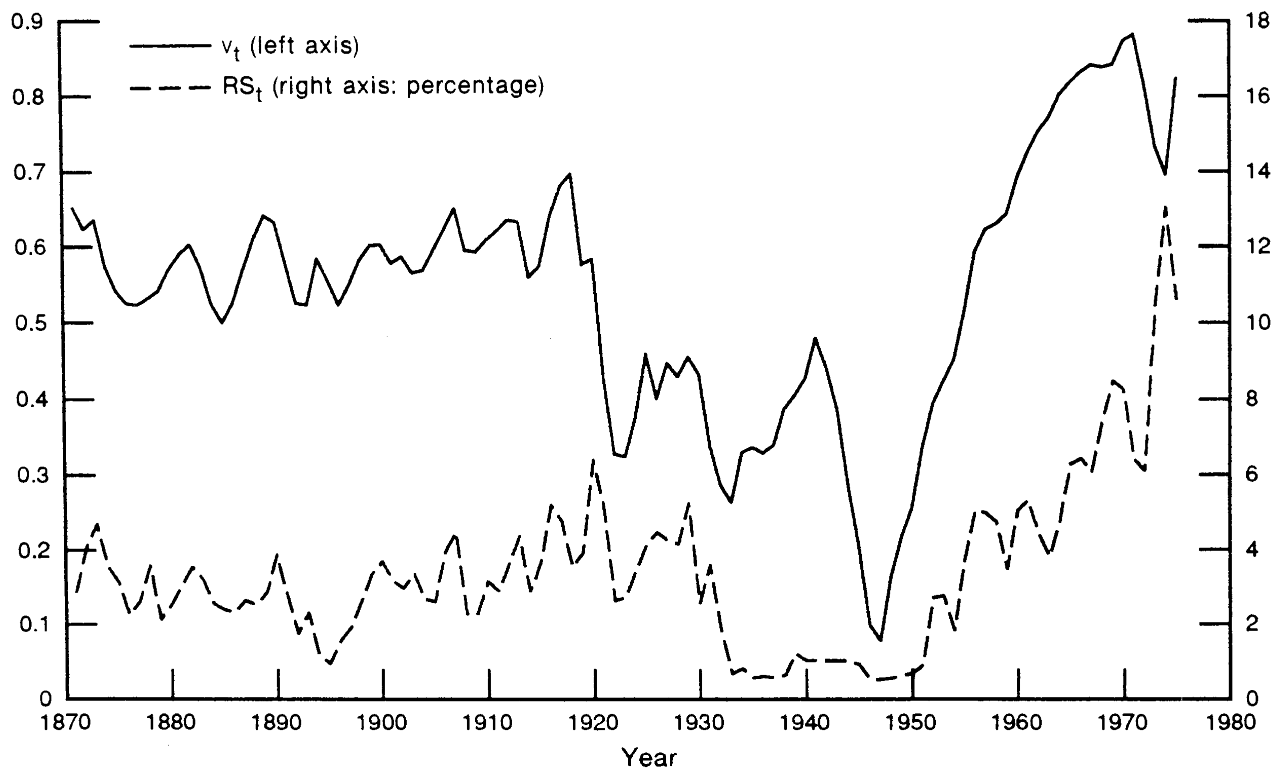

Figure 1. The log of the velocity of money (v_t) and the yield on three-month bills (RS_t) (annual data).

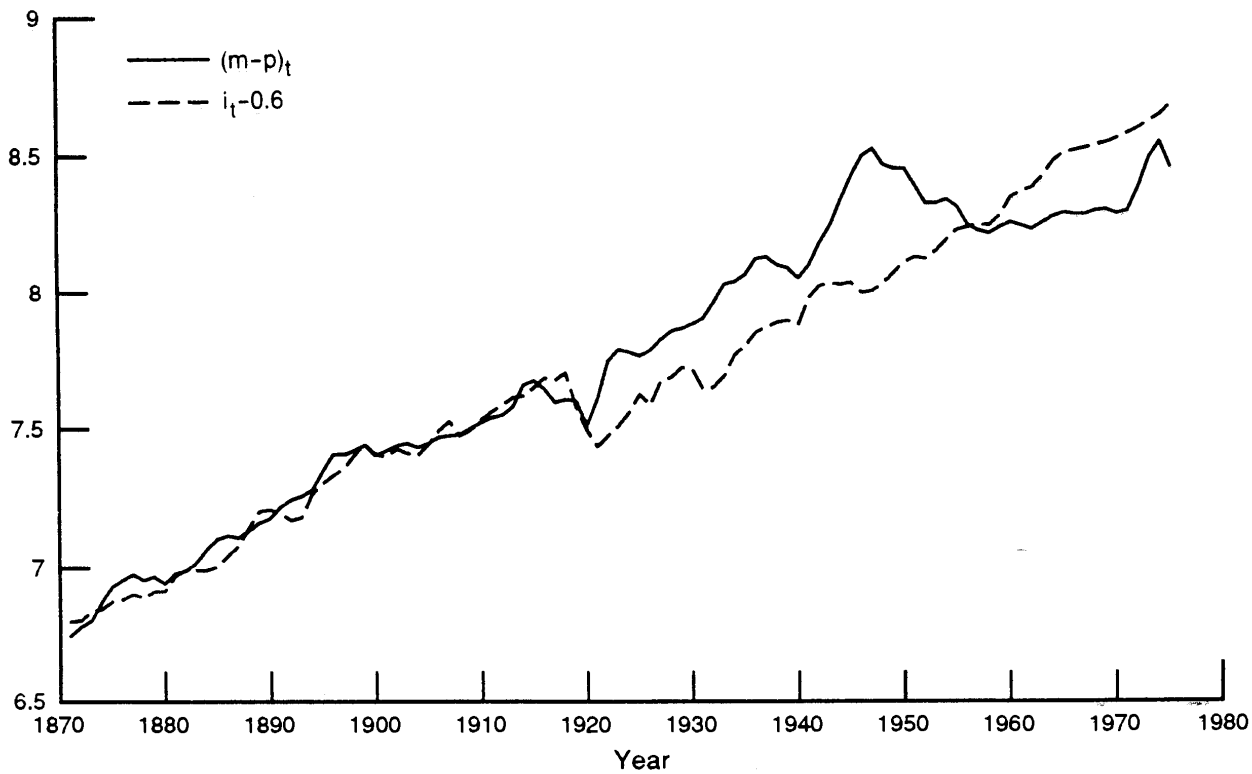

Figure 2. The log of the real money stock [$(m-p)_t$] and the log of real income (i_t) (annual data).

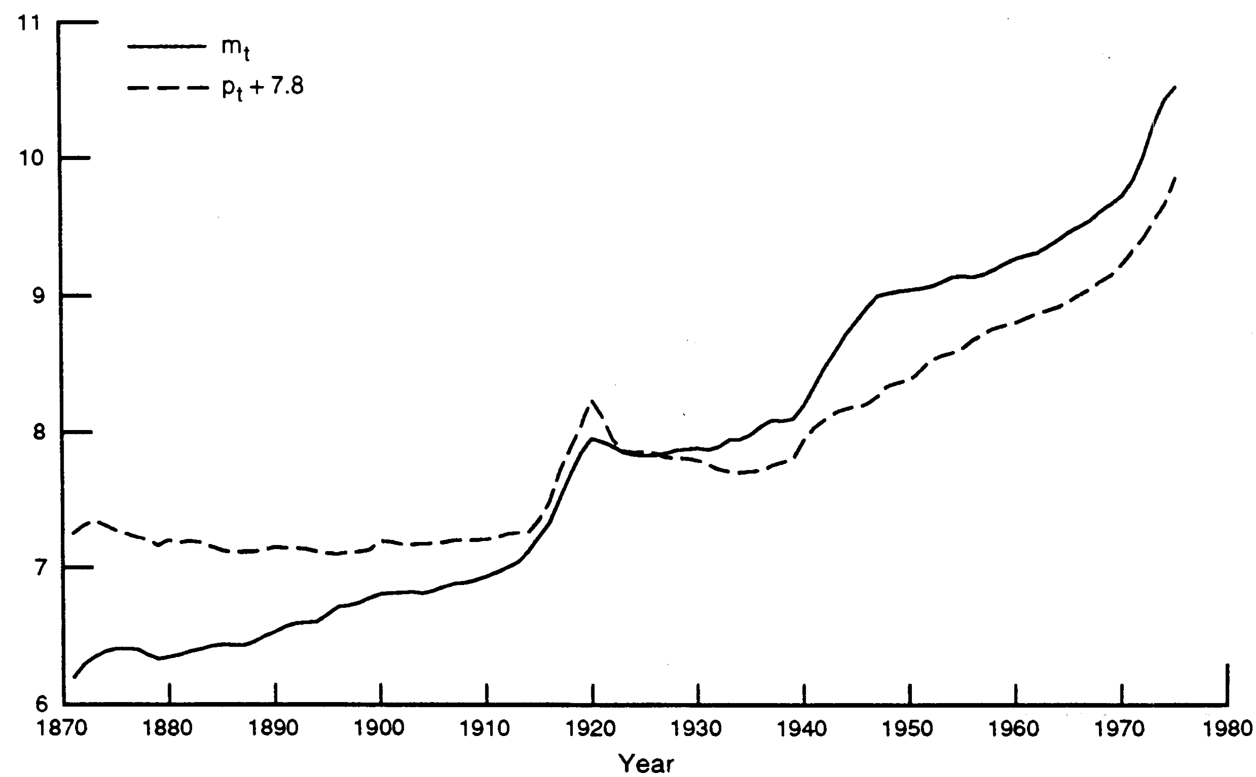

Figure 3. The log of the nominal money stock (m_t) and the log of the implicit price deflator (p_t) (annual data).

increases by 6.7 times), and during 1920–22 a large fall in p occurs alongside a small fall in m. To adequately represent the century of data, an econometric model of UK money demand must encompass such features.

Since Friedman and Schwartz aim to examine the long-period movements in the data, they do not analyze these annual series directly but first transform them by averaging separately over contraction and expansion phases of data-selected choices of reference business cycles. From some hundred years of annual UK observations, Friedman and Schwartz identify 37 such phases with average lengths of 2.1 and 3.4 years respectively for contraction and expansion phases. These phase averages, weighted by a function of duration, are the basic units of analysis (pp. 75–79 and Table 5.8) and are analyzed both in levels and as rates of change.[3] The latter are calculated from least-squares slopes fitted to triplets of overlapping phases (weighted appropriately) and are arithmetically nearly the same as differences from one expansion (or contraction) to the next.[4] The data to which these moving-average filters are applied are the logarithms of money, prices, incomes, and population, and the original values of interest rates. We denote phase-average data by a superscript bar, e.g., $\overline{m}_j$ for the j^{th} phase-average observation of the logarithm of money stock. These data are the basis for the analysis in Section II, whereas in Section IV we utilize the original annual time series. The relationship between the phase-average and the annual series for velocity is shown in Figure 6, discussed below.

II. Testing the UK Money-demand Model on the Phase-average Data

In this section, we summarize the central empirical results obtained by Friedman and Schwartz for UK money demand using the phase-average data, replicate one of their preferred models, and econometrically evaluate it.

[3] Unreferenced tables and page numbers refer to Friedman and Schwartz (1982).

[4] There are typographical errors in the reported values for "rates of change" in Table 5.10 affecting observations 18 through 21. We corrected those errors following the procedures described by Friedman and Schwartz (1982, Section 3.2): our amendments are reported in Hendry and Ericsson (1985, Appendix F).

Table 1 reports estimates of four equations out of those which Friedman and Schwartz record for the UK as establishing evidence concerning the demand for money, and the influences of money on income and on prices. "Levels" and "rates of change" equations are analyzed by Friedman and Schwartz but, as they see little to choose between them (e.g., see p. 286), we focus on the equations in levels: full details can be found in Friedman and Schwartz. We summarize their interpretation of the estimates in Table 1 as follows. Equation (a) is their preferred UK money-demand equation and has a nearly unit income elasticity (pp. 280–284). From equation (d), I does not depend upon M, whereas P does ((c)), and hence so does P·I ((b)); cf. pp. 422, 351.

Equations (a)–(d) represent types of models (of money, nominal incomes, prices, and output, respectively), but from our perspective their joint existence raises difficulties. Because M is a regressor in equations (b)–(d), M must be [weakly] exogenous if the coefficients in these regressions are to be interpreted as parameters of interest; cf. Robert Engle, Hendry, and Jean-François Richard (1983). With M exogenous, equation (a) is determining P, not M; but so is equation (c). Conversely, if M does not maintain its exogeneity status in equation (a), P and M are jointly determined and hence equation (c) must be invalid. However, since Friedman and Schwartz take (a) as one of their "final equations" for UK money demand (p. 281), we will evaluate it on that basis.

We could closely replicate equation (a):

$$(1)\qquad \widehat{(\overline{m}-\overline{p}-\overline{n})}_j = \underset{(0.19)}{0.012} + \underset{(0.049)}{0.885}\,(\overline{i}-\overline{n})_j - \underset{(3.3)}{11.21}\,\overline{RN}_j - \underset{(0.29)}{0.22}\,G(\overline{p}+\overline{i})_j + \underset{(0.58)}{1.37}\,\overline{W}_j + \underset{(2.7)}{20.6}\,\overline{S}_j$$

$$J = 36 \qquad \hat{\sigma} = 5.66\% \qquad dw = 1.51 \qquad R^2 = 0.97$$

where $\overline{RN}$ is the differential between $\overline{RS}$ and the "own-yield" on money, $G(\overline{p}+\overline{i})$ is the growth rate of nominal income (interpreted by Friedman and Schwartz as proxying for the rate of return on physical assets), $\overline{W}$ is a dummy for "postwar adjustment" (p. 228), and $\overline{S}$

Table 1.
Equations for UK money demand, nominal incomes, prices, and output from Friedman and Schwartz (1982) (phase-average data)

Source

(a) $$\widehat{(\bar{m}-\bar{p}-\bar{n})} = \underset{(0.08)}{0.16} + \underset{(18.13)}{0.88}\,(\bar{i}-\bar{n}) - \underset{(3.42)}{11.16}\,\overline{RN} - \underset{(0.74)}{0.22}\,G(\bar{p}+\bar{i}) + \underset{(2.38)}{1.4}\,\overline{W} + \underset{(7.56)}{21.}\,\overline{S}$$ p.282

$$\hat{\sigma} = 5.54 \quad R^2 = 0.970 \quad [dw = 1.51] \quad [\eta_1(18,12) = 6.3]$$

(b) $$\widehat{(\bar{p}+\bar{i})} = 0.38 + 1.01\bar{m} + 14.17\overline{RN} + 0.53G(\bar{p}+\bar{i}) - 1.1\overline{W} - 19.\overline{S}$$ p.349

$$\hat{\sigma} = 5.99 \quad R^2 = 0.9977 \quad [dw = 1.33] \quad [\eta_1(18,12) = 5.7]$$

(c) $$\hat{\bar{p}} = \underset{(31.1)}{-5.99} - \underset{(7.4)}{0.015}\bar{t} + \underset{(17.4)}{1.02}\bar{m} + \underset{(0.9)}{0.94}\overline{RS} - \underset{(2.8)}{1.10}G(\bar{p}+\bar{i})$$ p.420

$$\hat{\sigma} = 6.0 \quad [dw = 1.01] \quad [\eta_1(15,10) = 3.1]$$

(d) $$\hat{\bar{i}} = \underset{(34.2)}{6.50} + \underset{(8.3)}{0.017}\bar{t} - \underset{(0.9)}{0.05}\bar{m} + \underset{(2.4)}{2.34}\overline{RS} + \underset{(5.7)}{2.20}G(\bar{p}+\bar{i})$$ p.420

$$\hat{\sigma} = 5.9 \quad [dw = 0.97] \quad [\eta_1(15,10) = 2.1]$$

Notes.

a. Notation is as in Section I, but *'t'–values are in parentheses*, as reported in the original text. RN = RS·H/M; G(·) denotes a rate of change; and $\overline{W}$ and $\overline{S}$ are the dummies for post-war adjustment and demand shift, rescaled by 1/100 (see the Appendix). Phase averages 12–14 and 24–26 are omitted in (c) and (d).

b. Here and in Table 3, values of $\hat{\sigma}$ with logarithmic regressands are quoted as approximate percentages relative to the *level* of the regressand in its original units, e.g., if log(Y) is the regressand, $\hat{\sigma}$ is a percentage of Y.

c. Values in square brackets are our calculations and are not reported in Friedman and Schwartz.

d. Our equations replicating (c) and (d) had somewhat *smaller* values of $\hat{\sigma}$ than those in Friedman and Schwartz.

is a data-based dummy for "[a]n upward demand shift, produced by economic depression and war..." (p. 281) during 1921–55. $\overline{S}$ captures a 21% shift in (1), and so accounts for much of the variation in real per-capita money, conditional on real per-capita income. Figure 4 shows the fitted and actual values for $(\overline{m}-\overline{p}-\overline{n})$ derived from (1). Throughout, estimated standard errors are shown in parentheses (except in Table 1), $\hat{\sigma}$ is the standard deviation of the residuals (e.g., in (1), as a percentage of $\overline{M}/(\overline{P}\cdot\overline{N})$), adjusted for degrees of freedom, and R^2 is the squared multiple correlation coefficient for the corresponding unweighted regression.[5]

Having replicated equation (a) by (1), we evaluate (1) against a range of alternative models. A summary of our approach is provided in Section III; here we focus on the usual concerns of parameter constancy, price homogeneity, omitted variables, homoscedasticity, and normality. Once an empirical model has been formalized, then, conditional on treating it as provisionally valid, many empirical phenomena are excluded. Consequently, a model is testable against their potential occurrence, *using tests which would be valid given the assumptions of that model.* The resulting tests have central distributions with approximately 5% critical levels under the null hypothesis of correct specification and non-central distributions under their respective alternatives. Additionally, they may have power to reject alternatives other than those against which they were designed or have larger implicit nulls than explicit nulls; cf. Grayham Mizon and Richard (1986).

