MODELLING MONEY DEMAND IN AUSTRALIAN ECONOMY-WIDE MODELS:

SOME PRELIMINARY ANALYSES

Colin Hargreaves

No. 55 - October 1991

ISSN 0 157-0188
ISBN 0 85834 960 4
Abstract

Given the stress on monetary policy, it is important that policy analyses based on model simulations should reflect accurately the current state of the financial sector. Hence the relationships between money demand, the exchange rate and the current account are crucial. Furthermore the formulation of these equations is also known to have a great impact on the simulation properties of macroeconometric models. This paper presents initial work towards an analysis of the estimation and simulation of these relationships in the major models of the Australian economy. The money demand specification of 5 major macroeconometric models of the Australian economy (AMPS, IMP, MSG, MURPHY and NIF) are analysed in the light of the new developments in econometrics concerning integration and cointegration. An alternative specification is proposed that captures not only the long-run position but also the short-run dynamics of money demand. Despite many statements of the instability of money demand functions over the last ten years, the proposed specification is stable over the whole data period from 1972-1989.
1. Introduction

For a while now there have been some doubts raised concerning money demand equations, not just in Australia but also in other countries. This is due to the sometimes dramatic changes in monetary aggregates caused by the deregulation of the banking system. As many 'Non-trading bank' institutions became 'trading banks' their deposits were redefined and so the measures of the money supply, especially the broader measures, changed partly for statistical reasons unrelated to any real changes in activity.

1.1 Australian Monetary Policy

From 1976 to 1984, the Australian Government announced bounds for the growth of the money supply (M3). However the relationship between the money supply and real activity appeared to break-down in the early 1980's (documented in many Reserve Bank papers, eg Macfarlane, 1989) and this led the Reserve Bank to abandon the targeting of the money supply. The Bank of England had also abandoned monetary targeting. Since then the Reserve Bank of Australia has taken a broad perspective, looking at the economy as a whole and then forming an enlightened judgement on the appropriate stance of monetary policy. There have been various attempts to formalise this a little more into the 'checklist approach' (Johnston, 1987) and recently Peter Stemp has discussed the "Optimal Weights in a Check-List of Monetary Indicators" (Stemp, 1990).

However there is probably no single 'view of the Bank' but rather different members of the Bank staff have their own views and at different meetings different arguments will be raised and conclusions reached. To the general public the Reserve Bank appears simply to raise interest rates if activity, inflation or imports are up and lower interest rates if they are down. There is no explicit model of the inter-
relationships of inflation, employment, imports etc that one can discuss carefully and logically. Instead there are only personal judgements which are hard to pin down in any reasonable discussion.

1.2 Uses of Models

In order to have an enlightened logical debate about the economy one really needs a model of the economy that is known to all parties and around which discussion can concentrate. The model does not have to be perfect but rather it acts as a common base for discussion. All models are approximations to the underlying highly complex data generation process. Furthermore there is no one "super" model that explains everything and is better than all other models. Given the capacities of the human mind, such a "super" model would be too large and complicated to cope with. As a result different models are needed to capture different aspects and render them attainable for logical argument.

When old models break down, this is no reason to reject modelling but instead this is a sign of the need for more research. The old theories exemplified in the models may have broken down. The same theories held in a person's head would fair no better. Equally if a theory cannot produce quantifiable results as in an econometric model, then it is of little real use for managing the economy. When economic variables appear to become erratic, there may have been a change in definition or data collection methods (as in some countries' measures of unemployment), but if this is not the case, it may be the sign of a lack of understanding. While the former may apply to the broader monetary aggregates, it may not be so true for currency, base money and M1. The variables are not at fault. Rather an old paradigm may have collapsed. With reference to paradigm shifts in fact, it may well be argued that the econometric analysis of time series
has just passed through such a dramatic development with the research on integration and cointegration.

In addition, given all the changes in the financial sector and the government's stress on monetary policy, it is important that further research is undertaken to provide a better understanding of the present economy. Model simulations should reflect as accurately as possible the current state of the financial sector. Here the relationships between money demand, the exchange rate and the current and capital accounts are crucial as is the understanding of the long run sustainability of the foreign debt.

This paper presents initial work towards such an extensive analysis of the estimation and simulation of these relationships as defined in the major models of the Australian economy. This paper concentrates on the econometric estimation of money demand equations which are sometimes inverted in simulations to provide an interest rate equation. Simulation results will be considered later. In Section 2, various measures of the money supply are discussed. Section 3 outlines the major theoretical determinants of money demand. Section 4 discusses the specifications found in 5 economy-wide models. Section 5 details the importance of the econometric concepts of integration and co-integration in modelling time-series aggregates and Section 6 discusses the application of these concepts to the variables and money demand specifications. Section 7 describes an alternative specification that is shown to work very well and finally some concluding remarks are given in Section 8. The first question to be considered is what money aggregate should be used.

2. Measures of Money

The main measure of money used historically in Australia is M3 defined as currency held by the public plus all trading bank and savings bank deposits excluding government deposits
and inter-bank deposits. Figure 1 shows how M3's growth rose and fell quite dramatically in the seventies, then it stabilised from 1979 to 1984 and since then has become more volatile again. More striking is the change in trend of M3 velocity (defined as $GTM/M3$). Figure 2 shows the rise in velocity in the 1960's and 1970's which was experienced elsewhere in the world. However in the last few years M3 has experienced a dramatic change around largely due to the redefinition of many institutions as trading banks.

The earlier general rise in velocity appears in other measures of money except currency alone which has remained fairly stable since 1970. Figures 2 to 5 show the velocities of M3, M1, Base money and currency since 1970 and figure 6 shows these scaled to a common mean. The latter figure shows how the proportional rise in the velocity of M3 has been noticeably less than that in Base Money or M1.

If one looks at the growth in M1 and its velocity (figures 7 and 3, respectively) one sees that this variable shows a relatively more stable pattern over the last twenty years. Although there are differences in definition of these aggregates across countries (eg in the UK, non-residents' deposits and deposits denominated in foreign currencies are treated differently), it is noticeable that M1, rather than M3, tends to be the subject of money demand equations in the UK and the USA. Some modellers in Australia use a Base money concept (eg AMPS and Murphy, variously defined) and, given the deregulatory changes in M3, this seems to be a reasonable course discussed below. M1 is also the aggregate that relates best to the idea of money as a medium of exchange as it includes currency and bank deposits against which a cheque can be written.
Figure 1: M3 Growth

Sample Period is 1969(4) - 1989(4)

Figure 2: Velocity of M3

Sample Period is 1969(3) - 1989(4)
Figure 3: Velocity of M1

Figure 4: Velocity of Base Money
Figure 5: Velocity of Currency

Sample Period is 1969(3) - 1989(4)

Figure 6: Velocities of M3, M1, Base Money and Currency

scaled to a mean of one

Sample Period is 1969(3) - 1989(4)
Figure 7: M1 Growth

Sample Period is 1969(4) - 1989(4)
3. Determinants of Money Demand

3.1 Motives for Holding Money

The reasons for holding money may be classified under three main headings: (1) the transactions motive, (2) the precautionary motive and (3) the speculative motive. The inventory approach to transactions demand, developed by Baumol (1952) and Tobin (1956), treats money as an inventory of purchasing power. This leads to the square-root formula for money demand, i.e.:

$$M = \sqrt{TC \times Y_\$ / (2i)}$$

where TC is transaction cost, Y$ is nominal income and i is the interest cost of holding money. This approach does not involve any money illusion. Precautionary demand is found by relating the marginal cost of holding an extra dollar to the marginal benefit of holding an extra dollar of cash needed to facilitate payments. These two motives, transactions and precautionary, lead to money demand being positively related to transaction costs and nominal income and negatively related to short-term interest rates.

The speculative motive treats money not as a medium of exchange but rather as an asset. Money is seen as a risk-free asset. However costs for this security have to be born in terms of an inflationary reduction in purchasing power and the opportunity costs from not holding high interest bearing assets. Speculative demand for money would increase if the returns from other assets became more risky; this could be measured by the variability of other rates of return. Speculative demand would relate negatively to inflation and other interest rates since these are costs arising from holding money. If however the interest rates are nominal rates, it has been argued that these will take account of inflationary expectations and so an additional inflation variable may not be necessary. Speculative demand would
increase with the size of the portfolio and hence speculative
demand may be positively related to wealth although this is a
difficult variable to measure.

3.2 The Goldfield Equation

The standard money demand equation up unto the mid-70's
was the Goldfield equation (Goldfield, 1973), namely

$$\ln M = \beta_0 + \beta_1 \ln Y + \beta_2 \ln B90 + \beta_3 \ln RSSA + \beta_4 \ln M_1$$

where M is real M1 (quarterly), Y is real income, B90 is a
short-term interest rate (eg 90 day bill rate) and RSSA is a
typical interest rate on an M2 interest bearing deposit such
as that on savings bank passbook and statement accounts. As
to the signs of the coefficients, one expects \( \beta_1 \) to be
positive, \( \beta_2 \) and \( \beta_3 \) to be negative and \( \beta_4 \) to be positive.
Also, in the long-run, the interest rate elasticities are
expected to be much larger than in the short run. Finally
Goldfield found no money illusion, ie rising prices only
changed nominal money demand not real demand.

Then in the U.S.A., during the 1970's, the equation broke
down; it predicted a rise in money demand when there was a
substantial decline and vice versa, in 1982-3, a period
labelled as the 'great velocity decline'. If we now add the
quantity equation -

$$M \times V = P \times Y$$

one can rewrite the equation above in the form -

$$V = f(Y, B90, RSSA)$$

where one would expect a positive relationship to interest
rates and also to income if the income elasticity of demand
for real balances is the usual less than one.
However two factors raised in the discussion of speculative demand, namely inflation and risk, are not included in the Goldfield specification above. Phillip Cagan (1956) and Friedman et al (1956) identified inflation as a factor affecting money demand. Tobin (1958) identified risk as measured by the standard error on long-term bond rates. These are both incorporated into a money demand equation proposed by Baba, Hendry and Starr (1987).

Interest rates reflect the opportunity costs of holding money as opposed to other assets. Although not always modelled in this way, these costs are really net costs, and thus the after-tax interest rate returns should be analysed. The problem is determining an appropriate tax rate to use. For the USA, Baba, Hendry and Starr could compare the rates of return on stocks which are issued gross and net of tax. In Australia there are tax-free rebate stocks with a coupon of 5% but these are not traded often and nor are there enough to be able to argue that the ratio of the rates shows the market felt tax rate. The aggregate household income tax rate is used below as a simple indicator of the effective tax rate.

4. Model Specifications

4.1 Money Variables Used in the Economy-Wide Models

The economy-wide models considered here are AMPS (Murphy et al, 1986, and Arthy et al, 1989), IMP (Brain, 1986), MSG (McKibbin, 1989), MURPHY (Murphy, 1988), and NIF (Simes, 1988a&b). ORANI-F (Dixon and Parmenter, 1982, and Parmenter, 1988) is not considered here as it does not have a specific money demand equation. The variables in the models' money demand equations are shown in Table 1.
<table>
<thead>
<tr>
<th>Variables</th>
<th>AMPS</th>
<th>IMP</th>
<th>MSG</th>
<th>MURPHY</th>
<th>NIF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Money</td>
<td>M</td>
<td>M2$/GNFP$</td>
<td>M</td>
<td>M money base; private sector holdings of currency</td>
<td>LM3$ money volume of new bank entries</td>
</tr>
<tr>
<td>Prices</td>
<td>PY</td>
<td>$PGNFP</td>
<td>P</td>
<td>- (uses nominal income variable)</td>
<td>PGTM price deflator for GDP</td>
</tr>
<tr>
<td>Income</td>
<td>YE$</td>
<td>GNFP$</td>
<td>Q</td>
<td>GNE$</td>
<td>GTM</td>
</tr>
<tr>
<td>Income rates</td>
<td>RCS</td>
<td>R2</td>
<td>i</td>
<td>RCS 90-day commercial bill rate</td>
<td>RGS &amp; RSSA</td>
</tr>
<tr>
<td>Taxes</td>
<td>POL2</td>
<td>-</td>
<td>-</td>
<td>POL2 (see AMPS)</td>
<td>-</td>
</tr>
<tr>
<td>Other</td>
<td>DEPIG and KG</td>
<td>NBFI$/GNFP$</td>
<td>-</td>
<td>DUMM, DUM01 &amp; 04 dummy variable for shift in currency demand 1985:1; March and December Quarterly Dummies</td>
<td></td>
</tr>
<tr>
<td>Data used</td>
<td>Semi-Annual</td>
<td>Annual</td>
<td>-</td>
<td>-</td>
<td>Quarterly</td>
</tr>
</tbody>
</table>
MSG is distinct from the others as it is a dynamic general equilibrium model in which the equation is not econometrically estimated and the documentation does not make it clear to what the term 'Nominal Money Supply' refers. The NIF model uses the highest aggregate namely M3, adjusted down for the entrance of new banks. No reasons are given for the choice of M3; this would clearly not be a permanent choice if one is to use 1980's data, as one would have to adjust continually for the entrance of new trading banks. But for this, M3 could be argued for on the grounds that it is used elsewhere in NIF as a quantity variable in the housing finance market.

IMP uses an M2 velocity arguing that "there is no 'supply' curve relevant to the demand for M3. Whereas monetary authorities do exert a considerable degree of control over trading bank deposits, by means of controls over the monetary base or by open market operations, the same cannot be said about savings banks deposits." (Brain, p 398) As to the use of gross non-farm product, this has been used in the past because of the fluctuations in farm product due to droughts and/or floods etc. Now that Gross Farm Product is a much smaller percentage of Gross Domestic Product, it may no longer be necessary to use Gross Non-Farm Product. IMP may need to however as it uses annual data stretching back into the 1950's.

Both AMPS and MURPHY refer to a Money Base variable. In AMPS this is defined within the model as the 'proportion of LGS assets accounted for by currency and private sector accounts at the Reserve Bank (excluding SDR's)'. In turn, LGS equals the the sum of the lagged values of LGS, the Balance of Payments Surplus and the Budget Deficit. MURPHY refers to private sector holdings of currency. These models both use interest rates as the dependent variable although MURPHY used to have the velocity as the dependent variable.
While MSG and NIF analyse the money supply in nominal terms, the other models do so in terms of a velocity. In AMPS and MURPHY the velocity is measured with respect to Gross National Expenditure and in IMP it is measured with respect to Gross Non-Farm Product. While Gross Non-Farm Product is not commonly used, Gross Domestic Product and Gross National Expenditure both occur in money demand equations. The UK modellers tend to favour national expenditure while the US modellers lean towards national product. Since transactions demand is discussed in relation to payments one might argue in favour of expenditure but there turns out to be little empirical difference.