Constancy is a major issue for money-demand equations (see John Judd and John Scadding (1982)), and Friedman and Schwartz regard their own UK money-demand equation as being constant:

> [A] more sophisticated analysis [than the simple quantity theory] reveals the existence of a stable demand function for money covering the whole of the period we examine. (p. 624)

[5]All our estimates using phase-average data are based on weighted least squares, correcting for the different phase lengths. However, parameter estimates are not very different whether ordinary or weighted least squares are used. All empirical calculations are from PC-GIVE (see Hendry (1989)).

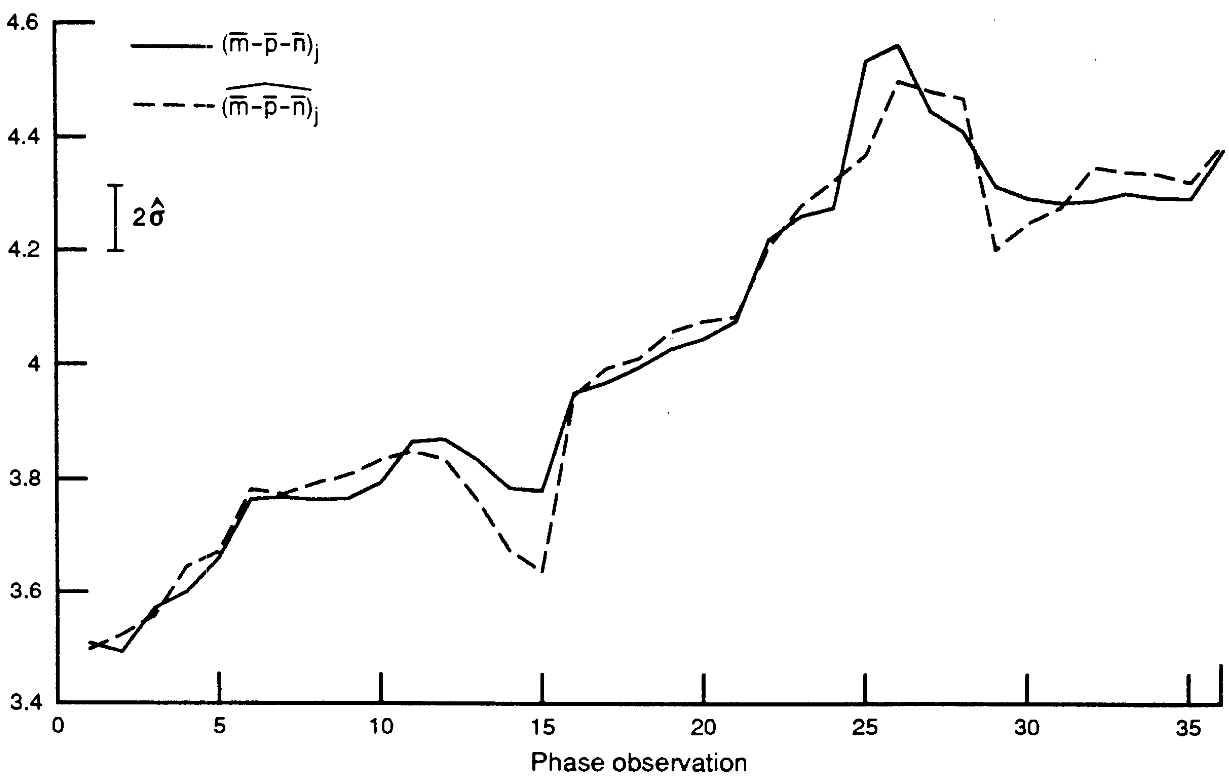

Figure 4. Equation (1): actual and fitted values for $(\overline{m}-\overline{p}-\overline{n})_j$ (the transformed regressand).

(See also pages 7, 14, 64, 283.) However, they do not formally *test* for constancy, and many investigators would regard the need for the data-based shift dummy $\overline{S}$ spanning one-third of the sample as *prima facie* evidence against the model's constancy. Refitting (1) to the first half of the sample and predicting over the second half (doing each with *both* $\overline{S}$ and $\overline{W}$), we tested for constancy using Gregory Chow's (1960, pp. 594–595) statistic: that yielded $\eta_1(18,12) = 6.3$ which exceeds the 1% point of the F–distribution. Although the one-step-ahead 95% confidence interval based on $\hat{\sigma}$ is larger than ±11%, parameter non-constancy can be detected, revealing an aspect about which the present data set is informative. The values of $\hat{\sigma}$ for the corresponding sub-periods are markedly different: 2.8% and 6.0% respectively. Even if these differences were due solely to heteroscedasticity, the inferences which Friedman and Schwartz draw from their regressions would be invalid because the t–ratios are biased. Moreover, non-constancy is not restricted to the residual variance. Figure 5 records the recursive estimates of the interest rate coefficient from phases 16 through 36, together with a confidence region based upon plus-or-minus twice its estimated standard error at each sample size.[6] As the sample size increases, the estimated coefficient alters substantially relative to its estimated uncertainty, with the final estimate lying outside the initial confidence interval. Such evidence refutes constancy in their reported model.

Since the dependent variable in (1) is $\overline{m}-\overline{p}-\overline{n}$, price homogeneity can be tested under two distinct maintained hypotheses about exogeneity, namely, whether M or P is exogenous. Treating M as endogenous and relaxing unit price homogeneity in (1), we obtain:

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[6]In textbook notation, Figure 5 plots the i^{th} coefficient and its estimated standard error: $\{\hat{\beta}_{ij} \pm 2\text{ese}(\hat{\beta}_{ij})\ ;\ j=16,\ldots,36\}$ where $\hat{\beta}_j=(\mathbf{X}_j'\mathbf{X}_j)^{-1}\mathbf{X}_j'\mathbf{Y}_j$, $\mathbf{X}_j=(\mathbf{x}_1\ldots\mathbf{x}_j)'$, $\mathbf{Y}_j=(y_1\ldots y_j)'$, and $\text{ese}(\hat{\beta}_{ij}) = \sqrt{\text{diag}_i[\hat{\sigma}_j^2\cdot(\mathbf{X}_j'\mathbf{X}_j)^{-1}]}$. Under the null hypothesis of correct specification, $\hat{\beta}_{ij}\rightarrow\beta_i$ and $\text{ese}(\hat{\beta}_{ij})\rightarrow 0$ as $j\rightarrow\infty$. See Andrew Harvey (1981, pp. 54–59) on the calculation of recursive least squares and associated test statistics and Kerry Patterson (1986) for an application. For annual data, the index j becomes t.

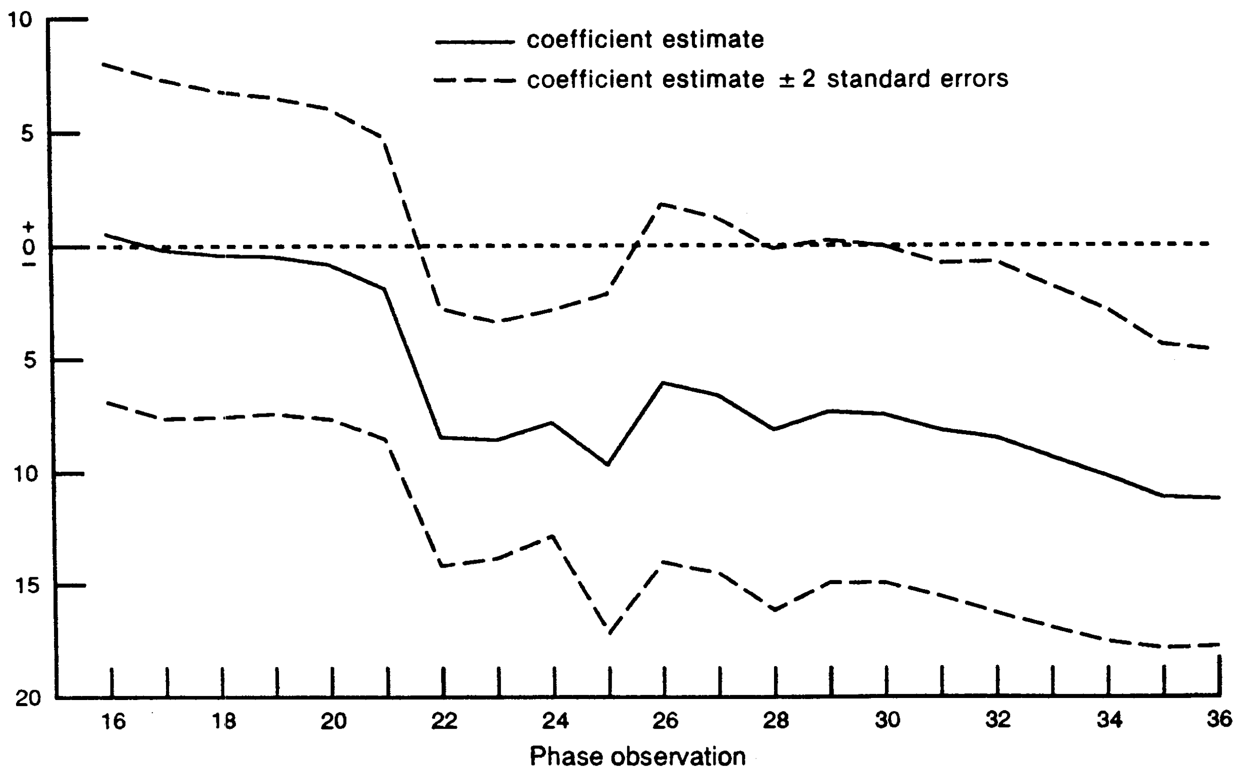

Figure 5. Equation (1): recursive estimation of the coefficient on $\overline{RN}_j$ and its estimated standard error.

$$(2) \quad \widehat{(\bar{m}-\bar{p}-\bar{n})}_j = \underset{(0.38)}{1.01} + \underset{(0.08)}{0.68}\,(\bar{i}-\bar{n})_j + \underset{(0.043)}{0.128}\,\bar{p}_j - \underset{(3.8)}{18.4}\,\overline{RN}_j - \underset{(0.26)}{0.04}\,G(\bar{p}+\bar{i})_j + \underset{(0.53)}{1.05}\,\bar{W}_j + \underset{(2.8)}{16.3}\,\bar{S}_j$$

$$J = 36 \qquad \hat{\sigma} = 5.03\% \qquad dw = 1.85 \ .$$

The coefficient on $\bar{p}_j$ is significant at the 99% level. If, instead, the exogeneity of M is maintained so (1) purports to explain $\bar{p}_j$, then adding $\bar{m}_j$ and $\bar{n}_j$ to (1) to relax the homogeneity assumption yields F(2,28) = 20.56, again rejecting the specification of (1).

Next, to test for the absence of a trend, we estimate (3):

$$(3) \quad \widehat{(\bar{m}-\bar{p}-\bar{n})}_j = \underset{(2.99)}{-13.92} + \underset{(0.16)}{0.14}\,(\bar{i}-\bar{n})_j - \underset{(2.7)}{16.0}\,\overline{RN}_j + \underset{(0.24)}{0.23}\,G(\bar{p}+\bar{i})_j + \underset{(0.46)}{1.80}\,\bar{W}_j + \underset{(3.7)}{6.1}\,\bar{S}_j + \underset{(0.0019)}{0.0090}\,\bar{t}_j$$

$$J = 36 \qquad \hat{\sigma} = 4.35\% \qquad dw = 1.99 \ .$$

The coefficient on $\bar{t}_j$ is statistically significant. By way of comparison, when Friedman and Schwartz tested for trends and price homogeneity in more restrictive models, they did not obtain rejections on this data set (pp. 253–259).

Although Friedman and Schwartz did not test for it, normality of the disturbances is also rejected: Carlos Jarque and Anil Bera's (1980) $\chi^2(2)$ statistic for testing normality via residual skewness and excess kurtosis is $\xi_5(2) = 6.9$ in (1).[7] Testing the normality of the disturbances is of interest for two reasons. First, Friedman and Schwartz often base their statistical inferences on critical values of the F–distribution (e.g., see pp. 232, 236), and, given the small sample size (J=36), those inferences may be affected substantively by non-normal disturbances. Second, the Jarque-Bera statistic also has power against other

[7]Given that the number of regressors fitted is often large relative to the sample size, we modify Jarque and Bera's (1980, p. 257) statistic to be $\xi_5(2) = [(T-k)/6]\cdot[\widehat{SK}^2+\widehat{EK}^2/4]$ where SK and EK are skewness and excess kurtosis respectively. $\xi_5(2)$ is asymptotically distributed as $\chi^2(2)$ under the null hypothesis of normality, in which case SK=EK=0.

alternatives, as suggested by it being *in*significant when unit homogeneity of money with respect to prices is not imposed.

Taking this evidence together, equation (1) is not an adequate characterization of the data and is not consistent with the hypothesis of a constant money-demand equation, homogeneous of degree one in prices over the last century, even though Friedman and Schwartz state that

> [t]his parallelism[8] is a manifestation of the stable demand curve for money plus the excellence of the simple quantity theory approximation. (p. 7)

The equations for nominal income and prices in Friedman and Schwartz were not further investigated because, as explained in Hendry and Ericsson (1985, Appendix D), they are approximately re-normalizations of their money-demand regression and so do not provide additional inferences; cf. pp. 344, 417. Additionally, any inferences based on (b)–(d) are hazardous because the split-sample Chow statistics for (b) and (c) are highly significant, and the Durbin-Watson statistics in (c) and (d) are less than the 5% lower bound.

When interpreting the outcomes of the above tests, four points should be borne in mind. Firstly, the rejections are not mutually independent sources of information since the implicit assumptions of any given test are shown to be invalid by the outcomes on other tests. Secondly, *none of the relevant hypotheses could have been tested by Friedman and Schwartz for this equation without their having obtained a rejection.* This shows the power of statistical evaluation to reveal the potential for model improvement and the ability of the data to discriminate between empirical models. Thirdly, discovering that their empirical model has a variety of specification problems has no implications for the existence (or otherwise) of a correctly specified empirical model of money demand being homogeneous in prices and having constant parameters. Finally, rejection of any null hypothesis does not

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[8]Of nominal income and the nominal quantity of money, and of the rate of change of nominal income and the rate of change of the nominal quantity of money.

imply that the alternative is correct. For example, constancy may have been rejected because of dynamic mis-specification, and not because the underlying money-demand model has non-constant parameters; or, in small samples, an F–test could yield a misleading outcome because of a highly non-normal error distribution. These problems frequently arise in approaches which proceed by generalizing simple models (see Hendry (1979)).

Thus, we disagree with the methodology adopted by Friedman and Schwartz of basing many of their inferences on the analysis of simple empirical models:

> Our ultimate objective is an explanation of the behavior of velocity, which is to say, of the quantity of money demanded, that takes account simultaneously of all the variables affecting velocity. Nonetheless, we believe that this ultimate objective is better approached indirectly, by examining variables one or two at a time, than by what has become the prevailing fashion in econometric work, the immediate computation of multiple regressions including all variables that can reasonably be regarded as relevant. We believe that the indirect approach yields insights that cannot be obtained from the more sweeping approach – that multiple correlations with many variables are almost impossible to interpret correctly unless they are backed by more intensive investigations of smaller sets of variables. Accordingly, we shall proceed in the following sections to consider variables one or two at a time, and reserve to section 6.7 estimating their simultaneous effect. [footnote:] The indirect approach played a critical role in the formulation of the multiple regressions that we calculate in section 6.7. ... (p. 215)

This quote raises four methodological issues. Firstly, the claim that simple models yield insights is frequently mistaken since the associated measures of relationship and of uncertainty are misleading unless such models are coherent with the data. Secondly, it is incorrect to test hypotheses in one model and infer that the outcome will hold in generalizations of that model unless all the additional influences are orthogonal to those already included and remain so throughout the sample. Thirdly, although we concur that it is difficult to interpret multiple regressions, this does not justify fitting mis-specified sub-models. Finally, the penultimate sentence of the above quote conflates the issues of estimation and modeling by seeming to imply that the only step remaining after examining the smaller sets is to estimate their joint effect: that would be true only if there were no interactions. The crucial issue is that a reject outcome at any stage of modeling invalidates *all previous inferences*, so that decision-taking during model generalizations is ill-founded. In Section III, we briefly describe an alternative methodology which resolves many of these issues and also reveals that there are other approaches to understanding general models. Moreover, a constructive empirical task remains to be undertaken and we turn to that in Section IV, using the model developed by Friedman and Schwartz as a benchmark against which to compare other equations.

Before proceeding, we address the question of whether to use the annual observations or the phase-average data, the latter being those which Friedman and Schwartz chose to analyze:

> In order to isolate the longer-term relations that are our primary concern, we have converted our basic data, which are annual, into a form designed to be free from the shorter-term movements that are called business cycles. ... The device we have used to free the data from cyclical fluctuations is to take as our basic observation an average of annual observations over a cycle phase... (p. 13)

This device is taken from the NBER approach to business cycle analysis, as documented by Arthur Burns and Wesley Mitchell (1946). Friedman and Schwartz argue that phase-averaging reduces serial correlation arising from the business cycle (p. 78) and attenuates measurement errors (p. 86). Doing so is important to sustain the validity of their statistical analyses since no explicit account is made for (e.g.) biases in coefficient estimates and estimated standard errors resulting from residual autocorrelation. Friedman and Schwartz claim that phase-averaging successfully isolates longer-run behavior:

> All in all, we conclude that our phase bases do eliminate the bulk of the systematic cyclical fluctuation. (p. 81)

The use of phase-average data raises three distinct issues: the theoretical statistical effects of phase-averaging (*qua* aggregation), the observed effects of phase-averaging on Friedman and Schwartz's data, and the impact of selecting the intervals over which to average by prior analysis of an interrelated data set. Julia Campos, Ericsson, and Hendry (1990) address these issues and show that (i) the aggregation from annual data to phase averages entails a loss of information by retaining only a subset of a previously averaged annual data set, (ii) phase-averaging does not materially reduce the serial correlation in their data, and (iii) phase-averaging involves a data-based set of filters, but ignores the statistical consequences of such filters on later inferences. Figure 6 illustrates points (i) and (ii) for the time-series on velocity by jointly plotting $\{v_t\}$ and $\{\bar{v}_j\}$. Neither the variance nor the autocorrelation of $\bar{v}_j$ is notably smaller than that of v_t, whereas period-to-period changes in $\bar{v}_j$ are much larger than those in v_t due to the observations being a phase rather than a year apart.

Thus, because of these unsatisfactory characteristics of phase-averaging, we analyze Friedman and Schwartz's original annual observations in an attempt to develop a money-demand equation which encompasses (1) and accounts for its failures. We next summarize the statistical framework and the associated theory of testing on which both the above analysis and the later models are based.

III. Econometric Modeling and Economic Theory

This section discusses the nature of empirical econometric models and serves as a guide to our uses of test statistics. Modeling is seen as an attempt to characterize data properties in simple parametric relationships which are interpretable in light of economic knowledge, remain reasonably constant over time, and account for the findings of pre-existing models. For general expositions of the associated methodology, see Hendry and Richard (1982, 1983), Hendry (1983, 1987), Hendry and Kenneth Wallis (1984), Ericsson and Hendry (1985), Aris Spanos (1986), and Christopher Gilbert (1986).

The formal methodology is based on the statistical theory of data reduction. Empirical models arise from *transformations* and *reductions* of the data generation process (DGP, a shorthand for the actual mechanism which generated the observed data) which is characterized by the joint density of the observable variables. The main steps producing models from the DGP are aggregation, algebraic transformation of data, marginalization,

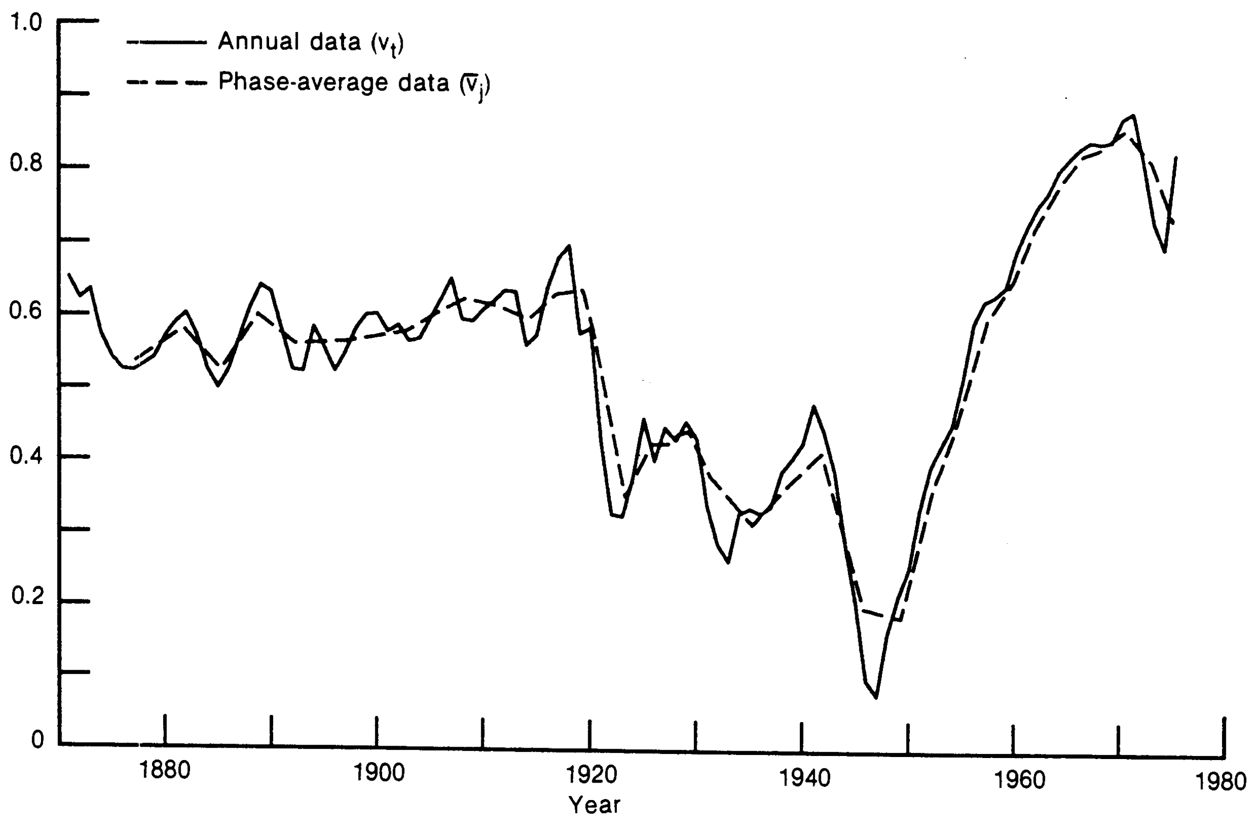

Figure 6. The log of the velocity of money: annual and phase-average data.

sequential conditioning, contemporaneous conditioning, truncation of lag length, and linearization. Each step entails a corresponding reduction and/or transformation of the parameters of the DGP to produce the reduced re-parameterization in the econometric model. As a consequence, *all empirical models are derived entities.* Additionally, given the observed data and a formal model specification, the model's error process must contain everything in the data not explicitly allowed for by the model, and hence it also is derived rather than autonomous. This implies that models can be designed to satisfy pre-assigned criteria, as when residual autocorrelation is removed by a Cochrane-Orcutt transformation. While this example may be optimal in some circumstances, in others it entails invalid restrictions; cf. Hendry and Mizon (1978).

The applied methodology distinguishes between the constructive and destructive roles of econometrics. The former corresponds to John Herschel's (1830) "context of discovery" and concerns issues of model design such as research efficiency. The latter is Herschel's "context of justification" and, for model evaluation, was illustrated in Section II. Criteria relevant to both design and evaluation are entailed by the conditions required to validate the (sometimes implicit) sequence of reductions and transformations from which empirical models arise. Clearly, the validity of one-to-one data transformations is not an issue. However, reductions may entail a loss of information, and to judge that loss we use a taxonomy which partitions the universe of available information into disjoint sets: (a) economic theory, (b) the past, (c) present, and (d) future data of one's own model, (e) the measurement system of the data, and (f) the data of alternative models. These information sets generate the following criteria for design (in the context of discovery) and for evaluation (in the context of justification): (A) theory consistency, (B) innovation errors, (C) weak exogeneity, (D) parameter constancy, (E) data admissibility, and (F) encompassing. A model is said to be *congruent* if it satisfies all of (A)–(F) and hence captures the salient features of the data and delivers reliable inferences on economic issues. Many of the criteria from (A)–(F) are standard and include the statistical and economic interpretation of estimated coefficients and the validity of a priori restrictions; goodness-of-fit and the absence of both residual autocorrelation and heteroscedasticity; valid exogeneity; predictive ability and parameter constancy; appropriate functional form; and the ability of a model to account for the properties of alternative models.

In the context of discovery, satisfying a given criterion implies no loss of information from the associated reduction. In the context of evaluation, the criteria are interpretable as null hypotheses and Table 2 summarizes the associated statistics. Since satisfying these criteria is a necessary condition for an empirical model to be congruent, failing any one of them is a sufficient condition for rejection. Conversely, since the route chosen for discovery cannot affect the *intrinsic validity* (or otherwise) of the finally selected model, issues of model design only concern the *efficiency* of alternative model-building strategies. Thus we emphasize both explicitly *designing* empirical economic models to be congruent and rigorously *testing* the congruency of given model specifications. Since the latter takes models as formulated by their proprietors, the evaluative role of econometrics is not impugned by any of the current methodological debates; cf. Christopher Sims (1980), Edward Leamer (1983), Michael McAleer, Adrian Pagan, and Paul Volker (1985), and Hendry and Mizon (1985). The failure to emphasize evaluation and testing is a major lacuna in Leamer's analysis, and our paper is a counter-example to the view that data evidence is not able to discriminate between alternative hypotheses. Rigorous evaluation of empirical claims seems a necessary first step towards taking the con out of economics, and indeed, Halbert White (1988) has shown that a sufficiently thorough testing procedure will arrive at a well-specified characterization of the DGP with confidence approaching certainty as the sample size grows without bound. The remainder of this section discusses the above criteria, their inter-relationships, and their role in progressive research strategies.

A. *Theory Consistency*

Economic theory often suggests long-run relationships between economic variables, such as between two variables Y and Z (e.g., money and income) of the form $Y = KZ$

Table 2. Criteria for evaluating and designing econometric models

Null	Alternative	Statistic	Sources
(B)	first-order residual autocorrelation	dw	Durbin and Watson (1950, 1951)
(B)	q^{th}-order residual autocorrelation	$\xi_2(q)$; $\eta_2(q,T-k-q)$	Box and Pierce (1970); Godfrey (1978), Harvey (1981, p. 173)
(B)	q invalid parameter restrictions	$\eta_3(q,T-k-q)$	Johnston (1963, p. 126)
(B)	q^{th}-order ARCH	$\xi_4(q)$, $\eta_4(q,T-k-2q)$	Engle (1982)
(B)	skewness and excess kurtosis	$\xi_5(2)$	Jarque and Bera (1980)
(B)	heteroscedasticity quadratic in regressors (q quadratic terms)	$\eta_6(q,T-k-q-1)$	White (1980), Nicholls and Pagan (1983)
(B)	q^{th}-order RESET	$\eta_7(q,T-k-q)$	Ramsey (1969)
(C)	q instrumental variables not independent of errors	$\xi_8(q-k)$; $\eta_8(q-k,T-q)$	Sargan (1958, 1964); Sargan (1980a, p. 1136)
(D)	parameters not constant over subsamples	$\eta_9(k,T-2k)$	Fisher (1922), Chow (1960, pp. 595ff)
(D)	predictive failure over a subset of q observations	$\eta_1(q,T-k-q)$	Chow (1960, pp. 594–595)

Notes.

a. There are T observations and k regressors in the model under the null. The value of q may differ across statistics, as may those of k and T across models and samples.

b. $\xi_i(q)$ and $\eta_i(q,r)$ denote statistics which have central $\chi^2(q)$ and $F(q,r)$ distributions respectively under a common null and against the i^{th} alternative. Thus, $\xi_2(q)$ and $\eta_2(q,T-k-q)$ both test for q^{th}-order residual autocorrelation.

c. We have labelled the Chow statistic $\eta_1(q,T-k-q)$ both to highlight the pre-eminence of the issue of constancy in the substantive debate on monetary behavior and because of its crucial role as an indirect test of weak exogeneity through testing the conjunction of hypotheses embodied in super exogeneity. The covariance test statistic $\eta_9(k,T-2k)$ is often (and confusingly) referred to as the "Chow statistic" although Chow (1960, p. 592) was well aware of its presence in the literature.

where K is a constant. In logs, that theory becomes $y = \kappa + z$ with $\kappa = \ln(K)$. *Cointegration* links the economic notion of a long-run relationship between variables with a statistical model of those variables.[9] For convenience, we adopt the time-series notation that a non-stationary variable integrated of order d [i.e., $I(d)$] requires differencing d times to make it stationary [i.e., $I(0)$]. For $I(1)$ variables y_t and z_t, arbitrary linear combinations $y_t + \delta z_t = u_t$ are also $I(1)$. If a value of δ exists such that u_t is $I(0)$, then y_t and z_t are "cointegrated" and so don't drift too far apart, e.g., because of agent behavior. Proportionality between Y and Z implies $\delta = -1$. Cointegration of y_t and z_t can be tested by testing for the absence of a unit root in u_t: that is, whether u_t is $I(0)$ rather than $I(1)$, with $I(0)$ being necessary for theory consistency.