4.2 Explanatory Variables

On interest rates, the models fall into two distinct groups. AMPS, MSG and MURPHY use short term interest rates while IMP and NIF use a two-year bond rate. The money demand literature mostly refers to short-term rates. As discussed above, one could argue for a number of rates and so below we analyse the empirical merits of three different interest rates. These are the two mentioned plus a second rate used in the NIF model; this is an average of the rates on Savings Bank Passbook and Statement Accounts (RSSA). This latter variable reflects deregulation in that the Passbook Account rate is constant throughout but the Statement Account rate rises steadily after deregulation. This raises problems with this variable as it will no doubt be highly correlated to the interest rates offered on some cheque accounts that would feature in M1; if so it would be positively related to M1 rather than negatively related.

As to other variables, AMPS and MURPHY are the only models to use an after tax rate of return; this is probably because of the problems in calculating this. MURPHY noticeably appears to have dropped this now. As a matter of simple expediency, MURPHY uses a data determined dummy variable for
an unexplained shift in currency demand in 1985, 'possibly associated with the introduction of automatic teller machines' (Murphy, 1990, page III-2). Such a dummy variable is constant throughout forecasting simulations. The quarterly dummies in earlier versions of the model have been removed. In the most recent version the earlier data period has been removed from the estimation as 'unsatisfactory estimates were obtained' (op. cit. p. III-3) and the estimation period is now only 1980.1 to 1989.3.

In the AMPS model, the nominal depreciation of government capital stock is subtracted from the expenditure figure. The capital stock data is only available on an annual basis. The use of simple interpolation to create half-yearly data may affect results and may well not be valid for the quarterly models. In terms of payments for actual transactions, it is unclear as to why AMPS subtracts the depreciation of Government capital stock from gross national expenditure.

Finally IMP is the only one to use inflation and finds it to be significant. In addition IMP finds a relationship to Assets of Non-Trading Bank Financial Institutions which "suggests that in the short run an increase in the money supply to some extent creates its own demand, by way of a multiple expansion that by increasing the demand for non-bank financial assets also increases, for portfolio reasons, the demand for money balances." (Brain, 1986, p400).

4.3 Estimation Results of the Models

Some preliminary comments on the modeller's estimation of these equations is worth making (the estimation results are provided in Appendix 1). Over the three years between the two papers on AMPS, we find that the R-squared has dropped although the Durbin-Watson has improved from a significant 1.56 to 2.18. This is reflected in the way that the coefficient of the lagged endogenous variable has increased
dramatically from 0.483 to 0.721; since on both occasions the
standard error is 0.12, this reflects quite a significant
change. Given the lagged endogenous variable, an h statistic
would have been preferable to the Durbin-Watson.

The IMP equation, using annual data, has 3 lags on all
explanatory variables except real non-farm product. The
resulting equation has a very high R-squared of 0.989 but a
poor Durbin-Watson of 1.58. MURPHY has an even higher R-
squared of 0.999 and a good Durbin-Watson value of 2.03 but
only after the first order serial correlation has been
removed. However as we shall see below, these equations have
their problems to which we shall return later. Near perfect
R-squared's in economics are often a sign of something
worrying.

In NIF, the money demand equation is estimated in two
ways, NLS for diagnostic reasons and FIML in a block with the
exchange rate equation and a monetary reaction function. The
speculative demand equation might lead to an income
coefficient of 0.5 in the Error Correction Mechanism, the
quantity equation would lead to an income coefficient of one.
In NIF, 'the long-run coefficient on prices was constrained to
be unity while that on output was constrained to 0.8. Both
constraints were consistent with the data, although the
coefficient on output was not precisely determined' (Simes,
1988b, p 26).

This value of 0.8 seems to have been imposed not only in
the error-correction mechanism but also on the differenced
price and income variables; it is not clear why this was done
for in the long-run these variables would drop out of the
equation. The R-bar-squared's of this equation (for NLS and
FIML) are quite respectable although much lower than the
others because the dependent variable is the differenced M3$.
A comparison of the standard errors is not possible as this is
the only model to use M3$. Usually one would expect the
There is clearly a specification problem with the equation in that there is significant 2nd-order autoregression accounted for in the estimation process. Accounting for the autocorrelated error by using an appropriate estimator does not remove the problem that error autocorrelation is almost invariably a sign of a mis-specification. Furthermore when simulating equations with autocorrelated errors, the error structure is normally removed and hence it does not add to the accuracy of the simulation.

5. Integration and Cointegration

5.1 Integration

Before continuing, the concepts of integration and cointegration need to be defined. Firstly a variable is said to be integrated of order k if it needs to be differenced k times before the resulting variable is stationary. For instance the random walk –

\[ x_t = x_{t-1} + u_t \]

(where \( u_t \) is white noise) is integrated of order one, written I(1). Many economic variables are I(1). The characteristics of an integrated variable are that it does not have a stable long-term mean and its variance is infinite in the long-run. Integrated variables are not only the obviously trended variables like nominal money supply or the price level that look like they are shooting off to infinity but also variables such as the exchange rate and interest rates which wander around but have no stable mean.
Why is it important to consider integration? The point is that a linear function of I(0) variables can never be I(1) and hence could not be used to explain an I(1) variable. Vice versa, except in very special circumstances to be discussed below, I(1) variables cannot be used to explain an I(0) variable. Both of these would be logically inappropriate for on one side of the equation one has a result that has an unstable mean and an infinite variance while on the other side the result has a constant mean and a finite variance.

Also for statistical inference it is necessary to have variables of the same order of integration throughout the equation. In particular they generally need to be I(0) as otherwise the common assumption of NID(0,\sigma^2) errors will be violated. Thus for any specification the orders of integration of all the variables should be found and then the final specification created such that the final variables on either side of the equation have the same order of integration. This analysis is now referred to as integration accounting.

5.2 Cointegration

What are the exceptions to the rules above? Mathematically it is possible to take a linear function of I(k) variables such that the function itself has a lower order of integration, say I(k-s) and then the variables are said to be 'cointegrated' of order CI(k,s), (k,s > 0), i.e. if all components of a vector x_t are I(k) and

$$\alpha'x_t = z_t - I(k-s)$$

for some vector \(\alpha\), not equal to zero (Engle and Granger, 1987). However \(\alpha\) would be a very specific vector and in general for most sets of non-stationary variables, there is no linear function of them that has this property.
The concept of cointegration has a very interesting and useful interpretation in economics. If variables are cointegrated together it implies that there might be some steady state relationship between them. Usually a linear function of I(1) variables will fluctuate like a random walk but if they are cointegrated this implies that the function is constantly returning back to a constant mean, i.e. the function may represent an equilibrium process. Since I(1) variables are usually not cointegrated, the presence of cointegration is strong evidence in favour of a long-run relationship between the variables. The cointegrating relationship is none other than an error-correction mechanism (ECM) whereby the long-run equilibrium is maintained.

5.3 Testing for Integration and Cointegration

Testing for integration and cointegration, especially the latter, is, however, not as simple and clear-cut as one would like; as is so often the case it depends on the model assumed to set up the hypothesis tests. The most commonly used tests of integration are the Dickey-Fuller and Augmented Dickey-Fuller tests (Dickey and Fuller, 1979 and 1981); these are essentially tests of whether the coefficient in a first order auto-regression is significantly different from one. Another test that is very easy to use is based on the Durbin-Watson (DW) Statistic (Bhargava, 1984). An I(1) variable will have a DW value near zero and so the test is for a non-zero value; the usual DW test is for a value different from two which would be a test of whether an I(0) variable has first order autocorrelation.

To test for cointegration, a number of tests abound. Engle and Granger (1987) recommend analysing the errors of the cointegrating equations. From simulation results they give critical values for seven different statistics (including ADF) calculated on the errors. This approach is used below for it is very easy to compute. In addition Johansen (1988) puts
forward a maximum likelihood estimator of the space of cointegration vectors and from this a likelihood ratio test. Phillips and Ouliaris (1988) put forward a bounds test with a null of no cointegration based on the eigenvalues of the correlation matrix of the variables; if the variables are cointegrated the matrix will not have full rank and so one tests for zero eigenvalues. Finally Bewley (1988) discusses another test based on the work of Box and Tiao (1977).

6. Integration of Variables in the Money Demand Equations

6.1 Orders of Integration of the Variables

To draw consistent comparisons between different equations, quarterly data was used throughout even though AMPS is a semi-annual model and IMP is annual. It was felt that quarterly data would permit a better investigation of the relevant variables. Firstly ADF statistics were calculated for all the variables featuring in the various model equations and are presented in Table 2.

From Table 2 it can be seen that the only I(0) variable is AVA which is a standard error on the yields on 15 year Treasury notes calculated by the formula presented in Baba, Hendry and Starr. Most variables are I(1). The price deflators are understandably I(2) given that the inflation rate itself is I(1) and hence not surprisingly the nominal national income figures are also I(2). Both nominal and real M2 were I(2) while other money aggregates were I(1) except for the AMPS model definition of Base Money.

All the velocities were I(1) except for M2 where the velocity was of a higher order. This also means that the velocity equation does not represent a cointegrating relationship between nominal money supply and nominal income. Finally the Savings Bank Passbook and Statement Account interest rate (RSSA) turned out to be I(2) which is possibly
Table 2: ADF Statistics
(using constant and 4 lags, -2.92)

<table>
<thead>
<tr>
<th>Order of Integration</th>
<th>Variable</th>
<th>On X</th>
<th>On δX</th>
<th>On δδX</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>AVAI</td>
<td>-2.95</td>
<td>-3.25</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>AVA</td>
<td>-1.93</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>AMPS' BaseM</td>
<td>-2.65</td>
<td>-2.98</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>GNM</td>
<td>1.02</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>GTM</td>
<td>0.84</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>GNE</td>
<td>0.81</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>GNE$</td>
<td>-1.91</td>
<td>-3.08</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>B90</td>
<td>-1.55</td>
<td>-6.77</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>M1</td>
<td>-1.24</td>
<td>-4.12</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>$M1</td>
<td>-0.62</td>
<td>-4.29</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>M3</td>
<td>0.72</td>
<td>-3.61</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>$M3</td>
<td>1.71</td>
<td>-3.59</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>NetB90</td>
<td>-2.45</td>
<td>-4.20</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>PGTM</td>
<td>0.68</td>
<td>-3.58</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>RTN</td>
<td>-1.34</td>
<td>-4.71</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>RGS</td>
<td>-1.15</td>
<td>-5.37</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>TaxRate</td>
<td>-2.63</td>
<td>-3.80</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>TB10</td>
<td>-1.64</td>
<td>-3.18</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>AMPS' BaseM</td>
<td>-2.08</td>
<td>-2.27</td>
<td>-5.27</td>
</tr>
<tr>
<td>2</td>
<td>GNMS</td>
<td>-2.41</td>
<td>-2.23</td>
<td>-6.49</td>
</tr>
<tr>
<td>2</td>
<td>GMTS</td>
<td>-2.38</td>
<td>-2.34</td>
<td>-6.34</td>
</tr>
<tr>
<td>2</td>
<td>M2</td>
<td>0.94</td>
<td>-2.51</td>
<td>-5.23</td>
</tr>
<tr>
<td>2</td>
<td>$M2</td>
<td>1.17</td>
<td>-1.74</td>
<td>-4.19</td>
</tr>
<tr>
<td>2</td>
<td>NBFIS</td>
<td>1.55</td>
<td>-1.99</td>
<td>-5.03</td>
</tr>
<tr>
<td>2</td>
<td>PGNE</td>
<td>-2.78</td>
<td>-1.30</td>
<td>-4.75</td>
</tr>
<tr>
<td>2</td>
<td>PGNM</td>
<td>-2.16</td>
<td>-1.60</td>
<td>-4.37</td>
</tr>
<tr>
<td>2</td>
<td>RSSA</td>
<td>-1.17</td>
<td>-2.19</td>
<td>-5.41</td>
</tr>
<tr>
<td>1</td>
<td>M3/GTM$</td>
<td>-0.71</td>
<td>-2.93</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>M3/GNE$</td>
<td>-0.81</td>
<td>-3.33</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>M2/GTM$</td>
<td>-0.91</td>
<td>-1.25</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>M2/GNE$</td>
<td>-0.99</td>
<td>-1.42</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>M2/GNM$</td>
<td>-0.16</td>
<td>-1.90</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>M1/GTM$</td>
<td>-2.19</td>
<td>-4.19</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>M1/GTMS$</td>
<td>-1.97</td>
<td>-4.62</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Bm/GTM$</td>
<td>-2.23</td>
<td>-5.21</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Bm/GNE$</td>
<td>-2.02</td>
<td>-4.73</td>
<td></td>
</tr>
</tbody>
</table>

not surprising since for over half of the data period the rate was constant and since 1984 it has steadily risen. Before continuing it must be admitted that these results are very likely to change if one uses data at a different frequency as in the AMPS and IMP models.
6.2 Integration Accounting of the Model Equations

Looking at the model equations in terms of integration accounting, we find that the AMPS and MURPHY equations are between I(1) variables. Given the high DW's, the equations would appear to be cointegrated relationships. This explains the very high R-squared's and means that the relationships are really long-run relationships rather than short-run forecasting relationships. They are not likely to explain short-term fluctuations in money demand. IMP also appears to be a relationship between I(1) variables but this cannot be assured as the frequency there is annual rather than quarterly; if the equation is a cointegrating relationship, it would be strange to have all the lags in the equation. The MSG equation is also between I(1) variables as long as the imposed coefficients are used to interpret the equation as a relationship between velocity and interest rates; otherwise the price variable would be I(2).

The NIF equation makes a serious effort to capture short-run fluctuations by using differenced I(1) variables and an error-correction mechanism. However the ECM is not cointegrated and the interest rates, although often mistakenly thought to be I(0) variables, are actually I(1). Thus this equation has an I(1) variable explaining an I(0) dependent variable and hence cannot stand unless there is some other cointegrating relationship on the right-hand side not involving the dependent variable.

These results imply that none of these equations are very good specifications of a money demand equation catching the full dynamics of money demand. An alternative specification needs to be found.
7. An Alternative Money Demand Specification

7.1 Variables and Functional Form

Apart from attempting to determine the short-run dynamics, some new explanatory variables were considered. Firstly all the three interest rates used in the models were used, i.e. a short-term 90-day rate (b90), a two year bond yield (RGS) and the average of the Savings Bank Passbook and Statement Account rate (RSSA). All were converted to net of tax using a tax rate defined by the ratio of net household disposable income to household income. As a measure of the risk of other assets the AVA measure, defined by Baba, Hendry and Starr, was used. Furthermore the equation was formed in terms of the real demand for money rather than nominal money. All variables were logged.