B. *Innovation Errors*

Dynamic specification influences model design because of the statistical and economic importance of (white-noise) innovation errors. As a rule, dynamic *mis*-specification invalidates inference, so dynamics cannot be safely ignored. There are many possible dynamic formulations for economic models (e.g., see Hendry, Pagan, and Denis Sargan (1984)); but since cointegration implies and is implied by the existence of a (dynamic) error-correction representation of the relevant variables, we consider the properties of and intuition behind error-correction models (cf. Sargan (1964), James Davidson, Hendry, Frank Srba, and Stephen Yeo (1978, pp. 679–682), and Mark Salmon (1982)). For expositional simplicity, suppose that only the current values of y and z and their one-period lags matter, that y and z are cointegrated, and that the relationship is linear, in which case:

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[9]See Clive Granger (1981), Engle and Granger (1987), Hendry (1986), Stock (1987), Peter Phillips (1987), and Jeff Hallman (1987). Engle (1987) and Juan Dolado and Tim Jenkinson (1987) survey the literature.

$$(4) \quad y_t = \alpha + \alpha_1 y_{t-1} + \beta_0 z_t + \beta_1 z_{t-1} + \nu_t \qquad \nu_t \sim \mathrm{IN}(0,\sigma_\nu^2) .$$

In (4), long-run homogeneity between y and z requires $\alpha_1+\beta_0+\beta_1=1$. Rewriting the autoregressive-distributed lag relationship in (4) by imposing that restriction gives:

$$(5) \quad \Delta y_t = \alpha + \beta\Delta z_t + \gamma(y_{t-1} - z_{t-1}) + \nu_t$$

where α, β, and γ are the corresponding *unrestricted* parameters.[10] Intuitively, the term $\beta\Delta z_t$ reflects the immediate effect of a change in z_t on y_t. The term $\gamma(y_{t-1} - z_{t-1})$ (with γ negative for dynamic stability and therefore cointegration) is statistically equivalent to having $\gamma(y_{t-1} - \kappa - z_{t-1})$ instead, and hence reflects the effect on Δy_t of having y_{t-1} out of line with $\kappa + z_{t-1}$. Such discrepancies could arise from errors in agents' past decisions, with the presence of $\gamma(y_{t-1} - z_{t-1})$ reflecting their attempts to correct such errors; so, (5) belongs to the class of *error-correction* models (ECMs).[11] For a steady-state growth rate of Z_t equal to g (i.e., $g = \Delta z_t = \Delta y_t$) and $\nu_t=0$, then, solving (5), we have:

$$(6) \quad Y_t = Z_t \cdot \exp\{[-\alpha+g(1-\beta)]/\gamma\} ,$$

reproducing the assumption of proportionality between Y_t and Z_t from the non-stochastic steady-state theory. This example is readily extended to include further lags, non-proportionality, and nonlinearity, and so is representative of a large class of models which satisfy steady-state economic-theoretic restrictions and allow for general dynamic responses.

The choice of normalization of the cointegrating vector is an unresolved issue, but both economics and the data can help. Theory may suggest which variables agents aim to control and on which ones they condition their plans; and as parameter constancy in an empirical model is *not* invariant to normalization when the economy exhibits structural change, data can preclude some choices. Thus, normalization and conditioning both lead to the next two issues, exogeneity and parameter constancy.

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[10]With the lag operator L defined as $Lx_t = x_{t-1}$, we let the difference operator Δ be (1–L); hence $\Delta x_t = x_t - x_{t-1}$. More generally, $\Delta_r^q x_t = (1-L^r)^q x_t$. If q (or r) is undefined, it is taken to be unity.

[11]Alternatively, Stephen Nickell (1985) justifies error-correction mechanisms as arising from the optimal response of economic agents in certain dynamic environments.

C. *Weak Exogeneity*

The four distinct concepts of exogeneity, namely weak, strong, super and strict, discussed by Engle *et al.* (1983), correspond to different notions of being "determined outside the model under consideration" according to the purposes of the inferences being conducted, i.e., conditional inference, prediction, policy analysis, and forecasting, respectively.[12] In no case is it legitimate to "make variables exogenous" simply by not modeling them. Weak exogeneity can occur when agents act contingently on available information. If agents use that information efficiently, innovation errors are implied, relating back to the issue of dynamic specification. Weak exogeneity is testable, often as an implication of super exogeneity (and so of models having constant parameters). Section IV further discusses exogeneity in the context of the empirical model.

D. *Parameter Constancy*

Parameter constancy is at the heart of model design from both statistical and economic perspectives. Since economic systems are far from being constant, and the coefficients of derived ("non-structural" or "reduced form") equations may alter when any of the underlying parameters or data correlations change, it is important to identify empirical models which have reasonably constant parameters which remain interpretable when change occurs. As seen in Section II above and Section IV below, recursive estimation provides an incisive tool for investigating parameter constancy, both through the sequence of estimated coefficient values and via the associated Chow statistics for constancy.[13] The Chow statistics also play crucial roles (a) for testing weak exogeneity indirectly through testing the conjunction of hypotheses embodied in super exogeneity and

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[12]This formulation is also discussed in Jean-Pierre Florens and Michel Mouchart (1985a, 1985b), and builds on Tjalling Koopmans (1950) and Ole Barndorff-Nielsen (1978).

[13]These tests of constancy are intimately related to tests of forecast accuracy; cf. R. Brown, James Durbin, and J. Evans (1975), Hendry (1979), and Jan Kiviet (1987). Jean-Marie Dufour (1982) elegantly summarizes recursive techniques and their implications.

(b) for testing feedback versus feedforward empirical models; cf. Engle *et al.* (1983) and Hendry (1988).

E. *Data Admissibility*

Many economic variables are inherently positive, a model property ensured by the use of logarithmic transformations of the data. However, if the resulting model does not correspond to the DGP, the cost of enforcing data admissibility may be a loss of parameter constancy.

F. *Encompassing*

This concept can be understood intuitively as follows. Suppose Model 1 *predicts* $\tilde{\boldsymbol{\theta}}$ as the value for the parameter $\boldsymbol{\theta}$ in Model 2, whilst Model 2 *actually* has the estimate $\hat{\boldsymbol{\theta}}$. Model 1 encompasses Model 2 if $\tilde{\boldsymbol{\theta}}$ is "statistically close" to $\hat{\boldsymbol{\theta}}$, so that Model 1 explains why Model 2 obtains the results it does. To the extent that Model 1 accurately mimics the DGP, it will encompass Model 2. For single equations estimated by least squares, a necessary condition for encompassing is *variance dominance* where one equation variance-dominates another if the former has a smaller error variance.[14] Thus, encompassing defines a partial ordering over models, an ordering related to that based on goodness-of-fit; however, encompassing is more demanding. It is also consistent with the concept of a progressive research strategy (e.g., see Imre Lakatos (1970) and Alan Chalmers (1976)), since an encompassing model is a "sufficient representative" of previous empirical findings.[15]

These six criteria not only characterize the conditions required to sustain reductions, they also correspond to concepts central to econometric analysis. Taking the reductions in turn, a set of current-dated variables can be eliminated (marginalized) without loss of information if those retained correspond to *sufficient statistics*, and lagged variables can be

[14]Formally, variance dominance refers to the underlying (and unknown) error variances. Without loss of clarity, we often will say a model variance-dominates another if the *estimated residual* variance of the former is smaller than that of the latter.

[15]For comprehensive accounts of tests for encompassing and of related non-nested hypothesis tests, see Mizon and Richard (1986), Mizon (1984), James MacKinnon (1983), and Hashem Pesaran (1982).

marginalized if they do not *Granger-cause* the remaining variables. Sequential conditioning generates *innovation errors*, and contemporaneous conditioning is valid if the variables so treated are weakly *exogenous* for the parameters of interest. The concept of *encompassing* introduced above determines the limits to model reduction, i.e., the degree of *parsimony* feasible. As shown in Hendry and Richard (1987), parsimonious encompassing (where the smaller model accounts for the results of a larger model within which it is nested) is transitive, anti-symmetric, and reflexive, thus defining a partial ordering over models and thereby sustaining a progressive research strategy.

IV. Econometric Modeling of Money Demand Using the Annual Data

This section develops a conditional econometric model of money demand on the annual data series for 1878–1970 only (T = 93) since the data from 1971 to 1975 appear to have a different stochastic structure (see (11) below). We follow the procedures outlined in Section III, representing the joint density of (m_t, p_t, i_t, RS_t, $R\ell_t$) in terms of an autoregressive-distributed lag model for m_t conditional on (p_t, i_t, RS_t, $R\ell_t$) and a marginal model for (p_t, i_t, RS_t, $R\ell_t$). The conditional model is simplified to an ECM and evaluated in light of the model design criteria.[16] Phillips (1988) and Phillips and Bruce Hansen (1989) demonstrate that this error-correction approach produces nearly optimal inferences in cointegrated processes. Such a methodology of "learning from the data" whilst being guided by economic theory in the interpretation of results contrasts with the approach adopted by Friedman and Schwartz of using regression results to corroborate their economic theory. We conclude this section by considering two important issues for economic policy: the constancy of the money-demand function and the exogeneity of money.

The economic framework of our empirical model is that of a log-linear long-run money-demand function:

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[16]Cf. Hendry and Mizon (1978) and McAleer *et al.* (1985) on modelling from general to simple, and Leamer (1978) for an analysis of specification searches.

$$(7) \qquad (m-p)^* = \delta_0 + \delta_1 i - \delta_2 RS - \delta_3(1+\dot{p}) ,$$

where * denotes the long-run target value and $\dot{p}$ is the rate of inflation; cf. Friedman (1956). Equation (7) parallels the condition $y=\kappa+z$ in Section III.A. Dynamic adjustment is characterized by a contingent planning model of the form:

$$(8) \qquad \Delta(m-p)_t = \lambda_0(L)\Delta(m-p)_{t-1} + \lambda_1(L)\Delta p_t + \lambda_2(L)\Delta i_t + \lambda_3(L)\Delta rs_t + \lambda_4(L)\Delta r\ell_t + \lambda_5[(m-p)^*_{t-1} - (m-p)_{t-1}] + \epsilon_t ,$$

where $\lambda_i(L)$ $(i=0,\ldots,4)$ denotes a finite polynomial in the lag operator L and ϵ_t is the deviation of the outcome from the plan. This approach generalizes the conventional partial adjustment model, allows separate reaction speeds to the different determinants of money demand (reflecting potentially different costs of adjustment and of disequilibrium), yet via the error-correction mechanism ensures that long-run targets are achieved (e.g., velocity and interest rates are cointegrated); cf. Hendry *et al.* (1984). Economically, (8) is related to a Miller–Orr/Milbourne theory of money adjustment, where the short-run factors determine money movements *given* the desired bands, and the longer-run factors influence the levels of the bands (e.g., see Gregor Smith (1986)). To be interpretable as a demand equation, $\lambda_1(1)\leq 0$, $\lambda_2(1)\geq 0$, $\lambda_3(1)\leq 0$, and $\lambda_4(1)\leq 0$; and for cointegration $\lambda_5<0$. However, the choice of parameterization (e.g., in terms of lagged first differences or higher-order differences) is arbitrary *within* lag polynomials, so no sign restrictions on individual polynomial coefficients can be imposed a priori. Moreover, since monetary theory does not yet specify how quickly in real time agents react to changes, the orders of the $\lambda_i(L)$ must be data-based.

Statistically, (8) is an ECM re-parameterization of an autoregressive-distributed lag model of the variables in levels, as is (5) of (4). A model such as (8) is of interest only if the regressors are weakly exogenous for the resulting parameters, which in turn must be constant and invariant to historical changes in the processes determining the marginal distributions. The error in (8) will be an innovation if the plan efficiently incorporates available information and the model is correctly specified. All of these issues are examined below in order to discriminate between contingent planning and expectations interpretations of the empirical model.

In Hendry and Ericsson (1983), we presented an autoregressive-distributed lag representation of money conditional on prices, incomes, and interest rates to establish the innovation error variance. That formulation was simplified to an ECM like (8) based on extant money-demand models for the UK, with a static-equilibrium solution of the form $v = -\delta_0 + \delta_2 RS$ (thus taking v_t and RS_t to be cointegrated) and an equation standard error of 1.71% of M.[17] Those results stimulated further studies, including an improved specification on the same information set in Andrew Longbottom and Sean Holly (1985), a nonlinear reformulation in Alvaro Escribano (1985), and an extended information set for 1875–1913 in Jan Klovland (1987).[18] Longbottom and Holly's and Escribano's models were significant improvements on our 1983 model (i.e., each of their models encompassed ours, but ours could not encompass either of theirs). However, neither of their models could encompass certain features of the other, indicating that an improved specification might be possible.

Continuing in a progressive research strategy, we utilize their (and our previous) evidence, beginning with the cointegration regression for v_t and RS_t:

$$(9) \qquad \widehat{(m-i-p)}_t = -\,0.309 - 7.00 RS_t$$

$$T = 1873\text{–}1970 \quad R^2 = 0.56 \quad \hat{\sigma} = 10.86\% \quad dw = 0.33 \quad ADF(1) = -2.77 \;.$$

(Adding $R\ell$ makes little difference, unsurprisingly if RS and $R\ell$ are cointegrated.) Exact significance levels are not available for David Dickey and Wayne Fuller's (1979, 1981) augmented statistic ADF(1) and for Sargan and Alok Bhargava's (1983) Durbin-Watson-based statistic when testing for a unit root in the residuals, but the 10% critical values in

[17]Hendry and Ericsson (1985) investigate the hypothesis that v_t is a random walk and conclude that there is little contrary evidence. Likewise, the data on m, i, p, m–p, rs, $r\ell$, and p* all behave like I(1) series, whereas their corresponding first differences behave like I(0) series. Nevertheless, equations (9) and (10) below show that a more general cointegrating relationship can be established.

[18]Klovland constructs a new measure of the own interest rate on M.

Engle and Granger (1987) based on simulation are respectively –2.84 and 0.32 for 100 observations, leading to an inconclusive outcome. Engle and Granger show that these tests have low power against highly dynamic stationary alternatives, so we cautiously proceed under the assumption of cointegration. Economically, the solution to (9) is within the framework of (7) and implies that a one percentage point increase in the short-term interest rate (e.g., 5% to 6%) reduces M relative to PI by *seven percent* in the long run.

Cointegration implies an error-correction representation, so to model the behavior of money we estimate an unrestricted fifth-order autoregressive-distributed lag equation related to (4): it is shown in Table 3 together with relevant test statistics.[19] The model in Table 3 generalizes on (4) by *inter alia* allowing the speed of adjustment to vary with the extent of disequilibrium via nonlinear error-correction terms. Following Escribano, Table 3 includes the lagged level, square, and cube of $\hat{u}_t$, the residual from (9). Three zero-one dummies (D_1, D_2, and D_3) which are unity for 1914–18, 1921–55, and 1939–45 respectively also appear. This regression satisfies all of the diagnostic checks reported and provides generally sensible estimates despite very high inter-correlations between regressors. Most coefficients of lags beyond three are negligible as well as insignificant, and deleting those lags lowers $\hat{\sigma}$. The entailed static solution is consistent with long-run price and income elasticities of around unity.

The representation in Table 3 was simplified to the error-correction model (10) using the approach described in Hendry (1983) of first transforming the model to an interpretable and near orthogonal specification paralleling (8) and then eliminating negligible and insignificant effects.

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[19]We have chosen five lags on the grounds that that implies 36 parameters estimated in Table 3 (vs. 93 observations total), in line with guidelines in Sargan (1980b, p. 880). Also, five lags implies a maximum lag of approximately one cycle.