The first question was which money supply variable to use. M2 had already been rejected as it was I(2) and M3 was rejected for the reasons given above about deregulation. M3 was also found to be not cointegrated with the other variables implying possibly that some new explanatory variables might be needed to explain the higher monetary aggregates. Both Base money and M1 were used initially. The general relationship estimated was

\[
\frac{M}{P} = k \cdot \text{GNE} \cdot (1+\alpha_{B90}) \cdot (1+\alpha_{RGS}) \cdot (1+\alpha_{RSSA}) \cdot \left(\frac{\text{PGNE}}{\text{PGNE}_t}\right) \cdot \exp(\alpha_{AVA})
\]

The major difference between this and the Baba, Hendry and Starr model is the lack of variables reflecting new initiatives in the financial markets. The interest rates are also not exactly the same. The data period used was that of MURPHY, i.e. from 1973:3 to 1989:4. The really excellent statistical package used was PC-GIVE Version 6.01, written by David Hendry (1989).
7.2 Estimation of the Cointegrating Relationship

The first task was to find an acceptable cointegrating relationship if one existed. It appeared that both M1 and Base Money were cointegrated with nominal income and interest rates; there was very little difference between the use of GDP or GNE and only a slight difference between the use of the short term yield (B90) or the longer term yield (RGS). One thing that made a big difference was the use of net-of-tax interest rates and so hence forth net-of-tax rates were always used. Finally the imposition of unit coefficients on price and income (PY) made only a marginal difference and so the final cointegrating relationship was expressed as the inverse of the velocity related to the interest rate, e.g.

\[ \text{M1}_t = -0.582 (1 + \alpha B90) + 0.538 \text{GNE}_t \]

\[ \alpha \text{ is the after tax adjustment.} \]

A function with both B90 and RGS was tried but standard errors rose dramatically and so the equation above was used. This relationship was then used to form an ECM in the following; it is quite different to the sort of ECM's generally used given the introduction of the interest rate. Since the deregulation of banks the quantity equation appears to no longer provide the correct long-run relationship. Instead the long-run relationship could have really always involved interest rates but this may have been disguised by bank regulation.

7.3 General to Specific Estimation

This ECM was then placed with the first differences of all the other variables, except AVA the risk measure, as the other variables were all I(1) and AVA was I(0). A general unrestricted model was first which included 4 lags of all variables except the ECM which came in at lag 1, 35 variables in all. This had an R-squared of 0.8485, a standard error of 0.0148 and an h statistic near zero. After serial reduction of insignificant variables a function with only 6 variables
plus the ECM was found and is given in Table 3. The R-squared had fallen to 0.6909 and the standard error was now 0.0155. The Savings Bank Passbook and Statements Account interest rate (RSSA) and the risk measure both proved to be insignificant in the end. The inflation rate (δLPGNE) however proved to be significant. Overall this was the preferred M1 equation although the positive coefficient on δL(1+αB0.4) is not easy to rationalise.

Table 3: OLS results for preferred equation explaining δLM1/P

<table>
<thead>
<tr>
<th>VARIABLE</th>
<th>COEFFICIENT</th>
<th>STD ERROR</th>
<th>H.C.S.E.</th>
<th>t-VALUE</th>
<th>PARTIAL r</th>
</tr>
</thead>
<tbody>
<tr>
<td>δLM1/P</td>
<td>.1742819</td>
<td>.08349</td>
<td>.07304</td>
<td>2.08740</td>
<td>.0647</td>
</tr>
<tr>
<td>δL(1+αB90)</td>
<td>-.0537240</td>
<td>.01471</td>
<td>.02010</td>
<td>-3.65335</td>
<td>.1748</td>
</tr>
<tr>
<td>δL(1+αB90.4)</td>
<td>.0829891</td>
<td>.02097</td>
<td>.02566</td>
<td>3.95822</td>
<td>.1992</td>
</tr>
<tr>
<td>δL(1+αRG5.4)</td>
<td>-.1534772</td>
<td>.03380</td>
<td>.04636</td>
<td>-4.54112</td>
<td>.2466</td>
</tr>
<tr>
<td>δLPGNE</td>
<td>-.3890043</td>
<td>.16162</td>
<td>.20327</td>
<td>-2.40693</td>
<td>.0842</td>
</tr>
<tr>
<td>ECM</td>
<td>-.1123163</td>
<td>.02573</td>
<td>.02903</td>
<td>-4.36567</td>
<td>.2323</td>
</tr>
<tr>
<td>CONSTANT</td>
<td>.0173140</td>
<td>.00400</td>
<td>.00470</td>
<td>4.32373</td>
<td>.2288</td>
</tr>
</tbody>
</table>

R² = .6908819; σ = .0155423; F( 6, 63) = 23.47 [ .0000]; h = 0.497
RSS = .0152183943 for 7 Variables and 70 Observations

The equation was distinctly robust over the choice of period used to estimate the equation and if estimated without the last 12 observations the forecasts over these values were good (Figures 8 & 9). The pattern of the residuals was fairly steady (Figure 10). When recursive estimation was used from 1980 onwards, the coefficients and errors are reasonably stable (Figures 11-17) and the tests for normally distributed errors were acceptable (Figure 18). The Chow tests for one period ahead (Figure 19) show four particular observations after 1985 that stand out. Further investigation of these may be warranted to see if these reflect quarters in which the Reserve Bank was very active. The fixed point Chow tests for structural change and the 4-quarters ahead tests (Figures 20 & 21) are quite acceptable.

Now while interest rates may be considered to be exogenously fixed by the government, the rate of inflation is clearly endogenous. To cope with this sort of problem, instrumental variable estimators should be used. When this was done the inflation variable became positive and
insignificant; this may be due to the fact that nominal rates may take into account inflationary expectations although this does not cover direct inflationary reduction in purchasing power. Otherwise the results (see Table 4 and Appendix 2) are very similar.

Table 4: IV results for preferred equation explaining $\delta \text{LMI}/P$

<table>
<thead>
<tr>
<th>VARIABLE</th>
<th>COEFFICIENT</th>
<th>STANDARD ERROR</th>
<th>t-VALUE</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\delta \text{LMI}/P_{t-1}$</td>
<td>.16505</td>
<td>.09005</td>
<td>1.8329</td>
</tr>
<tr>
<td>$\delta L(1+\alpha \text{B90})$</td>
<td>-.04925</td>
<td>.01611</td>
<td>-3.0566</td>
</tr>
<tr>
<td>$\delta L(1+\alpha \text{B90}_{t-4})$</td>
<td>.09886</td>
<td>.02502</td>
<td>3.9512</td>
</tr>
<tr>
<td>$\delta L(1+\alpha \text{RGS}_{t-4})$</td>
<td>-.18114</td>
<td>.04097</td>
<td>-4.4217</td>
</tr>
<tr>
<td>$\delta \text{PGNE}$</td>
<td>.12023</td>
<td>.38839</td>
<td>.3095</td>
</tr>
<tr>
<td>ECM$_{t-1}$</td>
<td>-.14202</td>
<td>.03430</td>
<td>-4.1403</td>
</tr>
<tr>
<td>CONSTANT</td>
<td>.00679</td>
<td>.00837</td>
<td>.8117</td>
</tr>
</tbody>
</table>

$\text{RSS} = .0176165452$; $\sigma = .0167221$; $h = 0.191$

8. Conclusion

The final equation estimated fits the data well and passes many diagnostic tests. There may be some doubt about the sign of the four-period lagged short term interest rate and the significance of the rate of inflation. Since the latter is theoretically useful and is significant in models of model demand for other countries, it has been left there until further investigation determines definitely whether it should remain. The long-run equation shows no money illusion with the velocity relating directly to the short-term interest rate.

The lack of significance of the risk measure may be due to the possibility of a degree of market segmentation in Australia and lack of relationship of Australian long-term rates to foreign long-term rates. In Australia while the AVA measure may have varied, this may reflect a variation that has little meaning in the market place. It may prove better not to use such a long-term interest rate as 15 years.

The savings bank passbook and statement account variable (RSSA) may be highly related almost by definition to the arrival of interest bearing checkable deposits and the rise in interest rates on these deposits. In this case this variable
reflects both the opportunity cost of non-M1 deposits and the income obtainable from M1 deposits. The two factors may balance each other out leading to the insignificance of the variable overall.

That changes in the growth rate of gross national expenditure were not significant is not worrying. Firstly the long-run relationship is held constant in the ECM mechanism. Secondly, one might expect income to respond to changes in money supply rather than vice versa. Also the coefficient of -0.14 on the ECM (IV estimator) implies a long run of about 5 years or more (that is, 5 years has passed before 95% of the error has been corrected). In the short-run here of two or three quarters, the lack of relationship to GNE may be argued for on a permanent income basis.

Other variables could have been considered. With deregulation and the innovative creation of new financial products, one should possibly allow not only for the entry of the new products but also a learning period as people realise the new possibilities. Baba, Hendry and Starr (1987) use this learning-period approach to introduce new variables to reflect the introduction of NOW and SUPER-NOW accounts. While these were found to be significant on America data, such variables for Australia remain a subject for further investigation. Changes which could be analysed are the withdrawal of the Australian Savings Bond which is a form of quasi-money, the rise of Cash Management Trusts which sweep money out of the money supply definition and also the rise of interest bearing cheque accounts which clearly reduce the opportunity costs of holding money.

The final result shows that a stable relationship can be found to explain Australian money demand over the whole period from 1972 to 1989. Other relationships in the financial sector will be analysed shortly. Where appropriate, new specifications will be tested within the models to determine the effect on simulation results. This will be the subject of extensive analysis of the models to be carried out by EMBA in
the future. While the models tended to identify long-run relationships well, they generally did not identify the short-run dynamics of money demand. It is hoped that these efforts are of some use to the authors of the models discussed and to other modellers of the Australian economy.
References


Appendix 1: Model Estimation Results

1. AMPS

\[
\log((1-POL2) \times RCS) = 0.7210388 \times \left( -28.28162 \right) - 9.839076 \times \log\left( \frac{M}{(YE$-PY\times DEPIG\times KG(-1))} \right) \\
+ (1-0.7210388) \times \log((1-POL2.1) \times RCS.1) \\
R^2 = 0.59353; \ D.W. = 2.183 \\
Period: 1970:2 to 1985:1 \quad N=30
\]

ACF TESTS FOR AUTOCORRELATION

<table>
<thead>
<tr>
<th>LAG</th>
<th>ACF</th>
<th>T-VALUE</th>
<th>SIGNIFICANCE LEVEL</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>-0.6825</td>
<td>0.499</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>1.8590</td>
<td>0.071</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>-2.4698</td>
<td>0.019</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>-0.2984</td>
<td>0.767</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>-1.0200</td>
<td>0.315</td>
<td></td>
</tr>
</tbody>
</table>

Ljung-Box Q(15) = 26.1654 \text{ significance level } = 0.036

(t-values in brackets)

2. IMP

\[
\ln\left( \frac{M2}{GNFP$} \right) = 4.999 - 0.195 \times R2 - 0.089 \ln R2.1 + 0.021 \times R2.2 \\
\quad + 0.009 \ln R2.3 + 1.397 \ln\left( \frac{NBFI$/GNFP$}{GNFP$} \right) \\
\quad + 0.007 \ln\left( \frac{NBFI$/GNFP$}{GNFP$} \right) - 0.689 \ln\left( \frac{NBFI$/GNFP$}{GNFP$} \right) \\
\quad - 0.691 \ln\left( \frac{NBFI$/GNFP$}{GNFP$} \right) + 2.079 \times D\ PGNFP \\
\quad + 1.276 D\ PGNFP.1 + 0.662 D\ PGNFP.2 \\
\quad + 0.237 D\ PGNFP.3 - 0.523 \ln GNFP \\
R^2 = 0.969; \ D.W. = 1.91; \ Sample - 1954-55/1977-78
\]

(t-values in brackets)

3. MSG (not estimated)

\[
\frac{M}{P} = Q^1 \cdot i^{-0.6}
\]
4. MURPHY (Murphy 1988 version)

\[
\ln(M/GNE) = -1.76 - 0.0322 \text{ DUMM} - 0.01156 \text{ DUM01} \\
(0.0215) (0.0113) (0.00504)
- 0.00757 \text{ DUM04} - 0.00501 \ln((1-POL2)\times\text{RCS}) \\
(0.00477) (0.00141)
+ 0.481 u_1
(0.135)
\]

\[R^2 = 0.999\ SE = 0.016\ D.W. = 2.03\ (\text{original DW about 1.04})\]

(standard errors in brackets)

4. MURPHY (Murphy 1990 version)

\[
\text{RCS} = -251.6 - 4.87 \text{ DUMM} - 142.9 \log(M/GNE) \\
(61.7) (1.08) (33.1)
\]

\[R^2 = 0.418;\ S.E. = 2.30;\ D.W. = 1.85\]

Sample Period: 1980:1 to 1989:3

Autocorrelation Test (B-G): \[\chi^2(5) = 5.12\]
Heteroskedasticity Tests (G-Q): \[F(17,17) = 0.72\]
(B-P): \[\text{asy. t-stat = 0.15}\]
Structural Change Test (Chow): \[F(34) = 0.29\]
Non-Normality Test (B-J): \[\chi^2(2) = 1.34\]
Functional Form Test (RESET): \[\text{asy. t-stat = 1.49}\]

5. NIF (FIML Results)

\[
\delta \log(IM3) = 0.7037 + 0.2800 \delta \log(PGTM) + 0.4673 \delta \log(PGTM_1) \\
(4.34) (2.28) (6.02)
+ 0.2527 \delta \log(PGTM_2) + 0.2018 \delta \log(GTM) \\
(2.26)
+ 0.3101 \delta \log(GTM_1) + 0.2881 \delta \log(GTM_2) \\
(4.79)
- 0.0814 \delta \log(RGS) + 0.0516 \delta \log(RSSA) \\
(5.75) (5.20)
+ 0.2338 [\log(PGTM_1) + 0.8 \log(GTM_1) - \log(IM3^\text{s_1})] \\
(4.09)
+ 0.3491 u_1 - 0.2260 u_2 \\
(2.75) (1.93)
\]

R-Bar-squared = 0.271; \ s.e. = 0.013; \ D.W. = 1.79

Sample Period: 1972:3 to 1986:4; \ t-values in brackets.