Table 3.
A general autoregressive-distributed lag representation for money (m_t), conditional on incomes, prices, and interest rates

Variable	lag i (or index)						
	0	1	2	3	4	5	$\Sigma_{i=0}^{5}$
m_{t-i}	−1.0 (0.0)	1.316 (0.157)	−0.621 (0.226)	0.295 (0.242)	−0.091 (0.220)	0.00047 (0.111)	−0.100 (0.084)
p_{t-i}	0.447 (0.077)	−0.410 (0.120)	0.201 (0.119)	−0.176 (0.116)	0.083 (0.110)	−0.050 (0.074)	0.095 (0.093)
i_{t-i}	0.087 (0.072)	0.031 (0.121)	0.047 (0.090)	−0.024 (0.088)	0.034 (0.091)	−0.065 (0.071)	0.110 (0.078)
rs_{t-i}	−0.019 (0.00908)	0.014 (0.016)	−0.00417 (0.010)	0.00510 (0.011)	−0.00449 (0.011)	0.00407 (0.00889)	−0.00403 (0.013)
$r\ell_{t-i}$	−0.069 (0.045)	−0.075 (0.070)	0.147 (0.072)	−0.084 (0.075)	0.071 (0.073)	−0.00664 (0.052)	−0.016 (0.041)
$\hat{u}^{i}_{t-1}$		0.077 (0.092)	0.485 (0.204)	−1.821 (1.285)			
D_i		3.993 (1.220)	0.607 (1.751)	3.624 (1.024)			
constant	−0.201 (0.137)						

$T = 1878–1970$ $\quad R^2 = 0.99987$ $\quad \hat{\sigma} = 1.5535$

$dw = 1.94$ $\quad \xi_2(11) = 9.62$ $\quad \eta_2(3,54) = 0.46$

$\eta_4(4,49) = 1.39$ $\quad \xi_5(2) = 1.01$ $\quad \eta_6(39,17) = 0.23$

$\eta_7(2,55) = 1.28$

Nb. For readability, coefficients and estimated standard errors on D_1, D_2, and D_3 are reported times 100.

$$(10)\quad \widehat{\Delta(m-p)_t} = \underset{[0.06]}{0.45}\,\Delta(m-p)_{t-1} - \underset{[0.04]}{0.10}\,\Delta^2(m-p)_{t-2} - \underset{[0.04]}{0.60}\,\Delta p_t + \underset{[0.05]}{0.39}\,\Delta p_{t-1}$$

$$- \underset{[0.006]}{0.021}\,\Delta rs_t - \underset{[0.021]}{0.062}\,\Delta_2 r\ell_t - \underset{[0.59]}{2.55}\,(\hat{u}_{t-1}-0.2)\hat{u}^2_{t-1} + \underset{[0.002]}{0.005} + \underset{[0.6]}{3.7}\,(D_1+D_3)_t$$

$T = 1878\text{–}1970 \quad R^2 = 0.87 \quad \hat{\sigma} = 1.424\% \quad \eta_2(6,78) = 1.56 \quad \eta_3(27,57) = 0.50$

$\eta_4(4,76) = 1.24 \quad \xi_5(2) = 1.6 \quad \eta_6(15,68) = 0.87 \quad \eta_7(2,82) = 0.21$.

(See Table 2 above for definitions of the statistics.) $[\cdot]$ denotes heteroscedasticity-consistent estimated standard errors (see White (1980), Desmond Nicholls and Pagan (1983), and MacKinnon and White (1985)).

Concerning its economic interpretation, (10) is similar in form and in numerical parameter values to several successful money-demand models for the UK, cf. Hendry and Mizon (1978), Hendry (1979), John Trundle (1982), Davidson (1987), and Keith Cuthbertson (1988). Its coefficients satisfy the sign restrictions on the $\lambda_i(1)$ in (8) to be interpretable as a money-demand function. Their sizes imply large immediate responses to changes in inflation and interest rates, but slow adjustment subsequently via the error-correction term to remaining disequilibria. Inflation enters as $\Delta p_t+\Delta^2 p_t$ (approximately), which is a predictor of next period's inflation, optimal if prices vary quadratically. Thus, (10) has a forward-looking interpretation, albeit one based on *data functions* rather than on *models* of the right-hand side variables.[20] The coefficients correspond to nearly orthogonal decision variables (with only *two* of the twenty-eight regressor inter-correlations exceeding 0.5), consistent with (10) representing a contingent plan of agents who partition available information into conceptually separate entities.

The empirical parameterization in (10) exhibits multiple equilibria, with two corresponding to the long-run solution (9) and a third being that solution shifted by 20%. In that sense, the results are consistent with the use of an adjustment factor of about that

[20]Campos and Ericsson (1988) propose this interpretation to similar inflation terms entering an equation for consumers' expenditure.

order in Friedman and Schwartz. However, the dating of the disequilibria is determined by the values of $\hat{u}_{t-1}$ and operates over the entire sample, not just for the period 1921–55.

Concerning the statistical attributes of (10), the various diagnostic checks are insignificant (if regarded as test statistics) and indicate design of a model congruent with the information available. Even so, the range of alternatives considered is sufficiently large to endow (10) with some credibility. From η_2, the residuals are white noise and from η_3 also an innovation process against the information set in Table 3. There is no ARCH, RESET, or heteroscedastic evidence of mis-specification; the residuals are approximately normally distributed; and (10) encompasses our earlier models and those of Escribano and of Longbottom and Holly (but not conversely).[21] Figure 7 shows the actual and fitted values for the rate of change in real money over the sample period. Visual comparison of Figures 4 and 7 (noting the logarithmic scale in both) highlights the better fit of the annual model: the error variance of (10) is less than a tenth of that in (1). Although (10) has a rate of change as the dependent variable, it is an equation in log-levels because of the error-correction term, as shown in (4)–(5) above, so direct comparison of the two graphs is valid.

The two remaining issues are constancy and exogeneity. Any claim to the constancy of a model for money demand would need both constant parameters and a similar goodness-of-fit over each of the epochs described above for Figure 1; Section II above demonstrated that (1) has neither.[22] To investigate the constancy of our model (10), we adopt the

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[21]By appropriately (statistically) reducing the density for our model, one could derive an estimate of the parameters in Friedman and Schwartz's model. From that constructed estimate and the estimate which they actually obtain, one could test whether our model using annual data encompasses theirs using phase-average data. Note also that it is easy to construct examples for which the parameters in their model would not be constant over time but those in ours would be (e.g., the parameters in (10) are constant, p_t is Granger-caused by m_t, and the coefficients in that price equation change over time). Existence of the converse would immediately refute any claim to encompass their findings.

[22]A possible objection might be that a money-demand equation's "constancy" need not be precise but only relatively better than (say) the consumption function's constancy. Since Friedman and Schwartz assert that their model is indeed constant, such an objection is not germane. However, in response to Mayer (1982, p. 1534), we note that the UK consumption function was investigated in Hendry (1983) and was shown to be remarkably constant both before and after World War II.

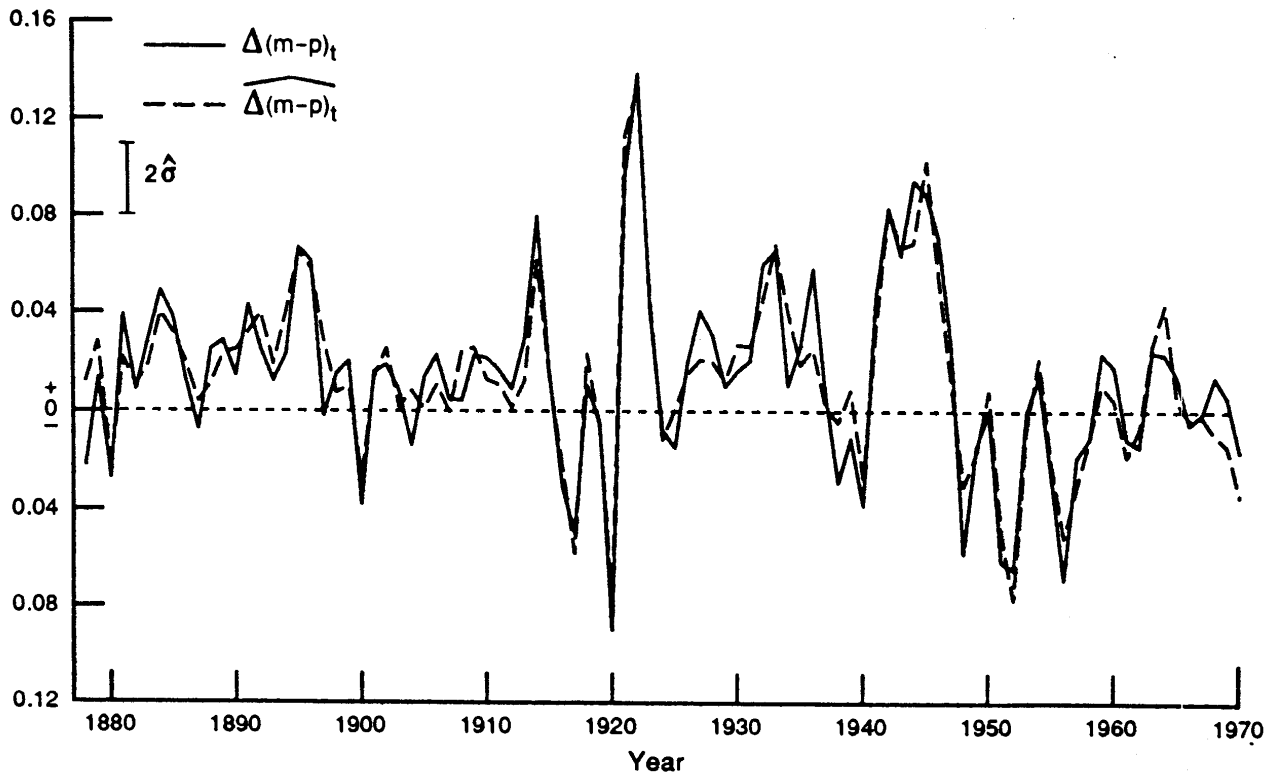

Figure 7. Equation (10): actual and fitted values for $\Delta(m-p)_t$.

recursive estimator since the one-step innovations allow the construction of sequences of constancy tests. Given the World Wars dummy (D_1+D_3), 1915 is the earliest date for a continuous sequence till 1970, although a separate exercise is possible for the subsample 1878–1913 (see Figure 11 below). Graphical presentation is efficient for reporting the large volume of evaluation output: Figure 8 records the one-step residuals and the corresponding calculated equation standard errors, i.e., $\{y_t-\hat{\beta}_t'x_t\}$ and $\{0.0\pm2\hat{\sigma}_t\}$ in a standard notation. *It is visually apparent that $\hat{\sigma}$ has varied little over the fifty-six year test period.* Further, none of the Chow statistics for the sequences (a) {1915, 1915–16, 1915–17, ..., 1915–70} *or* (b) {1915--70, 1916–70, 1917–70,..., 1969–70, 1970} is significant at even the 5% level. Figures 9 and 10 show the numerical values of two central coefficients, namely, those for Δp_t and the error-correction $(\hat{u}_{t-1}-0.2)\hat{u}_{t-1}^2$, together with plus-or-minus twice their sequentially estimated standard errors which provide an approximate 95% confidence interval.[23] Other than a minor fluctuation directly following World War I, the former varies by only a tiny fraction of its *ex ante* standard error; the latter is highly significant for the entire sample and also varies little relative to the estimated uncertainty. In both cases, the accrual of information is apparent from the reduction in the width of the confidence interval over time. Figure 11 graphs the one-step residuals for 1892–1913, using only 15 observations to initialize estimation: not only is $\hat{\sigma}$ constant, its value throughout is very close to that for the full sample. In brief, our *conditional* reformulation both fits well and is constant over the century to 1970, even though the time-aggregated phase-average data reveal the non-constancy of (1) despite the attendant loss of information.

Thus we reach the issue of the exogeneity of money. Our analysis has taken every contemporaneous variable other than m as if it were weakly exogenous (i.e., that it is valid to condition upon them for purposes of statistical inference), interpreting the coefficients of the resulting model as those of a money-demand equation; by construction, (10) is *invariant*

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[23]Note, however, that the coefficients within $\hat{u}_{t-1}$ are full-period estimates, as justified by the distributional results in Engle and Granger (1987).

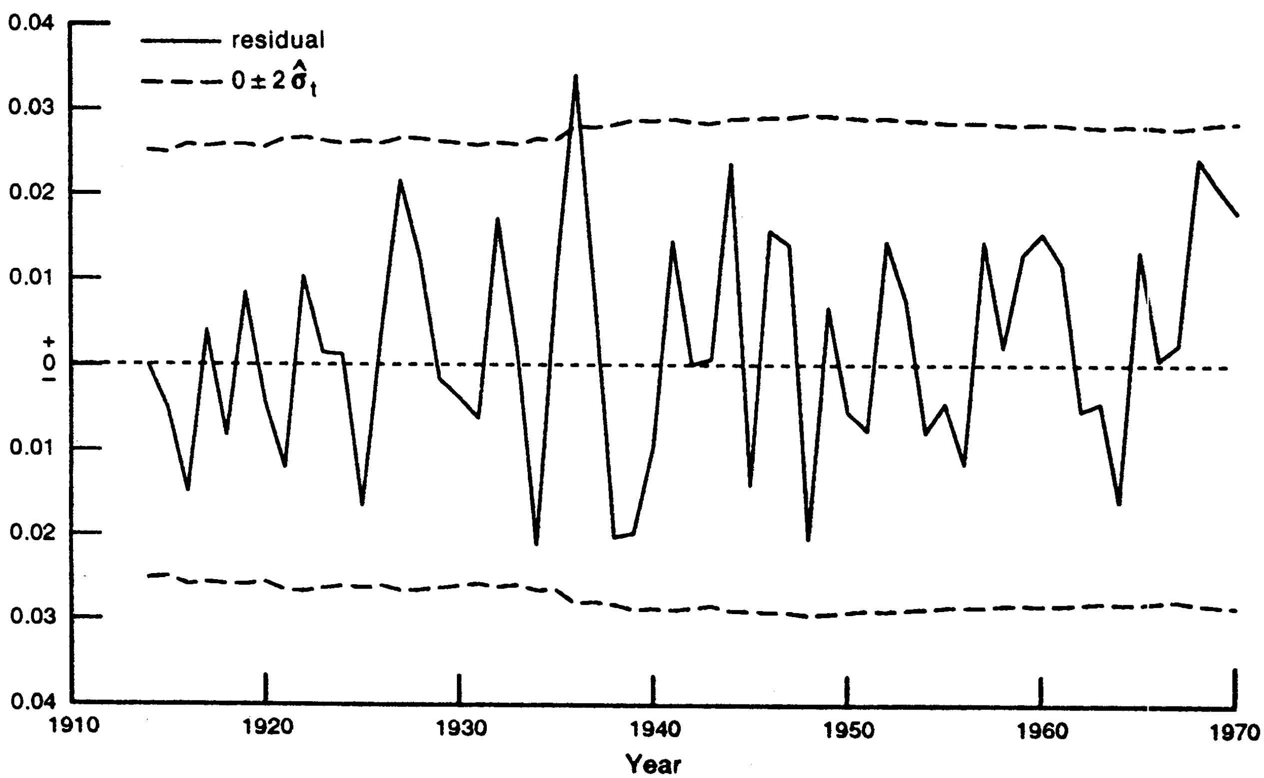

Figure 8. Equation (10): one-step residuals and the corresponding calculated equation standard errors.