The sum of the \log(PGTM) coefficients was constrained to one and the sum of the \log(GTM) coefficients to 0.8.
Appendix 2: New Estimation Results

Modelling δLM1/P by OLS
The Sample is 1972(3) to 1989(4) less 0 Forecasts

<table>
<thead>
<tr>
<th>VARIABLE</th>
<th>COEFFICIENT</th>
<th>STD ERROR</th>
<th>H.C.S.E.</th>
<th>t-VALUE</th>
<th>PARTIAL r²</th>
</tr>
</thead>
<tbody>
<tr>
<td>δLM1/P,1</td>
<td>.1742819</td>
<td>.08349</td>
<td>.07304</td>
<td>2.0874</td>
<td>.0647</td>
</tr>
<tr>
<td>δL(1+αB90)</td>
<td>-.0537240</td>
<td>.01471</td>
<td>.02010</td>
<td>-3.6533</td>
<td>.1748</td>
</tr>
<tr>
<td>δL(1+αB90.4)</td>
<td>.0829891</td>
<td>.02097</td>
<td>.02566</td>
<td>3.9582</td>
<td>.1992</td>
</tr>
<tr>
<td>δL(1+αRGS.4)</td>
<td>-.1534772</td>
<td>.03380</td>
<td>.04636</td>
<td>-4.5412</td>
<td>.2466</td>
</tr>
<tr>
<td>δLPGNE</td>
<td>-.3890043</td>
<td>.16162</td>
<td>.20327</td>
<td>-2.4069</td>
<td>.0842</td>
</tr>
<tr>
<td>ECM,1</td>
<td>-.1123163</td>
<td>.02573</td>
<td>.02903</td>
<td>-4.3656</td>
<td>.2323</td>
</tr>
<tr>
<td>CONSTANT</td>
<td>.0173140</td>
<td>.00400</td>
<td>.00470</td>
<td>4.3237</td>
<td>.2288</td>
</tr>
</tbody>
</table>

R² = .6908819  σ = .0155423  F( 6, 63) = 23.47 [ .0000]  DW = 1.91
RSS = .0152183943  for 7 Variables and 70 Observations
Information Criteria: SC = -8.008896; HQ = -8.144433; FPE = 0.00026

R² Relative to DIFFERENCE+SEASONALS = .73643

SEASONAL MEANS of DIFFERENCES are
.01247  -.00048  -.00069  -.01192

RESIDUAL CORRELOGRAM

70*(Sum of 16 Squared Residual Autocorrelations) = 23.171
1 2 3 4 5 6 7
.0284 .2178 .0428 .0459 .1390 -.0314 -.0330
8 9 10 11 12 13 14
-.2070 .0209 .1344 -.2152 -.2484 -.1036 -.0782
15 16
-.1001 -.2474

RESIDUAL AUTOREGRESSION of Order 8

<table>
<thead>
<tr>
<th>LAG</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
</tr>
</thead>
<tbody>
<tr>
<td>COEFF.</td>
<td>-.0105</td>
<td>.2045</td>
<td>.0243</td>
<td>.0167</td>
<td>.1768</td>
<td>-.0527</td>
<td>-.0580</td>
<td>-.2100</td>
</tr>
<tr>
<td>S.E.'s</td>
<td>.1432</td>
<td>.1419</td>
<td>.1448</td>
<td>.1458</td>
<td>.1489</td>
<td>.1503</td>
<td>.1449</td>
<td>.1440</td>
</tr>
</tbody>
</table>

RSS = .11809D-01  σ = .01585

CHI²( 5) = 7.128 with F( 8, 47) = .76 [ .6364]

Testing for Serial Correlation from Lags 1 to 5

CHI²( 5) = 4.709  and  F-Form( 5, 58) = .84 [ .5291]

Error Autocorrelation Coefficients:
.0499  .2260  .0390  .0190  .1349

ARCH TEST

Residuals Scaled by .1554D-01

<table>
<thead>
<tr>
<th>LAG</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
</tr>
</thead>
<tbody>
<tr>
<td>COEFF.</td>
<td>1.8330</td>
<td>-.2287</td>
<td>-.2929</td>
<td>-.2517</td>
<td>-.1294</td>
<td>-.1945</td>
<td></td>
<td></td>
</tr>
<tr>
<td>S.E.'s</td>
<td>.4050</td>
<td>.1358</td>
<td>.1393</td>
<td>.1395</td>
<td>.1410</td>
<td>.1399</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

RSS = .86378D+02  σ = 1.27662

CHI²( 5) = 8.219 with F( 5, 53) = 1.53 [ .1950]
ANALYSIS of SCALED RESIDUALS  
Sample Size  

<p>| | | | | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>0.000000</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Std.Devn.</td>
<td>0.955533</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Skewness</td>
<td>-3.12366</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Excess Kurtosis</td>
<td>-2.229611</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Minimum</td>
<td>-2.593771</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maximum</td>
<td>2.034475</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

CHI-SQUARED Test for NORMALITY : $\chi^2(2) = 1.163$

TEST for HETEROSCEDASTIC ERRORS \( 70*R^2 = 5.7020 \) with 13 Variables

\[ F(12, 50) = 0.3695 [0.9684] \]

Regressors used for forming the Quadratic are:
\( \delta L M_1/P, \delta L(1+\alpha B90) \delta L(1+\alpha B90.4) \delta L(1+\alpha RGS.4) \delta LPGNE ECM, 1 \)CONSTANT

HETEROSCEDASTICITY Coefficients and t-Values are:

<table>
<thead>
<tr>
<th>Vars: V1</th>
<th>V2</th>
<th>V3</th>
<th>V4</th>
<th>V5</th>
<th>V6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coeff:</td>
<td>0.00170</td>
<td>0.00041</td>
<td>0.00023</td>
<td>0.000088335</td>
<td>0.00146</td>
</tr>
<tr>
<td>t-Value</td>
<td>0.90</td>
<td>0.92</td>
<td>0.43</td>
<td>0.12</td>
<td>0.14</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Vars: V7</th>
<th>V12</th>
<th>V22</th>
<th>V32</th>
<th>V42</th>
<th>V5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coeff:</td>
<td>0.00019</td>
<td>-0.00452</td>
<td>-0.00030</td>
<td>-0.00084</td>
<td>0.00254</td>
</tr>
<tr>
<td>t-Value</td>
<td>1.26</td>
<td>-0.15</td>
<td>-0.24</td>
<td>-0.63</td>
<td>0.51</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Vars: V6</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Coeff:</td>
<td>-0.00015</td>
</tr>
<tr>
<td>t-Value</td>
<td>-0.05</td>
</tr>
</tbody>
</table>

RESET F-TEST for adding $\hat{Y}^2$:
\[ F(1, 62) = 0.150 [0.6997] \]

RESET F-TEST for adding $\hat{Y}^2$ for n=3
\[ F(2, 61) = 2.490 [0.0913] \]

RESET F-TEST for adding $\hat{Y}^2$ for n=4
\[ F(3, 60) = 1.640 [0.1896] \]
Modelling $\delta$LM1/P by IVE
The Sample is 1972(3) to 1989(4) less 0 Forecasts

1 ENDOGENOUS and 6 EXOGENOUS variables with 11 INSTRUMENTS

<table>
<thead>
<tr>
<th>VARIABLE</th>
<th>COEFFICIENT</th>
<th>STANDARD ERROR</th>
<th>t-VALUE</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\delta$LM1/P</td>
<td>.16505</td>
<td>.09005</td>
<td>1.8329</td>
</tr>
<tr>
<td>$\delta$L(1+a$\delta$B90)</td>
<td>-.04925</td>
<td>.01611</td>
<td>-3.0566</td>
</tr>
<tr>
<td>$\delta$L(1+a$\delta$B90.4)</td>
<td>.09886</td>
<td>.02502</td>
<td>3.9512</td>
</tr>
<tr>
<td>$\delta$L(1+a$\delta$RGS.4)</td>
<td>-.18114</td>
<td>.04097</td>
<td>-4.4217</td>
</tr>
<tr>
<td>$\delta$LPQNE</td>
<td>.12023</td>
<td>.38839</td>
<td>.3095</td>
</tr>
<tr>
<td>ECM.1</td>
<td>-.14202</td>
<td>.03430</td>
<td>-4.1403</td>
</tr>
<tr>
<td>CONSTANT</td>
<td>.00679</td>
<td>.00837</td>
<td>.8117</td>
</tr>
</tbody>
</table>

INSTRUMENTS USED:
LTB10        LRSSA     L1+aRSSA  aAVAl  A0aAVAl

$RSS = .0176165452 \quad \sigma = .0167221 \quad DW = 2.021$

Reduced Form $\sigma = .01624588$ Specification $\chi^2(4)/4 = 1.0$

$\chi^2(7)/7$ TESTING $\beta = 0$: 16.82

$\delta$LM1/P Fitted

RESIDUAL CORRELOGRAM

70*(Sum of 16 Squared Residual Autocorrelations) = 16.866

<table>
<thead>
<tr>
<th>LAG</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
</tr>
</thead>
<tbody>
<tr>
<td>COEFF.</td>
<td>-.0186</td>
<td>.1802</td>
<td>.0768</td>
<td>-.0095</td>
<td>.1939</td>
<td>-.0266</td>
<td>-.0897</td>
</tr>
<tr>
<td>S.E.'s</td>
<td>.1516</td>
<td>.1495</td>
<td>.1498</td>
<td>.1529</td>
<td>.1556</td>
<td>.1572</td>
<td>.1527</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>LAG</th>
<th>9</th>
</tr>
</thead>
<tbody>
<tr>
<td>COEFF.</td>
<td>.0774</td>
</tr>
<tr>
<td>S.E.'s</td>
<td>.1488</td>
</tr>
</tbody>
</table>

$RSS = .13335D-01 \quad \sigma = .01721 \quad \chi^2(5) = 6.592$ with $F(9, 45) = .61 [ .7854]$

Testing for Serial Correlation from 1 to 5

IVE AUTOCORRELATION TEST

<table>
<thead>
<tr>
<th>AUTOCORRELATION COEFFICIENTS:</th>
</tr>
</thead>
<tbody>
<tr>
<td>-.087</td>
</tr>
<tr>
<td>$\chi^2(5)/5 = .75$</td>
</tr>
</tbody>
</table>

ARCH TEST

Residuals Scaled by .1702D-01

<table>
<thead>
<tr>
<th>CNST</th>
<th>1 LAG</th>
<th>2 LAG</th>
<th>3 LAG</th>
<th>4 LAG</th>
<th>5 LAG</th>
</tr>
</thead>
<tbody>
<tr>
<td>COEFF.</td>
<td>1.6634</td>
<td>-.2016</td>
<td>-.2615</td>
<td>-.2915</td>
<td>-.0752</td>
</tr>
<tr>
<td>S.E.'s</td>
<td>.3738</td>
<td>.1394</td>
<td>.1418</td>
<td>.1382</td>
<td>.1371</td>
</tr>
</tbody>
</table>

$RSS = .80606D+02 \quad \sigma = 1.23323 \quad \chi^2(5) = 8.261$ with $F(5, 53) = 1.54 [ .1923]$
### ANALYSIS of SCALED RESIDUALS

<table>
<thead>
<tr>
<th>Sample Size</th>
<th>70</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>0.000000</td>
</tr>
<tr>
<td>Std.Devn.</td>
<td>0.938631</td>
</tr>
<tr>
<td>Skewness</td>
<td>-0.149900</td>
</tr>
<tr>
<td>Excess Kurtosis</td>
<td>-0.168958</td>
</tr>
<tr>
<td>Minimum</td>
<td>-2.572432</td>
</tr>
<tr>
<td>Maximum</td>
<td>2.152924</td>
</tr>
</tbody>
</table>

**CHI-SQUARED Test for NORMALITY**

\[ \chi^2(2) = 0.311 \]

**TEST for HETEROSCEDASTIC ERRORS**

\[ 70 \times R^2 = 7.6649 \text{ with 13 Variables} \]

\[ F(12, 50) = 0.5123 \left[ 0.8968 \right] \]

Regressors used for forming the Quadratic are:

- $\delta L P G N E$
- $\delta L M I / P$
- $\delta L (1 + \alpha B 90)$
- $\delta L (1 + \alpha B 90 \cdot \gamma)$
- $\delta L (1 + \alpha R G S \cdot \gamma)$
- ECM
- CONSTANT

### HETEROSCEDASTICITY Coefficients and t-Values are:

<table>
<thead>
<tr>
<th>Vars:</th>
<th>\text{V 1}</th>
<th>\text{V 2}</th>
<th>\text{V 3}</th>
<th>\text{V 4}</th>
<th>\text{V 5}</th>
<th>\text{V 6}</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coeff:</td>
<td>-0.00455</td>
<td>0.00174</td>
<td>0.00029</td>
<td>0.0032</td>
<td>0.00047006</td>
<td>-0.00008138</td>
</tr>
<tr>
<td>t-Value</td>
<td>-0.38</td>
<td>0.79</td>
<td>0.56</td>
<td>0.52</td>
<td>0.05</td>
<td>-0.01</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Vars:</th>
<th>\text{V 7}</th>
<th>\text{V 1}^2</th>
<th>\text{V 2}^2</th>
<th>\text{V 3}^2</th>
<th>\text{V 4}^2</th>
<th>\text{V 5}^2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coeff:</td>
<td>0.00031</td>
<td>0.01772</td>
<td>0.00249</td>
<td>-0.0049</td>
<td>-0.00176</td>
<td>0.00786</td>
</tr>
<tr>
<td>t-Value</td>
<td>1.75</td>
<td>0.10</td>
<td>0.07</td>
<td>-0.34</td>
<td>-1.13</td>
<td>1.37</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Vars:</th>
<th>\text{V 6}^2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coeff:</td>
<td>0.00051</td>
</tr>
<tr>
<td>t-Value</td>
<td>0.14</td>
</tr>
</tbody>
</table>

Econometric Modelling Session Finished at 3:14:56 on 11th June 1990
Sample Period is 1971(3) - 1989(4)

Figure 8
**Forecasts**

\[ \alpha_{LMSP} = \text{___} \quad \text{FORECAST=} \text{___} \]

**Scaled Residuals**

Sample Period is 1987(1) - 1989(4)

Figures 9 and 10
Figures 19 to 24
WORKING PAPERS IN ECONOMETRICS AND APPLIED STATISTICS


A Note on A Bayesian Estimator in an Autocorrelated Error Model. William Griffiths and Dan Dao, No. 3 - April 1979.


Bayesian Econometrics and How to Get Rid of Those Wrong Signs. William E. Griffiths, No. 31 - November 1987.