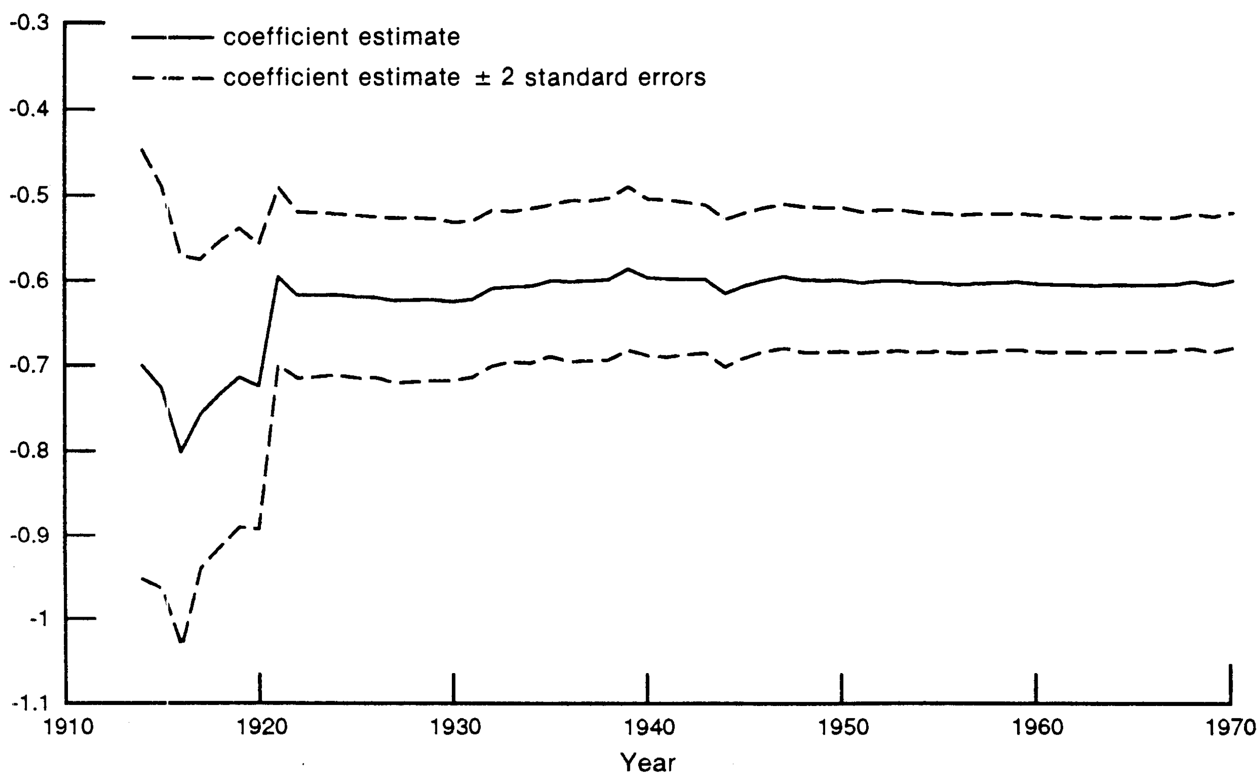

Figure 9. Equation (10): recursive estimation of the coefficient on Δp_t and its estimated standard error.

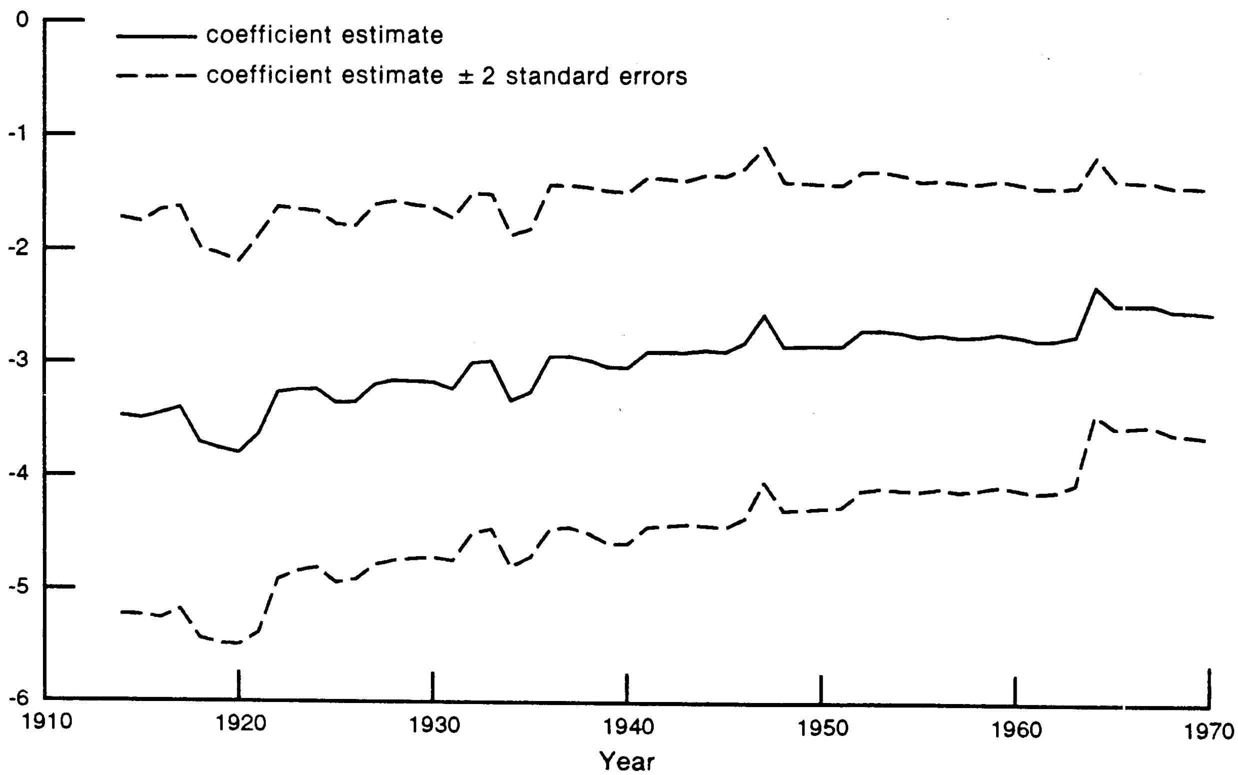

Figure 10. Equation (10): recursive estimation of the error-correction coefficient and its estimated standard error.

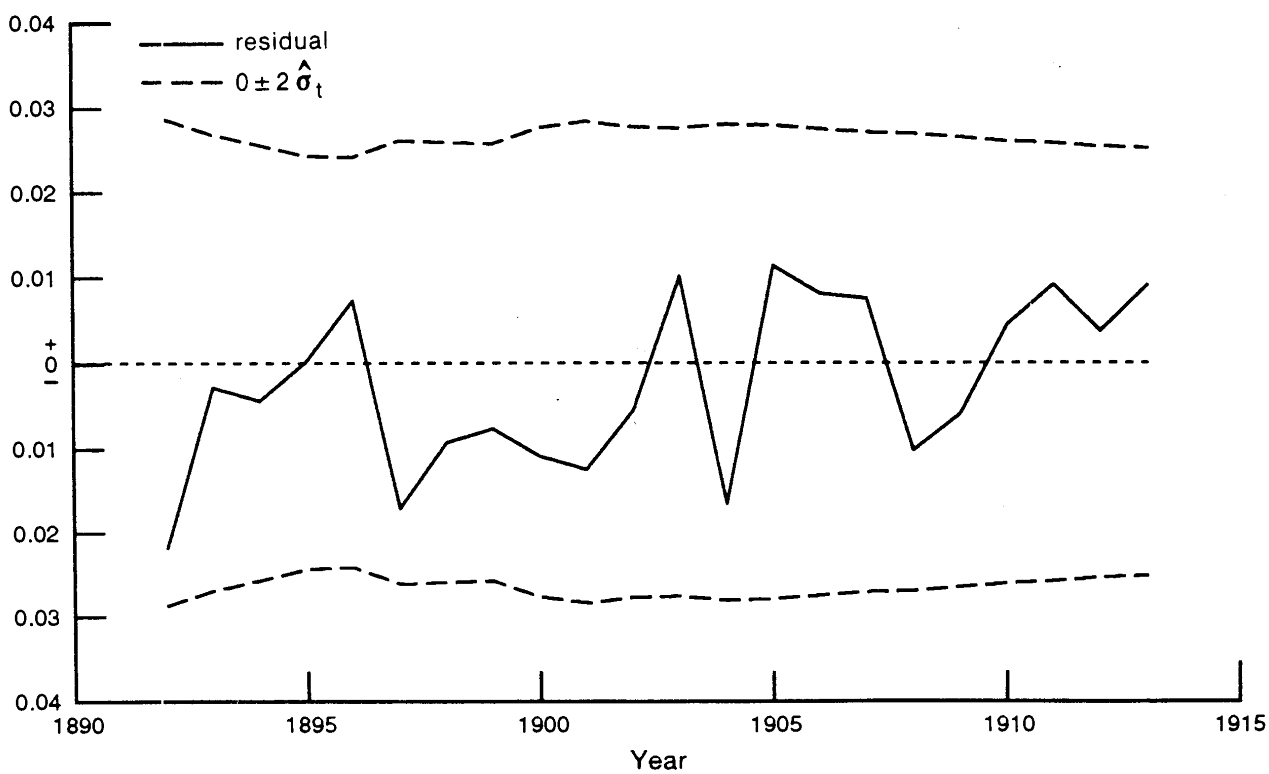

Figure 11. Equation (10) without $(D_1+D_3)_t$: one-step residuals and the corresponding calculated equation standard errors.

to whether Δm_t or $\Delta(m-p)_t$ is the regressand. The constancy of (10) reinforces our interpretation, which is also consistent with the institutional structure of UK money markets in which the money stock appears to be endogenously determined by the decisions of the private sector since the Bank of England in effect acts as a lender of the first resort by standing ready to rediscount first-class bills at the going Bank Rate or Minimum Lending Rate (see R. Hawtrey (1938), Goodhart (1984), and Congdon (1983) *inter alia*). Its constancy suggests that the conditioning variables may be super exogenous for the demand parameters over the sample, i.e., that the parameters of the conditional model remain constant even though the DGP of the conditioning variables changes over the sample. The exogeneity of prices and endogeneity of money are substantive issues, noting that it is commonplace in macroeconomics to determine prices via the money-demand equation, taking income, interest rates, and an observed money supply as given and equating supply to demand; cf. Robert Barro (1987, pp. 128ff, 195ff). In particular, the empirical super exogeneity of prices (shown below) invalidates "inverting" the money-demand equation to obtain prices. Engle and Hendry (1989) show that several implications of super exogeneity are testable.

First, direct tests of super exogeneity can be constructed, but they require additional observables, the relevance of which to (10) is that those observables should not have been used in model design (e.g., none of the variables dropped in simplifying from Table 3 to (10) would give the tests power). For this data, the crucial issue is the weak exogeneity of Δp_t since, if that is accepted, (10) cannot sustain the interpretation of determining prices with money exogenous. The additional instruments we have tried are a trend and current and lagged US inflation (Δp_t^* and Δp_{t-1}^*), using a recursive instrumental variables estimator to conjointly investigate constancy (see Hendry and Adrian Neale (1987)). On endogenizing Δp_t, $\hat{\sigma}$ remains virtually unchanged at 1.44% and Sargan's (1958) statistic for testing the validity of the instruments yields $\xi_8(2) = 3.62$, justifying the choice of instruments and being consistent with the weak exogeneity of Δp_t.[24] Moreover, the demand equation is constant despite the manifest non-constancy of the instrumenting equation (cf. Figure 12), revealing how informative this data set is and precluding a forward-looking expectations interpretation of (10); cf. Hendry (1988).[25]

Second, super exogeneity is not invariant to alternative factorizations of the joint density of money and prices when parameters in that density are not constant over time. That is, if the model (10) were inverted to make Δp_t the regressand, conditional on Δm_t as an exogenous variable, then the resulting equation should be non-constant. This is the case, as seen in Figure 13 which records the behavior of the estimated coefficient of Δm_t in the inverted equation. Further, the equation standard error becomes 2.6% and, unlike (10), the inverted equation cannot encompass the simple model that Δp_t^* determines Δp_t through a purchasing power parity condition: $\eta_3(1,83) = 14.9$.

This evidence is inconsistent with the hypothesis that, over the period 1878–1970, exogenous money determined prices in the UK via a stable money-demand function, *precisely because we have established a constant money-demand model conditional on prices.* In Hendry and Ericsson (1986), we propose an alternative mechanism for money causing inflation, one through the long-run effects of deviations from purchasing power parity.

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[24]We also investigated the assumed *joint* weak exogeneity of prices and short- and long-term interest rates in (10). (The weak exogeneity of income is not at issue because it appears only at a lag, via the error correction term.) When estimated with Δp_t^*, Δp_{t-1}^*, rs_{t-1}, rs_{t-2}, $r\ell_{t-1}$, $r\ell_{t-2}$, and a trend as instruments and treating $\Delta(m-p)_t$, Δp_t, Δrs_t, and $\Delta_2 r\ell_t$ as endogenous, $\hat{\sigma}$ increases only slightly to 1.56%, the coefficients remain virtually unchanged from (10), and Sargan's (1958) statistic is $\xi_8(4)=4.96$ (insignificant). Further, estimation of the reduced-form equations for Δp_t, Δrs_t, and $\Delta_2 r\ell_t$ by recursive multivariate least squares reveals non-constancy in each. If there were simultaneity bias in (10), the parameter estimates in (10) would change as those in the reduced-form equations did; thus the *constancy* of (10) in spite of non-constant reduced form equations implies the weak exogeneity of prices and interest rates. See Hendry, Neale, and Srba (1988) on recursive multivariate least squares, and Jean Bronfenbrenner (1953) on the relationship between simultaneity bias and reduced form parameters.

[25]See Engle (1984) for a survey of exogeneity tests and Kiviet (1985, 1987) for finite-sample evidence on their performance.

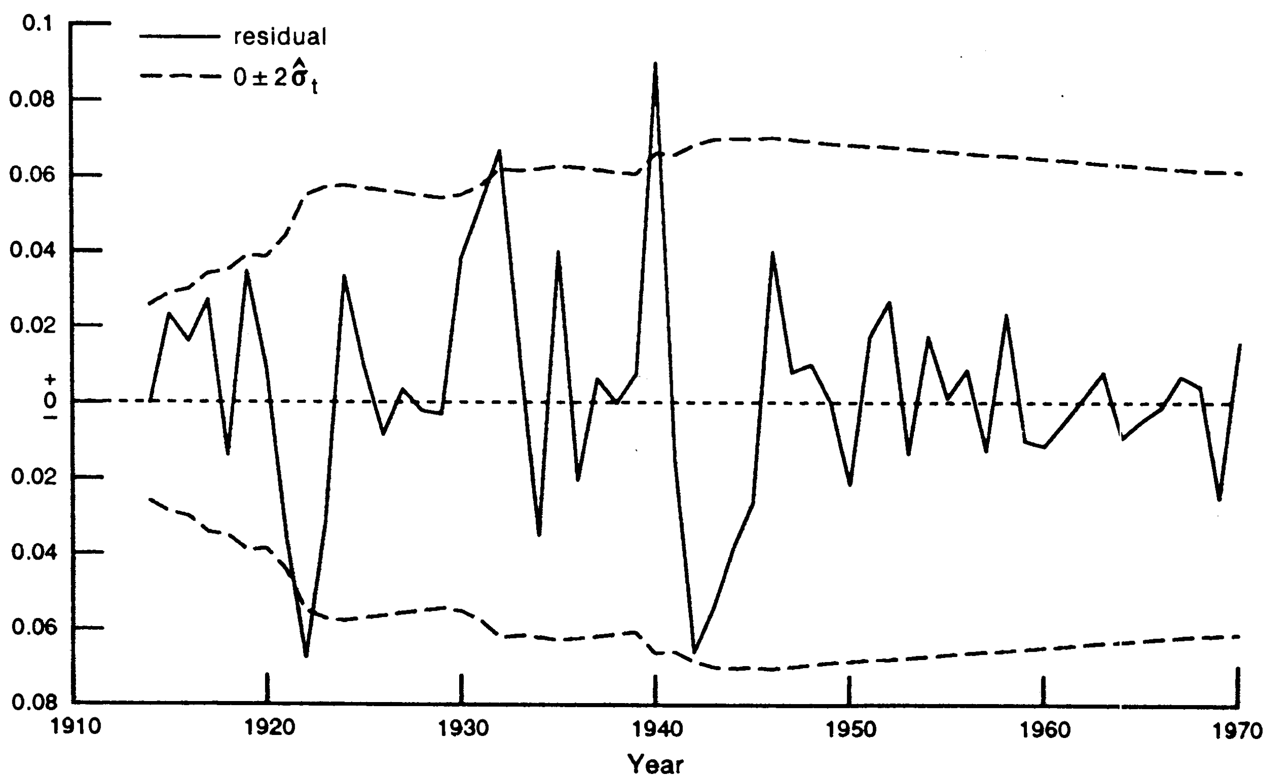

Figure 12. One-step residuals from the instrumenting equation for Δp_t using Δp_t^*.

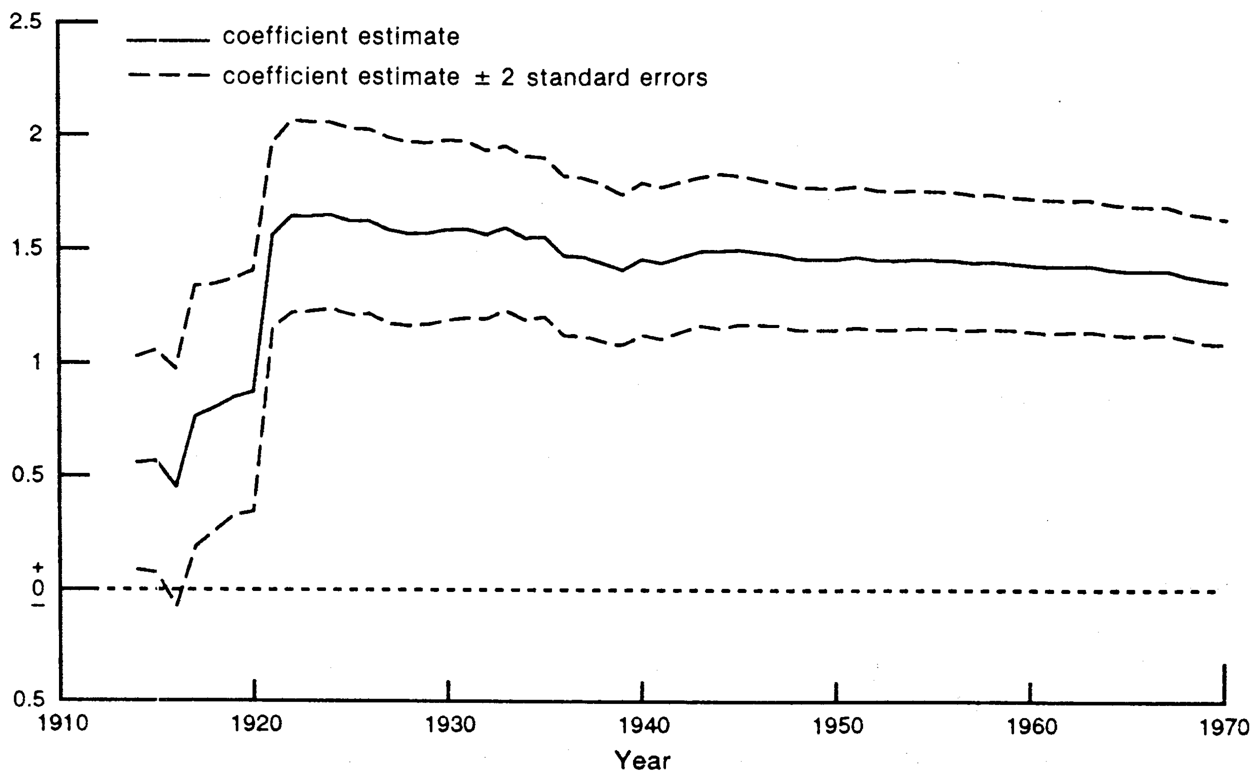

Figure 13. Recursive estimation of the coefficient on Δm_t in the inverted model for Δp_t using (10).

The final test of super exogeneity is that the parameters are invariant to regime changes: here we exploit the joint introduction of floating exchange rates and Competition and Credit Control regulations in 1971. Narrow money demand (UK M_1 measure) apparently was not perturbed by these switches, but most investigators have found major parameter changes in models of broad money measures (e.g., UK £M_3: see Hendry and Mizon (1978) and Michel Lubrano, Richard Pierce, and Richard (1986) for overviews). A Chow test of (10) using predictions over 1971–75 yields $\eta_1(5,84) = 19.5$ and $\hat{\sigma}$ rises to 2.03%, rejecting constancy and super exogeneity. The growth rate of nominal money over this test period substantially exceeds that of any previous episode (including both World Wars) and could reflect a disequilibrium adjustment to the removal of the chronic cartelization of the UK banking system (the motivation for the change in banking regulations). Indeed, Lubrano *et al.* (1986) find that the long-run relationship of money demand to prices and incomes holds after 1970 but that the short-run is severely perturbed, with money demand *increasing* as competitive interest rates increase. With that structure in mind, we obtained:

$$
\begin{aligned}
(11)\quad \widehat{\Delta(m-p)}_t = {} & \underset{[0.06]}{0.47}\,\Delta(m-p)_{t-1} - \underset{[0.04]}{0.11}\,\Delta^2(m-p)_{t-2} - \underset{[0.04]}{0.59}\,\Delta p_t + \underset{[0.04]}{0.41}\,\Delta p_{t-1} \\
& - \underset{[0.006]}{0.017}\,\Delta rs_t - \underset{[0.019]}{0.078}\,\Delta_2 r\ell_t - \underset{[0.19]}{1.15}\,(\hat{u}_{t-1}-0.2)\hat{u}^2_{t-1} \\
& + \underset{[0.002]}{0.007} + \underset{[0.6]}{3.4}\,(D_1+D_3)_t + \underset{[0.010]}{0.071}\,(D_4)_t + \underset{[0.020]}{0.090}\,(D_4)_t \cdot \Delta rs_t
\end{aligned}
$$

$$T = 1878\text{–}1975 \quad R^2 = 0.88 \quad \hat{\sigma} = 1.478\% \quad \eta_2(6,81) = 1.19$$

$$\eta_4(2,83) = 1.31 \quad \xi_5(2) = 2.9 \quad \eta_6(18,68) = 0.43\ ,$$

where D_4 is a dummy which is unity over the period 1971–75 and zero otherwise, and $\hat{u}_{t-1}$ is still calculated from (9). Now $\hat{\sigma}$ and most of the coefficients other than those involving D_4 are virtually unaltered, consistent with Lubrano *et al.*'s results.

A potential explanation for this finding, consistent with the earlier evidence and economic analysis, is presaged by Klovland's (1987) result for pre–1914 data that the *own* interest rate on broad money is an important omitted variable from the present information set.[26] Over much of the sample, UK commercial banks acted like a cartel with administered (and generally low) deposit interest rates, which situation altered after 1970 due to the competition regulations. Thus, own interest rates rose rapidly, altering the historical differentials and inducing predictive failure in models which excluded that variable. We plan to extend Klovland's data set to test this conjecture and to continue the progressive research strategy by encompassing previous models.

V. Conclusions

This paper focuses on the evaluation of Friedman and Schwartz's empirical model for UK money demand and the design of an improved specification using their annual data.

At the heart of model evaluation are the issues of model credibility and validity and the role of corroborating evidence. The failure by Friedman and Schwartz to present statistical evidence pertinent to their main claims about the UK leaves those claims lacking in credibility. The presence of substantial mis-specification invalidates many of their inferences from equations based on the phase-average data; cf. Table 1. In particular, their final money-demand equation is not constant, contrary to their claim; and, on testing assumptions such as price homogeneity and the absence of trends, rejection results. Such negative findings are consistent with those reported by Meghnad Desai (1981, especially ch. 4). The procedure of averaging data over business-cycle phases did not notably reduce the serial correlation in the data series but did lose information, leading to rather badly

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[26]We (1983, pp. 77–78) experimented with RS replaced by RN, Friedman and Schwartz's (p. 270) measure of the marginal cost of money ($RN \equiv RS \cdot H/M$). The resulting estimates are very similar to those found using RS and reveal no improvement in the constancy of the interest-rate coefficient over 1971–75. Following suggestions by Chris Pissarides and by Ross Starr (1983), we also experimented with adding variables which measured interest rate volatility, e.g., using $0.2\ \Sigma_{i=0}^{4}\ (RS_{t-i}-RS_t^*)^2$ where $RS_t^* = 0.2\ \Sigma_{i=0}^{4}\ RS_{t-i}$. The effect was largest for the most recent period but did not produce constant parameters or a constant fit over 1971–75.

fitting equations. As an alternative, we recommend analyzing the annual data and modeling "trend" and "cycle" jointly.

Corroborating a subset of the implications of a theory is not by itself an adequate justification for deeming the theory useful (see *inter alia* Friedman (1953, pp. 8–9), Karl Popper (1959, Section 82), and Lawrence Boland (1982, ch. 1)). That is illustrated by the contrast between Friedman and Schwartz's claims to have empirically corroborated various aspects of their theories and our evidence that those claims are actually refutable from the same data. Only well-tested theories which have successfully weathered tests outside the control of their proponents and which encompass the gestalt of existing empirical evidence seem likely to provide a useful basis for applied economic analysis and policy.

The tests used to evaluate Friedman and Schwartz's models indicate that scope exists for model development, but not what changes are required. We attempted an improved specification and presented an econometric model of the demand for money in the UK over 1878–1970 which incorporates economic theory, satisfies a wide range of statistical criteria, and encompasses existing models based on the same data set. Those features are essential for a model to characterize the underlying data generation process adequately. On a substantive level, the empirical constancy of our model is consistent with a structure in which nominal money is endogenously determined by demand factors, conditional on prices, incomes, and interest rates. Undoubtedly, the model proposed above is not the end of the story since (e.g.) parameter non-constancy is evident over 1971–75. That it is not perfect is less than surprising as the data span a century during which financial institutions altered dramatically: witness the growth of Building Societies and, after 1970, the introduction of Competition and Credit Control regulations and of floating exchange rates. Even so, the evidence suggests that substantial benefits are available in practice from a progressive research strategy exploiting tests in both model design and model evaluation.

DATA APPENDIX

Legend

D_1	A dummy variable for World War I (= 1 for 1914–18 inclusive, zero elsewhere)
D_2	A dummy variable for 1921–55, paralleling $\overline{S}$ for phase-average data (= 1 for 1921–55 inclusive, zero elsewhere)
D_3	A dummy variable for World War II (= 1 for 1939–45 inclusive, zero elsewhere)
D_4	A dummy variable for Competition and Credit Control regulations (= 1 for 1971–75, zero elsewhere)
$G(\overline{p}+\overline{i})$	Growth rate of phase-average nominal income (fraction)
H	High-powered money (million £)
I	Real net national product (million 1929 £)
M	Money stock (million £)
N	Population (millions)
P	Deflator of I (1929 = 1.00)
P*	Deflator of net national product in the USA (1929 = 1.00)
$R\ell$	Long-term interest rate (fraction)
RN	RS·H/M
RS	Short-term interest rate (fraction)
$\overline{S}$	A dummy variable for phase observations 16–28 (1921–1955; = 1 for observations 16–28 inclusive, zero elsewhere)
$\overline{W}$	A dummy variable for phase observations 13–15 and 26–28 (1918–1921 and 1946–1955; = –4, –3, –2, 8, 5, and 3 for phase observations 13, 14, 15, 26, 27, and 28 respectively; zero elsewhere)

Coefficients and estimated standard errors of the dummies D_1, D_2, D_3, (but not D_4), $\overline{S}$, and $\overline{W}$ are reported times 100 for readability.

The data are as in Friedman and Schwartz (1982, Tables 4.8 and 4.9), but relevant series are rescaled proportionately from 1871 to 1920 to remove the break in 1920 when Southern Ireland ceased to be part of the United Kingdom. Also, P, P*, $G(\overline{p}+\overline{i})$, RS, and $R\ell$ have been divided by 100 so that the values of P and P* in 1929 equal 1.00 (rather than 100) and the interest rates and $G(\overline{p}+\overline{i})$ are expressed as fractions (rather than as percentages).

Data measurement

We record several important *caveats* about their data, overlapping those which Friedman and Schwartz carefully document.

(i) The choice of monetary measure seems too broad to represent transactions demand yet too narrow for an overall index of "liquidity". M (above) is based on the UK monetary measure M_2 (pp. 111–114) and hence excludes interest-bearing liabilities of Building Societies but includes interest-bearing bank deposits. However, the Building Society movement has grown rapidly over the last century to become roughly equal in size to the whole commercial banking sector, and Building Society liabilities are amongst the most liquid assets available to the personal sector. Note that money-stock figures are centered on mid-years by averaging successive end-of-year values.

(ii) The measurement of the price series (P) is adjusted for rationing and controls (pp. 115–120), with real income then derived by deflating nominal income. However, it is unreasonable to hold measured nominal income constant when measured prices are believed incorrect. Furthermore, over a century, one must be concerned about the effects on the measurement of P of the many dramatic changes which have occurred in quality-adjusted relative prices.

(iii) Friedman and Schwartz emphasize an "errors-in-variables" paradigm and claim that the importance of errors in variables is reduced by phase-averaging, but enhanced by differencing (p. 86). All the variables undoubtedly contain substantial measurement errors, especially when interpreted as correspondences to economically meaningful latent constructs, but time series of over a century will also contain *systematic* errors. Differencing would remove most effects of such errors whereas averaging is of little help if errors are persistent, e.g., highly autoregressive.

Resolution of these difficulties is outside the scope of this paper, but they must influence the interpretation of the empirical evidence.

REFERENCES

Artis, Michael J., "Book Review," *Economica*, May 1984, *51*, 205–207.

Barndorff-Nielsen, Ole, *Information and Exponential Families in Statistical Theory*, Chichester: John Wiley, 1978.

Barro, Robert J., *Macroeconomics*, Second Edition, New York: John Wiley, 1987.

Boland, Lawrence A., *The Foundations of Economic Method*, London: George Allen and Unwin, 1982.

Box, George E.P. and Pierce, David A., "Distribution of Residual Autocorrelations in Autoregressive-integrated Moving Average Time Series Models," *Journal of the American Statistical Association*, December 1970, *65*, 1509–1526.

Bronfenbrenner, Jean, "Sources and Size of Least-squares Bias in a Two-equation Model," Chapter 9 in Wm.C. Hood and T.C. Koopmans, eds., *Studies in Econometric Method*, New Haven: Yale University Press, 1953, 221–235.

Brown, R.L., Durbin, James and Evans, J.M., "Techniques for Testing the Constancy of Regression Relationships over Time," *Journal of the Royal Statistical Society, Series B*, 1975, *37*, *2*, 149–192 (with discussion).

Burns, Arthur F. and Mitchell, Wesley C., *Measuring Business Cycles*, New York: National Bureau of Economic Research, 1946.

Campos, Julia and Ericsson, Neil R., "Econometric Modeling of Consumers' Expenditure in Venezuela," International Finance Discussion Paper No. 325, Board of Governors of the Federal Reserve System, Washington, D.C., June 1988.

Campos, Julia, Ericsson, Neil R. and Hendry, David F., "An Analogue Model of Phase-Averaging Procedures," *Journal of Econometrics*, 1990, *43*, forthcoming.

Chalmers, Alan F., *What Is This Thing Called Science? An Assessment of the Nature and Status of Science and Its Methods*, St. Lucia, Queensland: University of Queensland Press, 1976.

Chow, Gregory C., "Tests of Equality between Sets of Coefficients in Two Linear Regressions," *Econometrica*, July 1960, *28*, 591–605.

Congdon, Tim, "Has Friedman Got It Wrong?," *The Banker*, July 1983, 117–125.

Cuthbertson, Keith, "The Demand for M_1: A Forward Looking Buffer Stock Model," *Oxford Economic Papers*, March 1988, *40*, 110–131.

Davidson, James E.H., Hendry, David F., Srba, Frank and Yeo, Stephen, "Econometric Modelling of the Aggregate Time-series Relationship between Consumers' Expenditure and Income in the United Kingdom," *Economic Journal*, December 1978, *88*, 661–692.

Davidson, James E.H., "Disequilibrium Money: Some Further Results with a Monetary Model of the UK," Chapter 6 in C.A.E. Goodhart, D. Currie and D.T. Llewellyn, eds., *The Operation and Regulation of Financial Markets*, London: Macmillan Press, 1987, 125–149.

Desai, Meghnad, *Testing Monetarism*, London: Frances Pinter, 1981.

Dickey, David A. and Fuller, Wayne A., "Distribution of the Estimators for Autoregressive Time Series with a Unit Root," *Journal of the American Statistical Association*, June 1979, *74*, 427–431.

Dickey, David A. and Fuller, Wayne A., "Likelihood Ratio Statistics for Autoregressive Time Series with a Unit Root," *Econometrica*, July 1981, *49*, 1057–1072.

Dolado, Juan J. and Jenkinson, Tim, "Cointegration: A Survey of Recent Developments," Applied Economics Discussion Paper No. 39, Institute of Economics and Statistics, University of Oxford, Oxford, November 1987.

Dufour, Jean-Marie, "Recursive Stability Analysis of Linear Regression Relationships: An Exploratory Methodology," *Journal of Econometrics*, May 1982, *19*, 31–76.

Durbin, James and Watson, Geoffrey S., "Testing for Serial Correlation in Least Squares Regression. I," *Biometrika*, December 1950, *37*, 409–428.

Durbin, James and Watson, Geoffrey S., "Testing for Serial Correlation in Least Squares Regression. II," *Biometrika*, June 1951, *38*, 159–178.

Engle, Robert F., "Autoregressive Conditional Heteroscedasticity with Estimates of the Variance of United Kingdom Inflation," *Econometrica*, July 1982, *50*, 987–1007.

Engle, Robert F., "Wald, Likelihood Ratio, and Lagrange Multiplier Tests in Econometrics," Chapter 13 in Z. Griliches and M.D. Intriligator, eds., *Handbook of Econometrics*, Amsterdam: North-Holland, Volume 2, 1984, 775–826.

Engle, Robert F., "On the Theory of Cointegrated Economic Time Series, 1987," mimeo, University of California, San Diego, August 1987.

Engle, Robert F. and Granger, Clive W.J., "Co-integration and Error Correction: Representation, Estimation, and Testing," *Econometrica*, March 1987, *55*, 251–276.

Engle, Robert F. and Hendry, David F., "Testing Superexogeneity and Invariance," mimeo, Duke University, Durham, North Carolina, March 1989.

Engle, Robert F., Hendry, David F. and Richard, Jean-François, "Exogeneity," *Econometrica*, March 1983, *51*, 277–304.

Ericsson, Neil R. and Hendry, David F., "Conditional Econometric Modeling: An Application to New House Prices in the United Kingdom," Chapter 11 in A.C. Atkinson and S.E. Fienberg, eds., *A Celebration of Statistics: The ISI Centenary Volume*, New York: Springer-Verlag, 1985, 251–285.

Escribano, Alvaro, "Non-linear Error-correction: The Case of Money Demand in the U.K. (1878–1970)," mimeo, University of California, San Diego, December 1985.

Fisher, R.A., "The Goodness of Fit of Regression Formulae, and the Distribution of Regression Coefficients," *Journal of the Royal Statistical Society*, 1922, *85*, *4*, 597–612.

Florens, Jean-Pierre and Mouchart, Michel, (1985a) "Conditioning in Dynamic Models," *Journal of Time Series Analysis*, 1985, *6*, *1*, 15–34.

Florens, Jean-Pierre and Mouchart, Michel, (1985b) "A Linear Theory for Noncausality," *Econometrica*, January 1985, *53*, 157–175.

Friedman, Milton, *Essays in Positive Economics*, Chicago: University of Chicago Press, 1953.

Friedman, Milton, "The Quantity Theory of Money —— A Restatement," in M. Friedman, ed., *Studies in the Quantity Theory of Money*, Chicago: University of Chicago Press, 1956, 3–21.

Friedman, Milton and Schwartz, Anna J., *Monetary Trends in the United States and the United Kingdom: Their Relation to Income, Prices, and Interest Rates, 1867–1975*, Chicago: University of Chicago Press, 1982.

Gilbert, Christopher L., "Professor Hendry's Econometric Methodology," *Oxford Bulletin of Economics and Statistics*, August 1986, *48*, 283–307.

Godfrey, Leslie G., "Testing Against General Autoregressive and Moving Average Error Models when the Regressors Include Lagged Dependent Variables," *Econometrica*, November 1978, *46*, 1293–1301.

Goodhart, Charles A.E., "*Monetary Trends in the United States and the United Kingdom*: A British Review," *Journal of Economic Literature*, December 1982, *20*, 1540–1551.

Goodhart, Charles A.E., *Monetary Theory and Practice: The UK Experience*, London: Macmillan Press, 1984.

Granger, Clive W.J., "Some Properties of Time Series Data and Their Use in Econometric Model Specification," *Journal of Econometrics*, May 1981, *16*, 121–130.

Hallman, Jeff, "Attractor Sets: A Nonlinear Extension of the Cointegration Concept," mimeo, University of California, San Diego, November 1987.

Harvey, Andrew C., *The Econometric Analysis of Time Series*, Oxford: Philip Allan, 1981.

Hawtrey, R.G., *A Century of Bank Rate*, London: Longmans, Green and Co., 1938.

Hendry, David F., "Predictive Failure and Econometric Modelling in Macroeconomics: The Transactions Demand for Money," Chapter 9 in P. Ormerod, ed., *Economic Modelling*, London: Heinemann Education Books, 1979, 217–242.

Hendry, David F., "Econometric Modelling: The 'Consumption Function' in Retrospect," *Scottish Journal of Political Economy*, November 1983, *30*, 193–220.

Hendry, David F., ed., *Economic Modelling with Cointegrated Variables* (special issue), *Oxford Bulletin of Economics and Statistics*, August 1986, *48*.

Hendry, David F., "Econometric Methodology: A Personal Perspective," Chapter 10 in T.F. Bewley, ed., *Advances in Econometrics*, Cambridge: Cambridge University Press, Volume 2, 1987, 29–48.

Hendry, David F., "The Encompassing Implications of Feedback versus Feedforward Mechanisms in Econometrics," *Oxford Economic Papers*, March 1988, *40*, 132–149.

Hendry, David F., *PC-GIVE: An Interactive Econometric Modelling System*, Version 6.0/6.01, Oxford: Institute of Economics and Statistics and Nuffield College, University of Oxford, 1989.

Hendry, David F. and Ericsson, Neil R., "Assertion without Empirical Basis: An Econometric Appraisal of 'Monetary Trends in ... the United Kingdom' by Milton Friedman and Anna Schwartz," in *Monetary Trends in the United Kingdom*, Bank of England Panel of Academic Consultants, Panel Paper No. 22, 45--101 (with additional references), October 1983.

Hendry, David F. and Ericsson, Neil R., "Assertion without Empirical Basis: An Econometric Appraisal of *Monetary Trends in ... the United Kingdom* by Milton Friedman and Anna J. Schwartz," International Finance Discussion Paper No. 270, Board of Governors of the Federal Reserve System, Washington, D.C., December 1985.

Hendry, David F. and Ericsson, Neil R., "Prolegomenon to a Reconstruction: Further Econometric Appraisal of *Monetary Trends in ... the United Kingdom* by Milton Friedman and Anna J. Schwartz," mimeo, Board of Governors of the Federal Reserve System, Washington, D.C., March 1986.

Hendry, David F. and Mizon, Grayham E., "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*, September 1978, *88*, 549–563.

Hendry, David F. and Mizon, Grayham E., "Procrustean Econometrics: Or Stretching and Squeezing Data," Discussion Paper No. 68, Centre for Economic Policy Research, London, October 1985.

Hendry, David F. and Neale, Adrian J., "Monte Carlo Experimentation Using PC–NAIVE," *Advances in Econometrics*, 1987, *6*, JAI Press, 91–125.

Hendry, David F., Neale, Adrian J. and Srba, Frank, "Econometric Analysis of Small Linear Systems Using PC-FIML," *Journal of Econometrics*, May/June 1988, *38*, 203–226.

Hendry, David F., Pagan, Adrian R. and Sargan, J. Denis, "Dynamic Specification," Chapter 18 in Z. Griliches and M.D. Intriligator, eds., *Handbook of Econometrics*, Amsterdam: North-Holland, Volume 2, 1984, 1023–1100.

Hendry, David F. and Richard, Jean-François, "On the Formulation of Empirical Models in Dynamic Econometrics," *Journal of Econometrics*, October 1982, *20*, 3–33.

Hendry, David F. and Richard, Jean-François, "The Econometric Analysis of Economic Time Series," *International Statistical Review*, August 1983, *51*, 111–163 (with discussion).

Hendry, David F. and Richard, Jean-François, "Recent Developments in the Theory of Encompassing," C.O.R.E. Discussion Paper No. 8722, Louvain-la-Neuve, May 1987; *CORE Twentieth Anniversary Volume*, Cambridge: MIT Press, forthcoming.

Hendry, David F. and Wallis, Kenneth F., eds., *Econometrics and Quantitative Economics*, Oxford: Basil Blackwell, 1984.

Herschel, J., *A Preliminary Discourse on the Study of Natural Philosophy*, London: Longman, Rees, Brown & Green and John Taylor, 1830.

Jarque, Carlos M. and Bera, Anil K., "Efficient Tests for Normality, Homoscedasticity and Serial Independence of Regression Residuals," *Economics Letters*, 1980, *6*, *3*, 255–259.

Johnston, J., *Econometric Methods*, New York: McGraw-Hill, 1963.

Judd, John P. and Scadding, John L., "The Search for a Stable Money Demand Function: A Survey of the Post-1973 Literature," *Journal of Economic Literature*, September 1982, *20*, 993–1023.

Kiviet, Jan F., "Model Selection Test Procedures in a Single Linear Equation of a Dynamic Simultaneous System and Their Defects in Small Samples," *Journal of Econometrics*, June 1985, *28*, 327–362.

Kiviet, Jan F., *Testing Linear Econometric Models*, Amsterdam: Amsterdam University Press, 1987.

Klovland, Jan T., "The Demand for Money in the United Kingdom, 1875–1913," *Oxford Bulletin of Economics and Statistics*, August 1987, *49*, 251–271.

Koopmans, Tjalling C., "When Is an Equation System Complete for Statistical Purposes?," Chapter 17 in T.C. Koopmans, ed., *Statistical Inference in Dynamic Economic Models*, New York: John Wiley, 1950, 393–409.

Lakatos, Imre, "Falsification and the Methodology of Scientific Research Programmes," in I. Lakatos and A. Musgrave, eds., *Criticism and the Growth of Knowledge*, Cambridge: Cambridge University Press, 1970, 91–196.

Leamer, Edward E., *Specification Searches: Ad Hoc Inference with Nonexperimental Data*, New York: John Wiley, 1978.

Leamer, Edward E., "Let's Take the Con Out of Econometrics," *American Economic Review*, March 1983, *73*, 31–43.

Longbottom, Andrew and Holly, Sean, "Econometric Methodology and Monetarism: Professor Friedman and Professor Hendry on the Demand for Money," Discussion Paper No. 131, London Business School, February 1985.

Lubrano, Michel, Pierse, Richard G. and Richard, Jean-François, "Stability of a U.K. Money Demand Equation: A Bayesian Approach to Testing Exogeneity," *Review of Economic Studies*, August 1986, *53*, 603–634.

MacKinnon, James G., "Model Specification Tests Against Non-nested Alternatives," *Econometric Reviews*, 1983, *2*, *1*, 85–158 (with discussion).

MacKinnon, James G. and White, Halbert, "Some Heteroskedasticity-consistent Covariance Matrix Estimators with Improved Finite Sample Properties," *Journal of Econometrics*, September 1985, *29*, 305–325.

Mayer, Thomas, "*Monetary Trends in the United States and the United Kingdom*: A Review Article," *Journal of Economic Literature*, December 1982, *20*, 1528–1539.

McAleer, Michael, Pagan, Adrian R. and Volker, Paul A., "What Will Take the Con Out of Econometrics?," *American Economic Review*, June 1985, *75*, 293–307.

Mizon, Grayham E., "The Encompassing Approach in Econometrics," Chapter 6 in D.F. Hendry and K.F. Wallis, eds., *Econometrics and Quantitative Economics*, Oxford: Basil Blackwell, 1984, 135–172.

Mizon, Grayham E. and Richard, Jean-François, "The Encompassing Principle and Its Application to Testing Non-nested Hypotheses," *Econometrica*, May 1986, *54*, 657–678.

Moore, Basil J., "*Monetary Trends in the United States and in the United Kingdom*, A Review," *The Financial Review*, May 1983, *18*, 146–166.

Nicholls, Desmond F. and Pagan, Adrian R., "Heteroscedasticity in Models with Lagged Dependent Variables," *Econometrica*, July 1983, *51*, 1233–1242.

Nickell, Stephen, "Error Correction, Partial Adjustment and All That: An Expository Note," *Oxford Bulletin of Economics and Statistics*, May 1985, *47*, 119–129.

Patterson, Kerry D., "The Stability of Some Annual Consumption Functions," *Oxford Economic Papers*, March 1986, *38*, 1–30.

Pesaran, M. Hashem, "Comparison of Local Power of Alternative Tests of Non-nested Regression Models," *Econometrica*, September 1982, *50*, 1287–1305.

Phillips, Peter C.B., "Time Series Regression with a Unit Root," *Econometrica*, March 1987, *55*, 277–301.

Phillips, Peter C.B., "Reflections on Econometric Methodology," Cowles Foundation Discussion Paper No. 893, Yale University, December 1988; *Economic Record*, forthcoming.

Phillips, Peter C.B. and Hansen, Bruce E., "Statistical Inference in Instrumental Variables Regression with I(1) Processes," Cowles Foundation Discussion Paper No. 869-R, Yale University, April 1989.

Popper, Karl R., *The Logic of Scientific Discovery*, London: Hutchinson, 1959.

Ramsey, J.B., "Tests for Specification Errors in Classical Linear Least-squares Regression Analysis," *Journal of the Royal Statistical Society, Series B*, 1969, *31*, *2*, 350–371.

Salmon, Mark, "Error Correction Mechanisms," *Economic Journal*, September 1982, *92*, 615–629.

Sargan, J. Denis, "The Estimation of Economic Relationships Using Instrumental Variables," *Econometrica*, October 1958, *26*, 393–415.

Sargan, J. Denis, "Wages and Prices in the United Kingdom: A Study in Econometric Methodology," in P.E. Hart, G. Mills and J.K. Whitaker, eds., *Econometric Analysis for National Economic Planning*, Colston Papers, Volume 16, London: Butterworths, 1964, 25–63 (with discussion); reprinted in D.F. Hendry and K.F. Wallis, eds., *Econometrics and Quantitative Economics*, Oxford: Basil Blackwell, 1984, 275–314.

Sargan, J. Denis, (1980a) "Some Approximations to the Distribution of Econometric Criteria which Are Asymptotically Distributed as Chi-squared," *Econometrica*, July 1980, *48*, 1107–1138.

Sargan, J. Denis, (1980b) "Some Tests of Dynamic Specification for a Single Equation," *Econometrica*, May 1980, *48*, 879–897.

Sargan, J. Denis and Bhargava, Alok, "Testing Residuals from Least Squares Regression for Being Generated by the Gaussian Random Walk," *Econometrica*, January 1983, *51*, 153–174.

Sims, Christopher A., "Macroeconomics and Reality," *Econometrica*, January 1980, *48*, 1–48.

Smith, Gregor W., "A Dynamic Baumol-Tobin Model of Money Demand," *Review of Economic Studies*, July 1986, *53*, 465–469.

Spanos, Aris, *Statistical Foundations of Econometric Modelling*, Cambridge: Cambridge University Press, 1986.

Starr, Ross M., "Variation in the Maturity Composition of Debt and Behavior of the Monetary Aggregates: The Maturity Shift Hypothesis," *Economic Review (San Francisco), Conference Supplement*, Fall 1982, 202–233.

Stock, James H., "Asymptotic Properties of Least Squares Estimators of Cointegrating Vectors," *Econometrica*, September 1987, *55*, 1035–1056.

Trundle, John M., "The Demand for M1 in the UK," mimeo, Bank of England, 1982.

White, Halbert, "A Heteroskedasticity-consistent Covariance Matrix Estimator and a Direct Test for Heteroskedasticity," *Econometrica*, May 1980, *48*, 817–838.

White, Halbert, *Specification Analysis in Econometrics*, manuscript, 1988; Cambridge: Cambridge University Press, forthcoming.

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